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Using Latent Class Analysis to Enhance Students' Positive Attitudinal Patterns in Mathematics

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ABSTRACT

This study aimed to identify latent classes among Grade 8A – 8D students at Statefields School, Incorporated (SSI) during the 2023–2024 school year to enhance teaching-learning and promote positive attitudes toward Mathematics. The respondents completed the Mathematics Self-Efficacy and Anxiety Questionnaire (MSEAQ), developed by May D. (2017) for her Ph.D. dissertation at the University of Michigan, via Google Forms. Results indicated that a five-class model optimally fits the attitudinal patterns of the students. The latent classes, derived through Latent Class Analysis (LCA), were Class 1 (Math Anxiety), Class 2 (Growth Mindset), Class 3 (Competitive Achiever), Class 4 (Self-Efficacy), and Class 5 (Enthusiasm). Among the 143 respondents, most students were categorized in Class 4 (Self-Efficacy), indicating a high prevalence of self-efficient attitudes. Conversely, students in Class 1 (Math Anxiety) require educators who can proactively foster excitement about math and help them develop confidence as successful problem solvers.

INTRODUCTION

In a world where mathematics often gets a bad rap for being tough, its importance can't be overstated. It's not just about dealing with numbers; it's the backbone of our tech, the engine behind our systems, and the key to solving real-world puzzles; from the gadgets we use daily to the intricate networks shaping our society, mathematics is everywhere! Mathematics empowers businesses, guides financial decisions, and fuels scientific breakthroughs. Whether it's calculating profits, analyzing data trends, or predicting the next big thing, math is the secret sauce in today's fast-paced world. So, while math may seem daunting at times, its impact is undeniable. Hence, in education, students' attitudes toward Mathematics have greatly impacted their performance level in school, especially in achievement and mastery of various mathematics competencies.

Thus, modification of teachers' strategies and seminars offered by the school to students must be diversified, relevant, interesting, motivating, and/ or significant for our students. To answer the existing trend problem in the field of Mathematics, this study focuses on ATM, exploring the reciprocal relationship between attitudes and skills, and highlighting the concept of attitudinal patterns toward Mathematics which greatly affects students' performances, and the possible activities or recommendations that would hone and or cultivate students' positive mathematical attitudes while transforming negative attitudinal patterns. Consequently, establishing positive attitudes (Mathematics self-efficacy and growth mindset) promotes math achievement and subsequent positive attitudes. Hence, negative attitudes, conversely, can lead to avoidance of math-related activities, resulting in a detrimental cycle of declining achievement and worsening attitudes (Ma, 1997; Hembree, 1990). Thus, this study is done to contribute and confirm a diversified approach and strategy to the procurement of a more transformative exploration and a loving environment while learning and exploring the heart of and the undeniably significant Mathematics in modern times.

LITERATURE REVIEW/RELATED WORKS

Attitude toward mathematics (ATM) is the student's organized predisposition to think, feel, perceive, and behave toward mathematics (Jovanovic and King 1998); ATM is an aggregated measure of "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (Neale 1969, p. 632); ATM Scale measures an individual's feelings, interests, and predispositions toward mathematics (Askar 1986).

A growth mindset refers to the belief that one person's ability can be developed through efforts, whereas a fixed mindset means viewing ability as fixed and unchangeable (Yeager and Dweck, 2012; Xu et al., 2022). It is the belief that intellectual abilities can be developed through effort and perseverance (Dweck, 2006). Students with a growth mindset tend to perform better and exhibit greater resilience in the face of challenges (Blackwell, Trzesniewski, & Dweck, 2007; Yeager et al., 2016). A growth mindset, therefore, plays a crucial role in shaping students' reactions to setbacks and challenges in mathematics learning (Yeager & Dweck, 2012). Therefore, students with growth mindsets have a better feeling of control over their mathematics learning, which leads to higher mathematics self-efficacy, believing that they would improve their mathematics learning by making more effort. This could, in turn, contribute to better mathematics learning results.

Mathematics anxiety, highlighting its detrimental effects on students' performance and attitudes towards math (Ashcraft, 2002; Richardson & Suinn, 1972). Mathematics anxiety is associated with negative emotions and avoidance behaviors, ultimately leading to decreased mathematical achievement (Cates & Rhymer, 2003). The link between math anxiety and performance underscores the importance of addressing anxiety-related issues in mathematics education. According to Ramirez, Chang, Maloney, Levine & Beilock, 2016, pg. 84, Math anxiety (MA) is negatively related to Math achievement both because it leads to avoidance of Math and because it disrupts the working memory resources students use to solve difficult Math problems. Hence, Zakaira, Zain, Ahmad, & Erlina (2012) said that students with high Mathematics anxiety levels engage in negative thinking about their self-ability. These students will exhibit less confidence working with numbers and mathematical concepts through a problem-solving process (pg. 1762-1763).

Mathematics self-efficacy is the individuals' beliefs regarding their abilities in mathematics (Bandura, 1997). High levels of self-efficacy are associated with increased motivation, persistence, and better academic performance (Pajares & Graham, 1999; Zimmerman, 2000). Sources of self-efficacy include mastery experiences, vicarious experiences, social persuasion, and physiological states (Bandura, 1997).

As per Enneagram, Competitive achievers are likely to value achievement and want to be the best. As a result, efficiency, results, recognition, and image are very important to them. Competitive achievers strive for success in their chosen field and tend to be highly flexible and willing to adapt to achieve their goals. At their best, others will experience competitive achievers as hard-working, principled, and receptive, offering the gifts of hope and integrity to the world. In an unhealthy state, the competitive achievers' over-expressed need for achievement may seem self-important and inconstant. This stems from a sense of self-worth that is built on what the competitive achievers do, rather than who they are.

Enthusiasm is a feeling of energetic interest in a particular subject or activity and a desire to be involved in it, or a subject that produces such a feeling. Hence, as defined by Collins Dictionary, an enthusiast is a person who is very interested in a particular activity or subject and who spends a lot of time on it. He is a great sports enthusiast.

Given the predictive power of early math skills on later academic success, it plays an important role in fostering positive attitudes toward mathematics from an early age (Claessens & Engel, 2013; Duncan et al., 2007). Moreover, it emphasizes the need to transform negative attitudes into enriched and motivated learning-teaching processes.

Bolstering means to support or improve something or make it stronger. The strategies for bolstering mathematics attitudes are promoting growth mindset principles, normalizing challenges, and providing specific, task-focused feedback (Blackwell et al., 2007; Mueller & Dweck, 1998; Smith et al., 2013). Similarly, the importance of avoiding harmful messaging that promotes or reinforces fixed mindsets and failure narratives is also highlighted (Rattan, Good, & Dweck, 2012).

MATERIAL & METHODOLOGY

The specific objective of the present study is to use the latent Class Analysis (LCA) in categorizing the data set. Moreover, it sought to answer the following questions:

a. What model best fits the pattern of the respondents' responses on MSEAQ?
b. What is the probability of class membership for each latent class extracted from the analysis of the data?
c. Who are the students belonging to each class?
d. What are the recommended actions to bolster students' positive attitudes toward Mathematics?

The researcher used a qualitative method via a survey questionnaire (MSEAQ) on latent variables. Qualitative research collects participants' experiences, perceptions, and behavior, answering the how and why rather than how many or how much (Tenny, S. 2022). The study involved 143 Grade 8A – 8D students from Statefields School, Inc. (SSI). The researcher adopted the MSEAQ questionnaire from a published study and created a Google form for assessment. Latent Class Analysis (LCA) was used to determine students' latent classes and the optimal-fit model based on MSEAQ responses. Factor Analysis identified latent factors or aptitudes.

Lin and Tai (2015) describe LCA as a method to identify unobserved subpopulations based on multiple measures, like cluster analysis for latent or categorical variables. Statistical tests and analyses were conducted using JAMOVI version 2.4.14.0, including the LCA package. The lowest AIC and BIC values identified the best-fit model for mathematics attitude.

Ethically, the researcher obtained permission from the MSEAQ questionnaire's author (Diana K. May) and the school principal. Consent was also obtained from parents/guardians and assent from the students via Google Forms before data collection.

RESULTS AND DISCUSSION

The results of LCA for mathematics attitude are presented in Table 1. 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 (4126 and 4583, respectively). Thus, the five-class model is the best-fit model for students' attitudinal pattern toward mathematics based on the group of respondents who responded to the study.

Table 1. Summary of AIC and BIC Criteria – Class 2 to Class 6 .

Model	AIC	BIC
2-class	4311	4491
3-class	4319	4591
4-class	4169	4534
5-class	**4126**	4583
6-class	4151	4699

The AIC which has the smallest value for the five-class model is 4126, the five-class model is a suitable model for students' Math attitudinal pattern. All 143 students were divided into five classes.

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 2. For class 1 (Math Anxious), the class probability indicated that 16.5% of the students were thus classified. For the remaining classes, 21.2% of the students were classified as Class 2 (Growth Mindset), 16.5% were classified as Class 3 (Competitive Achievers, 26% were classified as Class 4 (Self-Efficient), and 13.3% were classified as Class 5 (Enthusiastic).

Tables 2 – 5 show the item response per indicator. The probability values presented in each category for individual indicators were used to assign a label to each class. Hence, the labels for each classification were based on the literature review per se.

In Class 1 (Math Anxiety), the probability approached a value of 1.00. The indicators shown below have the highest probability of belonging to category 1. Hence, these indicators or variables shown in Table 2 below determine the attitudinal pattern that highlights mathematics anxiety. This class is labeled as Math Anxiety since as per definition from Cates & Rhymer, 2003 it means that it is associated with negative emotions and avoidance behaviors, ultimately leading to decreased mathematical achievement.

Table 2. Item Response – Class 1 Math Anxiety (23.78%).

	INDICATORS	Class 1	Class 2	Class 3	Class 4	Class 5
13	Working on mathematics homework is stressful for me.	0.935	0.634	0.837	0.634	0.000
14	I worry I will not be able to understand the mathematics.	0.970	0.863	0.963	0.865	0.211
15	I get nervous when asking questions in class.	0.910	0.689	0.655	0.743	0.158
16	I get tense when I prepare for a mathematics test.	0.962	0.783	0.852	0.846	0.211
19	I worry that I will not be able to do well on mathematics tests.	0.940	0.966	0.872	0.813	0.263
26	I get nervous when I have to use mathematics outside of school.	0.849	0.250	0.727	0.489	0.158
29	I am anxious when mathematics instructors are lecturing.	0.6494	0.1509	0.3467	0.3689	0.0526
30	I worry that I will have to use mathematics in my future career.	1.000	0.413	0.919	0.530	0.105

In Class 2 (Growth Mindset), the probability approached a value of 1.00. The indicators shown below have the highest probability of belonging to category 2. Hence, these indicators or variables shown in Table 3 below determine the attitudinal pattern that highlights the growth mindset attitude toward Mathematics. The class is labeled as a Growth Mindset as per the definition from (Yeager and Dweck, 2012; Xu et al., 2022) (Dweck, 2006). It refers to the belief that one person's ability can be developed through efforts, whereas a fixed mindset means viewing ability as fixed and unchangeable. It is the belief that intellectual abilities can be developed through effort and perseverance.

Table 3. Item Response – Class 2 Growth Mindset (25.87%).

	INDICATORS	Class 1	Class 2	Class 3	Class 4	Class 5
1	I have been able to understand mathematics.	0.819	1.000	0.915	1.000	
10	I have worked with other students in my mathematics classes.	0.880	1.000		0.946	0.947
12	I regularly do assigned homework in my mathematics classes.	0.640	0.900	0.648	0.872	0.789
22	I worry that I will not be able to get a good grade in mathematics courses.	0.910	1.000	0.703	1.000	1.26e-

In Class 3 (Competitive Achievers), the probability approached a value of 1.00. The indicators shown below have the highest probability of belonging to category 3. Hence, these indicators or variables shown in Table 4 below determine the attitudinal pattern that highlights the competitive achiever attitude toward Mathematics. The class is labeled as Competitive Achievers since as per the definition from Enneagram it is likely to value achievement and want to be the best. As a result, efficiency, results, recognition, and image are very important to them. Competitive achievers strive for success in their chosen field and tend to be highly flexible and willing to adapt to achieve their goals.

Table 4. Item Response – Class 3 Competitive Achievers (2.10%).

	INDICATORS	Class 1	Class 2	Class 3	Class 4	Class 5
3	I have enjoyed mathematics.	0.579	0.962	1.000	0.977	0.947
6	Mathematics instructors have been willing to help me learn the material.	0.910	0.967	1.000		
11	I have worked hard in my mathematics classes.	0.784	0.906	1.000	0.973	0.789
20	I worry that I do not know enough mathematics to do well in future mathematics courses.	0.970	0.867	1.000	0.973	0.211

In Class 4 (Self-Efficient), the probability approached a value of 1.00. The indicators shown below have the highest probability of belonging to category 4. Hence, these indicators or variables shown in Table 5 below determine the attitudinal pattern that highlights the mathematics' self-efficacy. The class is labeled as Self-efficient as per the definition from (Bandura, 1997) and (Pajares & Graham, 1999; Zimmerman, 2000). It means that it is the individuals' beliefs regarding their abilities in mathematics. High levels of self-efficacy are associated with increased motivation, persistence, and better academic performance. Sources of self-efficacy include mastery experiences, vicarious experiences, social persuasion, and physiological states.

Table 5. Item Response – Class 4 Self-Efficient (32.87%).

	INDICATORS	Class 1	Class 2	Class 3	Class 4	Class 5
1	I have been able to understand mathematics.	0.819	1.000	0.915	1.000	
2	I have done well in my mathematics courses.	0.189	0.646	0.331	0.929	0.895
4	I am the type of person who can learn mathematics well.	0.094	0.5689	0.3599	0.8155	0.7895
5	I have been happy in my mathematics courses.	0.269	0.753	0.656	0.861	0.842
8	I have sought help from mathematics instructors outside of class.	0.438	0.480	0.435	0.694	0.474
9	I have set goals in my mathematics classes.	0.472	0.751	0.741	0.842	0.737
24	I believe I can think like a mathematician.	0.0323	0.1341	5.06e-	0.6430	0.5789
25	I believe I can complete all of the assignments in a mathematics course.	0.323	0.331	0.728	1.000	0.947

In Class 5 (Enthusiast), the probability approached a value of 1.00. The indicators shown below have the highest probability of belonging to category 5. Hence, these indicators or variables shown in Table 6 below determine the attitudinal pattern that highlights the enthusiastic attitude towards mathematics. The class is labeled as Enthusiastic since as per the definition from Collins Dictionary it is a feeling of energetic interest in a particular subject or activity and a desire to be involved in it, or a subject that produces such a feeling and an enthusiast is a person who is very interested in a particular activity or subject and who spends a lot of time on it.

Table 6. Item Response – Class 5 Enthusiast (15.38%).

	INDICATORS	Class 1	Class 2	Class 3	Class 4	Class 5
7	I have asked questions in my mathematics classes.	0.500	0.526	0.623	0.536	0.789
17	I believe I can do mathematics in a mathematics course.	0.124	0.501	0.551	0.857	0.947
18	I believe I am the kind of person who is good at mathematics.	4.61e-106	0.104	0.226	0.715	0.789
21	I believe I can get an “A” when I am in a mathematics course.	0.135	4.83e-171	0.321	0.536	0.684
23	I believe I can learn well in a mathematics course.	0.313	0.870	0.910	0.970	1.000
27	I believe I can understand the content of a mathematics course.	0.378	0.771	0.809	0.974	1.000
28	I believe I can do well on a mathematics test.	0.136	0.288	0.674	0.967	1.000

Table 7 below shows the sample size per class. The IDs of students or respondents belonging to each class were identified as well as presented in the table below. Hence, out of 143 students, 34 students belong to the “Math Anxious” Class, 37 students belong to the “Growth Mindset Class”, 3 students belong to the “Competitive Achievers” and 47 students belong to the “Self-Efficient Class” and 22 belongs to Class 5 “Enthusiastic”. Furthermore, the class with the highest number of student involvement is Self-Efficient Class while the class with the lowest number of student involvement is Class 3 (Competitive Achiever). Generally, instead of considering the latent class probability based on observed constructs, identified members of students per class were predicted through modal posterior probability as shown in Table 7.

The last column in Table 7, it shows students grouped based on their attitudinal pattern toward Mathematics, thus, we can give specific activities that will be able to cater the needs and interests of the students. Significantly, this group of students having the same attitudinal pattern toward mathematics will be given a more supportive strategy because one size does not fit all as stated by Kaplan Rogers (2003, W. Tomlinson (2003) and differentiated activity must be modeled to a specific group of students depending on their interests, concluded by Chin-Wen Chien (2014).

Table 7. Predicted Class Membership by Modal Posterior Probability.

CLASS	POSTERIOR PROBABILITY	PERCENTAGE	NO. OF STUDENT	STUDENT'S ID BELONGING TO THE CLASS
CLASS 1 - MATH ANXIETY	0.2378	23. 78%	34	1, 4, 10, 11, 12, 17, 19, 21, 30, 36, 37, 41, 42, 43, 53, 59, 61, 75, 83, 84, 85, 86, 90, 100, 109, 116, 118, 123, 126, 131, 132, 137, 142, 143
CLASS 2 - GROWTH MINDSET	0.2587	25. 87%	37	2, 5, 7, 8, 15, 23, 25, 26, 27, 28, 36, 46, 47, 48, 49, 51, 63, 65, 69, 70, 71, 77, 89, 92, 93, 94, 95, 97, 101, 102, 103, 105, 106, 112, 121, 128, 136
CLASS 3 - COMPETITIVE ACHIEVER	0.021	2. 10%	3	3, 99, 141
CLASS 4 - SELF-EFFICIENT	0.3287	32. 87%	47	6, 9, 13, 14, 18, 20, 22, 24, 31, 32, 33, 34, 35, 44, 50, 52, 57, 60, 62, 64, 66, 67, 68, 72, 73, 76, 79, 80, 81, 87, 88, 91, 98, 107, 113, 114, 115, 117, 120, 122, 125, 129, 130, 133, 135, 138, 140
CLASS 5 - ENTHUSIASTIC	0.1538	15. 38%	22	16, 29, 38, 40, 45, 54, 55, 56, 58, 74, 78, 82, 96, 104, 108, 110, 111, 119, 124, 127, 134, 139
TOTAL	1	100%	143	

CONCLUSIONS

The study concluded that most respondents are self-efficient, followed by those with a growth mindset, and then those with math anxiety. Ashcraft (2002) and Richardson & Suinn (1972) noted that math anxiety negatively impacts students' performance and attitudes toward math, necessitating proactive measures. Students with math anxiety need educators who can make math exciting and build their confidence as successful problem solvers.

To enhance and diversify the teaching-learning process, specific activities are suggested for each class to cater to individual differences and interests based on their pattern prevalences. For Class 1, Math Anxiety, activities include math mindfulness sessions, collaborative problem solving, real-life math applications, math journals, and positive reinforcement seminars. For Class 2, Growth Mindset, suggested activities are math challenge projects, growth mindset workshops, peer teaching opportunities, reflective learning sessions, and celebrating mistakes. Class 3, Competitive Achiever, can benefit from math competitions, leaderboards and badges, advanced math clubs, real-time feedback tools, and guest speaker series. For Class 4, Self-Efficient, activities like independent study contracts, self-paced learning modules, mentor programs, goal-setting workshops, and tech-enhanced learning tools are recommended. Lastly, Class 5, Enthusiastic Group, can engage in math explorations, interactive math games, math in arts and music, math fairs, and field trips.

The study recommends conducting similar research on other math attitudes with larger sample sizes to have more parsimony and stable Latent Class Models. Hence, a more detailed Latent Class Analysis on math attitudes is also suggested, along with another factor consideration where ANOVA will be utilized so that studies of John Reynor (2023), Abalde & Oco (2023) about Teacher Influence and Instructional Methods affecting students' attitude toward Mathematics may be further testified, supported, or do not significantly affect either. Additionally, customized seminars or webinars should be proposed for each class based on the study's structured model.

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