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Exploring Latent Class Profiles of Mathematics Performance: Insights from PISA 2022 Using Growth Mindset Indicators and Group Comparison Analysis

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ABSTRACT

Purpose of the study: This study investigates the influence of a growth mindset on Filipino students' mathematics performance as assessed in the PISA 2022 survey. The research aims to identify distinct latent class profiles based on growth mindset indicators and to explore their relationship with mathematics achievement.

Methodology: Data from 6,791 Filipino students who participated in PISA 2022 were analyzed. Latent Class Analysis (LCA) was employed to classify students into distinct mindset profiles, while Analysis of Variance (ANOVA) assessed differences in mathematics performance across these groups. Tukey's post hoc analysis was used to examine pairwise differences further.

Main Findings: Based on the data, three distinct latent classes were identified among Filipino learners: Limitation Acceptors (50%), Optimistic Learners (17%), and Mindset Explorers (33%). Optimistic Learners, who exhibited a strong growth mindset and disagreed with statements endorsing fixed intelligence, achieved the highest average scores in mathematics. ANOVA results confirmed significant differences in mathematics performance among these three groups. Tukey's post hoc analysis further revealed that Optimistic Learners significantly outperformed Limitation Acceptors and Mindset Explorers, while no significant performance difference was found between Limitation Acceptors and Mindset Explorers.

Novelty/Originality of this study: These findings highlight the critical role of a growth mindset in shaping academic achievement and suggest that fostering growth-oriented beliefs could enhance mathematics performance. This study provides actionable insights for educators and policymakers, emphasizing the need for targeted interventions to cultivate positive beliefs about intelligence among students.

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1. INTRODUCTION

Mathematics education in the Philippines faces significant challenges. These challenges are highlighted by international assessments like the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) [1]-[3]. Assessment results reveal that Filipino students continue to perform at lower levels. This is an indication of deficits in critical thinking, a crucial skill for 21st-century learners. Moreover, interest in mathematics has been steadily declining. It is an issue that was made

worse by the COVID-19 pandemic. Learning modes during the pandemic forced a shift to modular and asynchronous learning. This sudden transition exposed gaps in readiness for both learners and teachers who were unprepared for remote instruction, particularly in mathematics.

The widespread reliance on traditional teaching methods in the Philippines inadequately prepares students to address real-world problem [2], [3]. Challenges are further compounded by disparities across regions and between public and private schools. As a result, it persistently widens the gaps in student performance. Mathematics proficiency is fundamental to students' academic and professional opportunities. Yet various factors have contributed to the ongoing decline in Filipino students' performance. This includes insufficient teaching practices [1], [2]. For students to improve, educators need to recognize students' diverse levels of proficiency. In addition, policymakers essential to address infrastructure gaps, reduce teacher-student ratios, and invest in teacher training [4].

To address these issues, understanding student diversity in mathematical proficiency is key. Latent Class Analysis (LCA) offers a robust statistical approach. It identifies latent patterns in data, making it particularly useful for analyzing mathematics performance. Unlike traditional grouping techniques like cluster or factor analysis, LCA is model-based. It estimates the probability of class membership for each individual based on observed variables. Research demonstrated that LCA can uncover unobservable characteristics that significantly impact student performance. Thus, it provides valuable insights for targeted educational interventions [5]-[7].

Research suggests that growth mindset—defined as the belief that abilities can be developed through effort—may significantly influence academic outcomes. Findings also advocate for integrating growth mindset indicators in assessment practices to capture students' resilience and strategies in mathematics learning [5], [7], [8]. Students with a growth mindset are more likely to demonstrate perseverance and intrinsic motivation. Hence, provides a positive impact on their academic performance. Consequently, growth mindset considerations are crucial for mathematics education because it is aligned with broader goals of promoting equity and enhancing learning outcomes.

While numerous studies have examined factors influencing mathematics performance, such as teaching methods, socioeconomic status, and student attitudes, there remains a lack of comprehensive analysis of latent traits underlying students' mathematical achievement [9]-[10]. Specifically, limited attention has been given to the role of growth mindset a belief that abilities can be developed through effort in shaping mathematics outcomes among Filipino students. Furthermore, existing research has not sufficiently explored the heterogeneity of student beliefs about intelligence and their corresponding academic performances [12]-[18]. This gap in the literature highlights the urgency of understanding the nuanced relationships between growth mindset, latent student profiles, and mathematics achievement. Addressing these gaps can provide actionable insights for improving educational policies and practices.

This study aimed to offer insights that can inform educational policy and practices in the Philippines. Results potentially shed light on factors contributing to students' declining interest in mathematics. It sought to highlight systemic issues that may hinder critical thinking and problem-solving skills among Filipino students compared to international peers. By focusing on targeted interventions, the findings provided support efforts to enhance mathematics performance and overall educational quality.

Specifically, this study aimed to address these gaps by utilizing Latent Class Analysis (LCA) to explore Filipino students' growth mindset profiles and their relationship with mathematics performance. Specifically, the study seeks to: 1) Identify latent class profiles among Filipino students based on their responses to growth mindset indicators in the PISA 2022 questionnaire; 2) Determine significant differences in mathematics performance among these latent classes; 3) Examine variations in mathematical proficiency as measured by PISA 2022 scores across latent profiles. By achieving these objectives, the study sought to clarify the varied levels of mathematics performance among Filipino students and the potential impact of growth mindset on their achievement, thereby advancing the understanding of effective interventions that address the needs of diverse student populations.

Mathematics education in the Philippines aspires to teach critical thinking and problem-solving skills [19]. However, the COVID-19 pandemic has exacerbated challenges in achieving K–12 curriculum goals. As a result, it compromises instructional quality. Remote teaching became necessary. However, many teachers were inadequately prepared for this mode of instruction [20]. This shift neglected the diverse needs of learners, as researchers point out, recommending that the Philippines invest in educational strategies that address societal challenges and foster critical thinking [21]. Several discussions also highlight the importance of integrating mathematics with other fields and addressing inequalities in language and educational access, especially for marginalized students. Improving assessment tools and incorporating technology into informal learning contexts can further support mathematics education outside traditional classrooms [20]-[22].

These issues were underscored by the Philippines' performance in PISA 2018, PISA 2022, and TIMSS 2019, where Filipino students showed significant deficiencies in mathematical proficiency and critical thinking [19], [22]-[24]. Filipino students' performance lagged behind that of neighboring countries. This only reveals

gaps in skills and a declining interest in the subject [19], [22]-[24]. The continued prevalence of traditional teaching methods has contributed to challenges in developing students' problem-solving skills [19], [22]-[24]. Performance disparities between public and private schools, as reported in PISA 2018, further underscore systemic inequities that compound students' struggles.

Several studies have explored factors influencing mathematics performance among Filipino students. These are teaching methods, socioeconomic background, and student attitudes. Teacher-related variables (i.e. pedagogical competencies and resource availability) are crucial in shaping students' academic achievement. These variables were identified as significant predictors of student success in mathematics. Therefore, it requires an emphasis on the importance of effective teaching practices and adequate resources. Similarly, studies highlight the need for diverse instructional approaches to address students' varying learning preferences [25], [26].

Socioeconomic factors and educational inequality are also influential. Researches show that while students' attitudes and study habits impact performance, socioeconomic factors have a more pronounced effect on outcomes [1], [22], [26]. Family and school environment play pivotal roles., with teacher efforts being especially critical in influencing student success [27], [28]. Student attitudes, particularly their perceptions of mathematics, are also important. Although positive attitudes and effective study methods can enhance performance [29], other factors like learning preferences may not directly correlate with academic success [26].

A recurring theme is the persistent struggle of the Philippine educational system to achieve high-quality mathematics education. Studies highlight a complex interaction of factors affecting performance, with teacher-related variables, educational resources, socioeconomic backgrounds, and student attitudes all playing significant roles[22], [29], [30]. Addressing these multifaceted challenges is essential to improve mathematics education, and consequently, student outcomes in the Philippines. Insights from these studies underscore the need for systemic changes in the Philippine educational landscape. To enhance student outcomes, efforts should focus on improving teacher competencies, providing adequate resources across regions, and addressing socioeconomic disparities. Additionally, fostering positive attitudes towards mathematics among students can promote more effective learning experiences.

Cultivating a growth mindset is increasingly recognized as essential for improving mathematics outcomes. Researches emphasize that a growth mindset significantly impacts academic performance, particularly in mathematics [31]-[33]. By fostering classrooms that promote a growth mindset, educators can help bridge achievement gaps, especially for underprivileged students. It was identified intrinsic motivation as a key factor influenced by growth mindset [33]. Also, they illustrate how societal mindset norms also shape academic outcomes [34]. Consequently, promoting growth mindset interventions in the classroom, particularly through problem-based learning, can positively influence Filipino students' performance in mathematics.

Latent Class Analysis (LCA) is another powerful approach to understanding students' performance in mathematics. In educational research, LCA is valued for its ability to reveal underlying structures within data, grouping individuals based on shared characteristics [7], [8], [35], [36]. Unlike traditional clustering techniques, LCA is model-based and allows for nuanced classification of student responses. Research also highlighted the LCA's advantages over other methods, noting its capacity to analyze distinct item types and provide insights into group dynamics [37]. Similarly, LCA is utilized in exploring heterogeneous data, underscoring its value in identifying latent segments across various educational contexts [36].

In conclusion, Latent Class Analysis (LCA) offers an effective method for identifying latent profiles among Filipino students based on their responses to growth mindset indicators. Through LCA, this study can better understand the factors influencing Filipino students' mathematics performance and provide educators with valuable insights for developing targeted interventions that support educational outcomes. Understanding the diversity of growth mindset profiles and their link to mathematics performance is critical for addressing the declining interest and proficiency in mathematics among Filipino students. By employing LCA, this study provides a nuanced perspective on the interplay between mindset and academic achievement, offering insights for targeted educational interventions. These findings can inform strategies to foster a growth mindset, enhance mathematics instruction, and reduce disparities in student outcomes. Additionally, the study's implications extend to policymakers, emphasizing the need for systemic reforms to improve teacher training, address resource gaps, and promote equity in educational access.

By bridging the gaps in current research, this study aspires to advance mathematics education in the Philippines, fostering critical thinking and problem-solving skills that are essential for students' success in the global arena.

2. RESEARCH METHOD

This study employs a quantitative, non-experimental, and descriptive-correlational research design. It analyzes secondary data from the Philippine dataset of the Programme for International Student Assessment (PISA) 2022, focusing on students' responses to growth mindset indicators and their mathematics performance.

The descriptive approach is used to identify latent profiles through Latent Class Analysis (LCA), while the correlational aspect investigates relationships between these profiles and mathematics achievement.

This paper used the Philippine data set for PISA 2022 uploaded on the OECD website. PISA is a large-scale assessment triennially administered among its member countries to a randomly selected group of 15-year-old students for the academic areas of mathematics, reading, and science literacy. There is a focus on one educational place for each assessment, and for 2022, mathematics literacy is the primary domain. In this study, the area examined is the growth mindset indicators employed by the students and mathematics literacy. PISA uses different forms to other students designed to obtain a piece of broader and comprehensive information regarding the factors connected to student performance, attitudes, behaviors, and education systems (e.g., demographic variables, previous educational career choices, instruction time, and class size). Thus, students who did not respond to the questions scaling the growth mindset of the students was deleted.

The sample consists of Filipino 15-year-old students who participated in PISA 2022. PISA employs a stratified random sampling method to select participants, ensuring representativeness across schools, regions, and demographic categories. After excluding students with incomplete responses to growth mindset questions, the final dataset included 6,791 students, as shown in Table 1. Out of these valid participants, 3470 of which are female (51.1%) and 3321 are male (48.9%). The sample distribution by sex is as table 1.

Table 1. Filipino Students Participated in PISA 2022 in Terms of Sex

Sex	Frequency	Percentage (%)
Female	3470	51.1
Male	3321	48.9
Total	6791	100.0

One of the advantages that the PISA has as an international is it includes questions that scale the indicative of the student's mindset. Students were asked to rate statements (e.g. “Your intelligence is something about that you cannot change.”, “Some people are just not good at mathematics, no matter how hard they study.”, “Some people are just not good in the English language, no matter how hard they study.”, and “Your creativity is something about you that you cannot change very much.”). Students will choose among the four response options (“Strongly disagree”, “Disagree”, “Agree”, “Strongly agree”). Thus, with the varying mindsets among Filipino students, Latent Class Analysis (LCA) will be employed to explore latent classes that may occur based on their responses to the stated question under the growth mindset category of the PISA questionnaire and how these classes or subgroups differ in terms of mathematics performance.

Table 2. Filipino students who responded to the Growth Mindset Questions

Growth Mindset Questions	Frequency	Mean	Std. Deviation
Agree/disagree: Your intelligence is something about you that you cannot change very much.	6791	2.64	.750
Agree/disagree: Some people are just not good at mathematics, no matter how hard they study.	6791	2.63	.786
Agree/disagree: Some people are just not good in [test language], no matter how hard they study.	6791	2.57	.783

Among the four questions, Filipino students did not answer the last question (“Your creativity is something about you that you cannot change very much.”). Thus, as shown in Table 2, only the three questions were used in conducting the Latent Class Analysis. In performing the Latent Class Analysis, it is important to simplify the responses of the participants (1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree) into binary, thus, were recoded into (1=Disagree, 2=Agree). The mean and standard deviation of the participant's responses were also revealed in Table 2. The instrument has been adopted from PISA and validated through prior studies. Its reliability has been demonstrated in multiple contexts, with a reported Cronbach’s alpha value of 0.76, indicating acceptable internal consistency for the growth mindset scale.

The dataset was downloaded from the OECD website, which hosts PISA data made available for educational research purposes. The data includes comprehensive information on students’ performance, demographic characteristics, and responses to growth mindset questions. Ethical considerations regarding data use were observed, as this study relied on publicly available, anonymized data. Several steps will be conducted in analyzing the data. First, to determine the latent class profiles of Filipino students based on growth mindset indicators, Latent Class Analysis (LCA) will be conducted. After determining the latent class profiles of the respondents, Analysis of Variance (ANOVA) will be used to determine whether there are differences between the profiles. If there are significant differences in the results, a post hoc test will be conducted to analyze the results. The level of significance for all the analyses will be determined at the 0.05 level.

3. RESULTS AND DICUSSION

3.1 Latent Class Profiles Among Filipinos Using Growth Mindset Indicators

Researchers advise using a combination of criteria in determining the number of classes in Latent Class Analysis modeling [38]. Among these criteria are the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), the Adjusted BIC, the Lo-Mendell-Rubin Adjusted LRT Test (LMR-LRT), and entropy are the most common and recommended statistical goodness of fit indices to be used for model selection. Smaller AIC, BIC, and adjusted BIC values show a better fit while a significant LMR-LRT value and a larger entropy value are optimal.

Table 3 shows the different models (2-class model up to 6-class model) tested to determine which one will give the best statistical fit using AIC, BIC, ABIC, LMR (LRT), and Entropy as criteria. Data used to run the Latent Class analysis were the re-coded responses of the Filipino learners who joined the PISA 2022. Examining Table 3, Model 3 or a 3-class model showed a better fit according to AIC (23659.195), BIC (23734.252), and ABIC (23699.296) values. On the other hand, Model 2 or a 2-class model is optimal if we look at the results given by the LMR (LRT) (3416.645, $p < .01$) and Entropy (0.777). Since theoretically, the growth mindset is multidimensional or heterogeneous, to explain further and to capture the variability in data, a 3-class model will be better [19], [32]-[34]. A growth mindset encompasses mental, physical, emotional, and spiritual aspects. It extends beyond intellectual abilities. This concept is referred to as a multidimensional growth mindset [21], [22], [39].

The 3-class model was selected as it provides meaningful subgroups with distinct characteristics or response patterns that align with theoretical expectations and practical implications. Analyzing these classes offers valuable insights into the mechanisms driving differences in growth mindset among Filipino students. Furthermore, adopting a 3-class model is beneficial for examining practical implications for educational interventions, policymaking, and targeted support programs to promote a growth mindset and improve mathematics performance among Filipino students.

Table 3. Latent Class Analysis Models

MODEL	AIC	BIC	ABIC	LMR(LRT)	P	ENTROPY
2	23651.195	23698.958	23676.714	3416.645	0.0000	0.777
3	23659.195	23734.252	23699.296	0.000	0.8921	0.611
4	23667.195	23769.545	23721.879	0.000	0.5367	0.498
5	23675.195	23804.838	23744.461	0.000	0.2770	0.596
6	23683.195	23840.132	23767.043	0.000	0.0000	0.512

Adopting the 3-class model, there were 3 425 (50%) Filipino students who fell under class 1, 1 111 (17%) students who were classified to be under class 2, and 2 255 (33%) were classified to be under class 3. Table 4 shows the student probabilities after examining the response patterns of Filipino learners in answering the questions under the growth mindset. Taking 0.208 as an example, it means that only 20.8% of the learners under class 1 responded "disagree" to the question "Your intelligence is something about you that you cannot change very much." This means that almost 80% of Filipino learners belonging to class 1 predominantly agree with the statements implying fixed intelligence. They believe that it is innate among them to have limitations in mathematics and language. This is quite alarming because as we can see, the total enumeration of this group is half of the total population of our respondents. Results from a 3-class model showed that the majority of Filipino learners (members in class 1) who took the PISA 2022 hold a belief that intelligence is fixed. Researchers explained that students in this kind of group are likely to fail in their academic activities, which is likely attributed to fixed abilities which is an attribute of a fixed mindset person [33]. This means that they believe that some individuals are inherently incapable of excelling in certain subjects, regardless of effort. Thus, this group of students is called "Limitation Acceptors."

Class 2 on the other hand showed different results as compared to class 1. Students in class 2 believe that they are capable of moving out of their shells and show better results in their performances as time passes by. In short, this group of students exhibits the characteristics associated with a growth mindset because they tend to disagree with statements suggesting fixed intelligence. 91.7% of students from this group answered "disagree" to the statements "Some people are just not good at mathematics, no matter how hard they study." and "Some people are just not good in (Test Language), no matter how hard they study." They disagree with having inherent limitations in subjects like mathematics and language. Members of this group may believe that their intelligence and academic abilities can be developed through effort and perseverance. Studies revealed that this type of learners who are intrinsically motivated and with boosted self-efficacy [32]. These students view failures as challenges and a learning opportunity, leading to better performance in mathematics. Thus, this group of students is termed as "Optimistic Learners."

Probabilities showed by the members in class 3, 41.6% of them disagreed in item 1, 62.1% answered a "disagree" in item 2, and 80.6% disagreed in item 3. Response patterns from this group showed an exploration in

terms of a growth mindset. It is a mixed response pattern, showing that some agree with the statements suggesting fixed intelligence and limitations while also expressing some disagreement. This attitude of responding to the statements exhibits ambivalence, and uncertainty regarding their beliefs about intelligence and academics beliefs. Students of this group actively seek to understand and apply the principles of a growth mindset. They keep on exploring various strategies to improve their learning. They are also capable of adapting to various challenges which helps them enhance their learning experiences [32]. Therefore, this group is being called "Mindset Explorers."

Table 4. Conditional and Latent Class Probabilities for Reading Strategies Using 3-Class Model.

	Item	Class 1	Class 2	Class 3
To what extent do you agree or disagree with the following statements?	1. Your intelligence is something about you that you cannot change very much.	0.208	0.594	0.416
	2. Some people are just not good at mathematics, no matter how hard they study.	0.022	0.917	0.621
	3. Some people are just not good in (Test Language), no matter how hard they study.	0.000	0.917	0.806

3.2 Differences in Mathematics Performance of Filipino Students in PISA 2022 Using Growth Mindset Profiles

Results of the mathematics performance of 15-year-old students in the Philippines are evidence of being consistently underperformed compared to their peers in neighboring countries and on a global scale. It also indicates that students in the Philippines have not acquired the essential competencies in mathematics, hence significantly behind international standards. On the other hand, educators and researchers believe that cultivating a growth mindset among learners can address the competency gaps that each country is experiencing [31]-[32], [39]-[41]. Encouraging educators to use more positive and proactive approaches to learning is one way of promoting a growth mindset among learners. Through a collaborative effort from the stakeholders, giving value and learning from mistakes, the Philippines may achieve significantly enhanced quality of education, contributing to stronger economic growth and global competitiveness.

Table 5 shows the mean performance of the classified growth mindset profiles of Filipino students who participated in the recently released results from PISA. The mathematics performance of the learners was identified using one of the Plausible Values in Mathematics (PV1MATH). These plausible values likely represent the proficiency of the learners based on their obtained scores in mathematics. Limitation Acceptors has 3425 Filipino students with a mathematics performance mean of 352.49. Optimistic Learners has 1111 test takers with a mathematics performance mean of 374. 44. Lastly, Mindset Explorers has 2255 students with a mean performance in mathematics of 352. 65. To determine if there is a difference in the mathematics mean performance among profiles, one-way ANOVA was used.

Table 5. Performance Growth Mindset Profiles of Filipino Students in Mathematics in PISA 2022

Growth mindset profiles	Number of respondents	Mean performance
Limitation Acceptors	3425	352.49 b
Optimistic Learners	1111	374.44 a
Mindset Explorers	2255	352.65 b

The mean difference is significant at the 0.05 level.

3.4 Variations in Mathematics Performance of Filipino Students in PISA 2022 Using Growth Mindset Profiles

ANOVA results ($F_{(2,\ 6788)} = 55.734$, $p < 9.81E\text{-}25$) showed that there is a statistically significant difference in mathematics performance among growth mindset profiles. In addition, the Tukey post hoc test revealed that Optimistic Learners performed significantly better in mathematics in PISA 2022 compared to Limitation Acceptors ($352.49 \pm 56.80, p < .01$) and Mindset Explorers ($352.49 \pm 64.18, p < .01$). On the other hand, the mathematics performances of Limitation Acceptors and Mindset Explorers showed no difference ($p = 1.71$).

Results from the ANOVA test further added to the limited literature in the Philippines showing how a growth mindset could help learners achieve better academic performances, especially in mathematics. Also, helping students to have positive views and outlook towards achieving academic goals will enhance the achievement and realization of academic goals and objectives specifically attaining all the necessary skills and competencies in mathematics.

Educational policymakers and teachers can leverage these findings to design interventions targeting specific learner profiles. Programs that emphasize the development of a growth mindset may help improve not only mathematics performance but also overall academic resilience. The study's reliance on self-reported data

from PISA limits its ability to account for external factors influencing learner responses. Additionally, the cross-sectional nature of the data restricts causal interpretations. Future research should explore longitudinal data to capture changes in growth mindset over time. Tailored interventions for Limitation Acceptors and support for Mindset Explorers transitioning to Optimistic Learners are highly recommended.

4. CONCLUSION

This study demonstrates the critical role of the growth mindset in shaping the mathematics performance of Filipino students, as evidenced by the distinct latent classes identified through analysis. The three classes Limitation Acceptors, Optimistic Learners, and Mindset Explorers illustrate the multifaceted nature of students' beliefs about intelligence and their potential for academic growth. Students categorized as Optimistic Learners exhibited significantly higher mathematics performance, underscoring the positive impact of a growth mindset on academic success. This highlights the importance of fostering beliefs in the malleability of intelligence and encouraging perseverance in learning. The findings provide empirical support for the implementation of interventions aimed at cultivating a growth mindset among learners. Moreover, the study's results contribute to the broader understanding of the multidimensional nature of the growth mindset and its implications for educational policy and practice. Future research may further explore the dynamics between growth mindset and performance across other domains and demographic groups, paving the way for the development of new theories and strategies to optimize educational outcomes.

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