Journal of Education, Learning, and Management (JELM)
ISSN: 3079-2541 (Online)
Volume 2 Issue 1, (2025)
https://doi.org/10.69739/jelm.v2i1.611
https://journals.stecab.com/jelm

Published by
Stecab Publishing

Research Article

Development of a 21st Century Positivist Learning Scale in Mathematics (PLSM): A Likert-Based Instrument using Factor Analysis to Measure Undergraduate Students' Learning Experiences

*[1]Reñel M. Sabanal, [1]Julius S. Valderama

About Article

Article History

Submission: May 01, 2025
Acceptance : June 06, 2025
Publication : June 17, 2025

Keywords

Factor Analysis, Mathematics Learning Practices, Positivist Pedagogy, Validation

About Author

[1] Nueva Vizcaya State University, Bayombong, Nueva Vizcaya, Philippines

Contact @ Reñel M. Sabanal
johnkielsabanal@gmail.com

ABSTRACT

This study developed and validated the 21st Century Positivist Learning Scale in Mathematics (PLSM) through a mixed-methods approach combining Exploratory Factor Analysis and expert validation. Conducted at Isabela State University-Echague Campus with 333 undergraduate students, the research identified 29 observable learning practices categorized into four reliable components (α=0.95): Active Note-taking, Note Reorganization, Self-Testing and Use of Technology, and Review Techniques. The scale demonstrated excellent psychometric properties (KMO=0.944, p<0.001) with a four-factor structure explaining 59.94% of variance. Expert validators (three PhD professors) confirmed the alignment of items with positivist principles of measurable learning practices. The PLSM bridges traditional study methods with modern technological approaches, offering educators a validated tool to assess evidence-based mathematics learning practices. The scale's development process involved statistical validation and theoretical grounding, making it suitable for diagnosing learning strategy profiles and informing pedagogical interventions in STEM education. Future researchers can adapt the PLSM to assess students' mathematics learning practices at specific universities or extend its application to K-12 education.

Citation Style:

Sabanal, R. M., & Valderama, J. S. (2025). Development of a 21st Century Positivist Learning Scale in Mathematics (PLSM): A Likert-Based Instrument using Factor Analysis to Measure Undergraduate Students' Learning Experiences. *Journal of Education, Learning, and Management, 2*(1), 234-246. https://doi.org/10.69739/jelm.v2i1.611

1. INTRODUCTION

Mathematics education plays a crucial role in developing critical thinking and problem-solving skills, which are essential for students' academic and professional success. According to Argun and Ulusoy (2019), learning mathematics in schools is designed to provide students with educational experiences that cultivate their critical thinking, problem-solving, curiosity, and ability to make predictions, while also encouraging a positive and enthusiastic attitude toward mathematics. Many students approach mathematical problems with a fixed mindset, believing that mastery comes only from memorizing formulas and procedures (Sintema & Mosimege, 2023). However, the effectiveness of learning strategies in mathematics largely depends on the underlying educational philosophies that guide instruction and student engagement. The study by Li and Acharya *et al.* (2021) highlight the cultural and pedagogical influences on mathematics learning, emphasizing the need for research on learning practices. Positivism, as a research paradigm of this study, emphasizes observable and measurable learning practices, providing a structured approach to understanding how students acquire mathematical knowledge (Ernest, 1991). Despite its benefits, there remains a gap in research on how positivist principles are applied in real-world educational settings.

1.1. Statement of objectives

This study aims to examine and measure the application of positivist learning principles in the mathematics of undergraduate students at Isabela State University – Echague Campus during the school year 2024-2025. By identifying key components and dominant components, the research seeks to develop a validated instrument that assesses the extent to which positivism influences learning practices in mathematics. Specifically, it aimed to achieve the following objectives:

1. To determine the key components of positivism embedded in the 21st-century learning practices in mathematics of undergraduate students.
2. To identify the dominant components and themes that define positivism with students' learning practices in mathematics.
3. To establish the Positivist Learning Scale in Mathematics (PLSM) that measures the degree of positivism applied in students' learning practices in mathematics.

1.2. Scope and delimitation of the study

This study focuses on examining and measuring positivist learning practices in mathematics among undergraduate students at Isabela State University – Echague Campus during the school year 2024-2025. The research specifically aims to develop and validate the Positivist Learning Scale in Mathematics (PLSM), a Likert-based instrument designed to assess the extent of positivist-aligned learning practices. Using a mixed-methods approach that combines quantitative statistical analysis with qualitative expert validation, the study seeks to identify key components of positivism embedded in students' learning practices through Exploratory Factor Analysis (EFA). The data collection is limited to 333 undergraduate student respondents to ensure statistical reliability.

2. LITERATURE REVIEW

Positivist approaches, which prioritize observation and quantifiable data, offer a systematic way to evaluate and improve student learning. The study by Odutayo and Fonseca (2023) demonstrate the effectiveness of positivist-aligned instructional strategies in improving mathematical achievement. These include explicit instruction, direct instruction, and the use of standardized assessments to measure student progress. However, while existing literature highlights the theoretical foundations of positivism in education, there is limited research on its practical application in mathematics classrooms, especially in Philippine higher education institutions. Additionally, scale development in mathematics education, as seen in the work of Hay *et al.* (2022), has focused on self-efficacy-effort in mathematics education rather than positivist-aligned learning behaviors. Student learning practices show the influence of positivism in mathematics. Students who foster a positivist approach tend to focus on accuracy, logic, and coming up with the right answers. Andal and Andrade's (2022) study supports this statement by showing that procedural fluency helps students solve word problems on algebra and probability quickly and accurately. The lack of information highlights the importance of investigating how positivist learning practices are evident among undergraduate students at Isabela State University - Echague Campus.

Without such a tool, teachers may struggle to identify which learning practices are most effective in identifying student's academic success. Additionally, while some studies have explored learning practices in mathematics (Isabel & Barbosa, 2022), few have specifically related the learning practices to the positivist principles or examined their applicability in a Philippine university. Comparative studies, like Wang and Lin (2005), suggest that learning practices in mathematics vary significantly across educational systems, reinforcing the need for localized scale development. This research gap highlights the need to develop a reliable and valid liker-based scale which is the 21st Century Positivist Learning Scale in Mathematics (PLSM).

To address these research gaps, this study aims to determine the validity and reliability of positivist learning practices in mathematics education at Isabela State University-Echague Campus. Specifically, it seeks to determine the key components of positivism embedded in students' learning practices, identify dominant themes, and establish a validated PLSM instrument. By employing a mixed-methods approach, combining Exploratory Factor Analysis (EFA) with thematic interpretation. The findings will offer insights for educators seeking to improve mathematics instruction. Ultimately, this paper aims to bridge the gap between theory and practice by developing a research-based tool that enhances the measurement and application of positivist learning in mathematics education.

This study follows a research paradigm to examine how positivist learning practices apply to mathematics education at Isabela State University-Echague Campus as seen in Figure 1. The framework has three main parts: input, process, and output. The input includes the learning practices of undergraduate students in learning mathematics. It is based on the idea that learning can be observed and measured, following positivist principles. The process involves developing and testing a survey tool (PLSM) to measure these learning practices. First, students provide actual examples of how they learn mathematics. Then, experts check if the survey statements are clear and relevant to the positivist approach. Finally, the survey is tested with a small group of students before being given to 200 students for final data collection. Statistical methods are used to identify key patterns in how students learn. The output is a validated instrument (PLSM) that measures positivist learning in mathematics, along with a list of the most important learning strategies used by students. The results can help teachers understand and improve how students learn mathematics.

2.1. Conceptual Framework

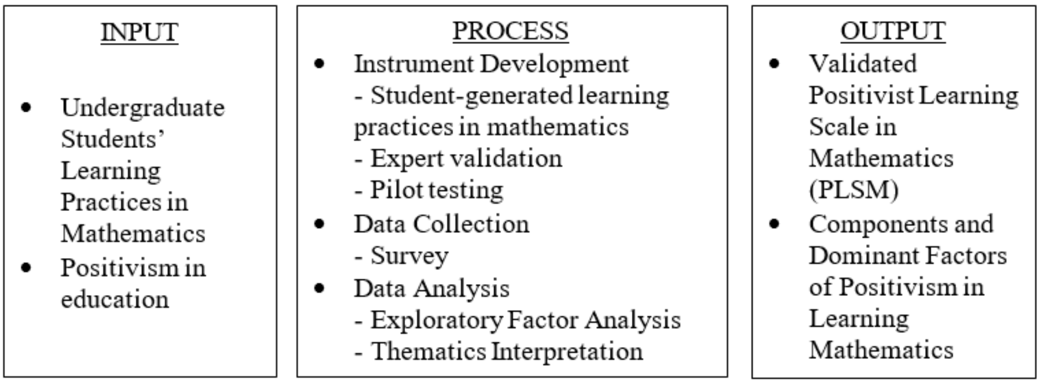

Figure 1. The research paradigm

3. METHODOLOGY

3.1. Research design

This study employs a quantitative-qualitative mixed-methods approach, combining Exploratory Factor Analysis (EFA) with thematic interpretation to examine the learning practices in mathematics of undergraduate students. The quantitative approach involves statistical analysis of Likert-scale survey responses to identify underlying component structures, while the qualitative approach provides a deeper interpretation of the identified components.

3.2. Research environment

The Isabela State University (ISU) comprises eleven campuses which are located across the province of Isabela, Philippines. These campuses are located in Roxas, Cauayan City, San Mateo, Santiago City, Jones, Echague, Angadanan, San Mariano, Ilagan City, Palanan Extension, and Cabagan. Among these, the ISU–Echague Campus was selected as the primary research environment for this study.

The ISU – Echague Campus is the largest area of ISU spanning an expansive 386 hectares of land and it is the main campus of IUS. It is located in San Fabian, Echague, Isabela, and serves as the central hub for academic, research, and extension activities within the university system. Given its extensive facilities, diverse student population, and established academic programs, the ISU-Echague Campus provides an ideal research environment for investigating undergraduate students' learning practices in mathematics.

3.3. Research respondents

The study involved two key groups of respondents to ensure the validity and reliability of the research instrument and data analysis:

3.3.1. Expert validators

• Three (3) PhD-holding university instructors, specializing in mathematics education, and physics from different SUCs, were engaged to validate the Positivist Learning Scale in Mathematics (PLSM).

• Their qualifications, expertise, and roles in the validation process will be discussed in detail in the next chapter.

3.3.2. Student respondents

• *Generating Statements on Learning Practices in Mathematics:* To ensure the development of the Positivist Learning Scale in Mathematics (PLSM), an initial group of statements was generated based on the actual learning practices of undergraduate mathematics students. For this phase, three classes of undergraduate students from Isabela State University – Echague Campus were purposively selected.

• *Pilot Testing Group:* A preliminary assessment of the instrument was conducted with one section of at least 30 willing undergraduate students to evaluate the clarity, reliability, and internal consistency of the survey items.

• *Full-Scale Data Collection Group:* For the final component analysis, the validated survey was administered to at least 290 undergraduate students from ISU – Echague Campus.

• All student answers were kept anonymous, and participation was voluntary. The research followed the university's rules for ethical studies.

3.4. Data gathering procedure

The study was conducted in five stages. First, the researcher generated statements are the learning practices in mathematics of the undergraduate students. These practices included problem-solving strategies, study habits, and resources used. The statements were then framed as Likert-scale items.

Next, the researcher rephrased and refined the statements to eliminate ambiguity or redundancy, ensuring clarity and neutrality. Following this, the statements underwent content validation through expert evaluation. Three university instructors with PhD degrees assessed the statements for clarity, relevance, and alignment with positivism. The experts rated each statement and the researcher used a Content Validity Index (CVI), and those learning practices not equal to 1 were removed.

After validation, the researcher conducted a pilot test with 34 students from one section to assess reliability and item comprehension. Internal consistency was measured using Cronbach's Alpha, with a threshold of greater than 0.7. Poorly performing items were revised or removed before proceeding to full-scale data collection. Finally, the researcher distributed the validated instrument to the 333 undergraduate students from Isabela State University – Echague Campus for component analysis. The participants rated each statement on a 5-point Likert scale, ranging from Always to Never.

3.5. Treatment of the data

The data will be analyzed using Exploratory Component Analysis (EFA) to identify underlying structures in the Likert-scale responses. Before conducting the EFA, the Kaiser-Meyer-Olkin (KMO) Measure and Bartlett's Test of Sphericity will be performed to assess the suitability of the data for component analysis. Principal Component Analysis (PCA) will then be employed to extract the key factors, followed by Varimax rotation to enhance the interpretability of the components by maximizing variance between them. Items with factor loadings below 0.4 will be excluded.

Additionally, a scree plot will be generated to determine the optimal number of factors based on eigenvalues greater than 1, providing a visual representation of the significance of each extracted component. Following the factor extraction, the identified factors will be thematically described and categorized according to the core principles of positivism. The interpretation of these factors will be supported by relevant literature.

4. RESULTS AND DISCUSSION

Section 1. Key components of positivism in 21st-century learning practices in mathematics

After finalizing the research title and objectives, the study begins with data collection to examine students' mathematics learning practices. The researcher distributed a Google Form survey to three sections at ISU - Echague Campus. The survey generated 370 initial statements regarding their learning practices in mathematics. These responses covered numerous dimensions of student learning practices, including problem-solving approaches and strategies (Gurat, 2017); study habits and time management techniques (Rambe & Siregar, 2022); classroom participation and engagement methods (Mesa, 2010); utilization of learning resources and materials (Pomerantz *et al.*, 2007); collaborative learning practices (Qureshi *et al.*, 2023).

After gathering all the responses, the researcher grouped similar learning practices and removed ambiguous or repetitive statements to ensure clarity and avoid redundancy. The analysis identified 60 distinct learning practices among undergraduate students. These learning practices can be broadly categorized into several key themes: active engagement with course material through note-taking strategies (rewriting, color-coding, prioritizing examples), self-regulated learning techniques (spaced repetition, Pomodoro method, error analysis), and collaborative methods (study groups, peer teaching, solution comparisons). Many students combine traditional approaches like careful lecture listening and handwritten notes with modern technological tools including educational apps (Gizmo), AI assistants (ChatGPT), and digital flashcards (Anki/Quizlet). The practices also demonstrate metacognitive awareness, evidenced by techniques like the Feynman method, self-testing through generated problems, and intentional environment management (quiet spaces, device control). Particularly is how students personalize their learning through multimodal reinforcement - blending auditory (recorded notes), visual (diagrams, color-coding), and kinesthetic (rewriting, teaching imaginary audiences) strategies while maintaining focus on core mathematical competencies through repeated problem-solving and concept mapping. These varied approaches reflect both individual learning preferences and evidence-based study methods adapted to mathematics education. These learning practices provide valuable insights into students' learning practices and will be used to develop the Positivist Learning Scale in Mathematics (PLSM) later in the study.

To align the learning practices with the positivist approach, the researcher engaged expert validators to evaluate the 60 distinct mathematics learning practices among undergraduate students. This validation process ensured the learning practices reflected measurable, observable, and evidence-based strategies consistent with positivism. For ethical considerations, the experts were assigned pseudonyms to protect their identities.

Table 1. Matrix of qualifications of the expert validators

Expert Validators	Qualifications
Ma'am Amy	• PhD in Science Education major in Mathematics • 37 years of teaching mathematics • Saint Mary's University
Ma'am Belle	• PhD in Institutional Development and Management • More than 39 years of teaching Physics • Isabela State University – Echague Campus
Ma'am Chloe	• PhD in Mathematics • 32 years of teaching mathematics • University of the Philippines – Open University

Table 1 presents the credentials of three expert validators who were selected to assess the alignment of learning practices with the positivist approach in this study. Each validator brings qualifications to ensure the PLSM's validity. Ma'am Amy holds a PhD in Science Education majoring in Mathematics and has 37 years of teaching experience and currently teaching at Saint Mary's University. Ma'am Belle has a Ph.D. in Institutional Development and Management and over 39 years of teaching Physics at Isabela State University – Echague Campus. Lastly, Ma'am Chloe possesses a PhD in Mathematics and 32 years of teaching experience and currently teaching at the University of the Philippines – Open University. Their advanced degrees, and decades of teaching, underscore their authority in validating the PLSM.

After aligning the learning practices with a positivist approach through expert validation, all three experts reached an agreement on a set of learning practices. Through this evaluation process, they unanimously agreed on 29 learning practices that fully conform to positivist principles. These validated practices demonstrate measurable, observable characteristics essential for empirical study in mathematics education. This agreement among all three experts each with decades of teaching experience underscores the reliability and objectivity of these selected practices. The 29 agreed-upon learning practices will form the foundation for developing the Positivist Learning Scale in Mathematics (PLSM), ensuring the instrument is grounded in verifiable teaching and learning strategies. Table 2 presents the 29 learning practices that will be incorporated into the Positivist Learning Scale in Mathematics (PLSM).

Table 2. Learning practices aligned with positivist principles for the PLSM instrument

Learning Practices in Mathematics	**5 Always**	**4 Often**	**3 Sometime**	**2 Rarely**	**1 Never**
I listen carefully during discussions and take notes for problem sets and definitions.					
I take notes during lessons to help me recall key concepts.					
I write down important details mentioned during discussions.					
I listen attentively during class discussions to make remembering easier.					
I actively listen to the instructor while jotting down key points.					
I rewrite my notes after class in a separate notebook for better retention.					
I summarize key takeaways in my own words after each lesson.					
I highlight or underline important terms in my notes for quick review.					
I write formulas and examples on a separate sheet for easier review.					
I take notes on both whiteboard content and verbal explanations.					
I prefer handwritten notes over digital for better concentration.					
I rewrite notes multiple times to reinforce memory.					
I draw diagrams or concept maps to visualize processes.					
I create summary notes and concept maps to simplify complex topics.					
I use flashcards for active recall.					
I solve practice problems repeatedly until I master the steps.					
I re-solve examples given in class to test my understanding.					
I look for additional problem sets online for extra practice.					
I write formulas on sticky notes and place them where I'll see them often.					
I recite notes aloud or record myself to reinforce memory.					
I employ spaced repetition for long-term retention.					
I test myself using flashcards or self-made quizzes.					
I rewatch lecture videos to reinforce learning.					
I solve problems without notes to assess my recall					
I set small daily study goals instead of cramming.					
I use Quizlet or Anki for digital flashcards.					

I record voice notes and replay them for auditory learning.
I connect lessons to real-life applications.
I revisit past quizzes and re-solve them for practice.

These learning practices all focus on hands-on learning, regular practice, and using different ways to review material - all things that can be seen and measured that fit in a positivist framework. Students work hard to make mathematics concepts more concrete by doing things like rewriting notes, using flashcards, and practicing problems repeatedly. These 29 learning practices will be used to create the PLSM instrument, which will track real, observable learning practices in mathematics classes.

Section 2. Dominant components and themes of positivism in mathematics learning practices

Upon completion of the content validation process, the PLSM was administered to 34 1st year undergraduates enrolled at Isabela State University – Echague Campus. In terms of reliability test results, the Cronbach's Alpha value is 95.13% which indicates that the items in the PLSM are extremely reliable (See Appendix E). After confirming the high reliability of the Positivism in Mathematics Learning Scale Model (PLSM) through a Cronbach's Alpha score, the study further assessed the data's suitability for component analysis using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity.

Table 3. KMO and bartlett's test result

Kaiser-meyer-olkin measure of sampling adequacy		0.944
Bartlett's Test of Sphericity	Approx. Chi-Square	0.0006
	df	406
	Sig.	<0.001

Table 3 demonstrates the KMO and Bartlett's Test Results. The KMO measure of 0.944 significantly exceeds the recommended threshold of 0.6, indicating that the sample size and variable correlations are excellent for identifying underlying components. Additionally, Bartlett's Test yielded a significant p-value (< 0.001), confirming that the variables are sufficiently correlated for component analysis. Together, these results support the strength of the PLSM and justify further analysis to uncover dominant themes in positivist mathematics learning practices.

Table 4. Total Variance Explained

Component	**Initial eigenvalues**			**Extraction sums of squared loadings**			**Rotation sums of squared loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	11.760	40.551	40.551	11.760	40.551	40.551	4.773	16.459	16.459
2	2.973	10.252	50.803	2.973	10.252	50.803	4.301	14.830	31.289
3	1.548	5.338	56.141	1.548	5.338	56.141	4.192	14.454	45.743
4	1.102	3.798	59.939	1.102	3.798	59.939	4.117	14.196	59.939
5	.852	2.938	62.878						
6	.812	2.801	65.679						
7	.796	2.746	68.425						
8	.718	2.476	70.901						
9	.695	2.397	73.298						
10	.650	2.240	75.539						
11	.601	2.073	77.612						
12	.566	1.950	79.562						
13	.542	1.870	81.433						
14	.500	1.726	83.158						
15	.474	1.635	84.793						
16	.452	1.560	86.354						
17	.417	1.437	87.791						
18	.406	1.399	89.190						
19	.374	1.291	90.481						

20	.359	1.239	91.719
21	.337	1.162	92.881
22	.329	1.135	94.042
23	.297	1.025	95.042
24	.268	.924	95.965
25	.259	.892	96.858
26	.247	.852	97.709
27	.242	.835	98.545
28	.222	.765	99.309
29	200	.691	100.000

Extraction method: Principal component analysis

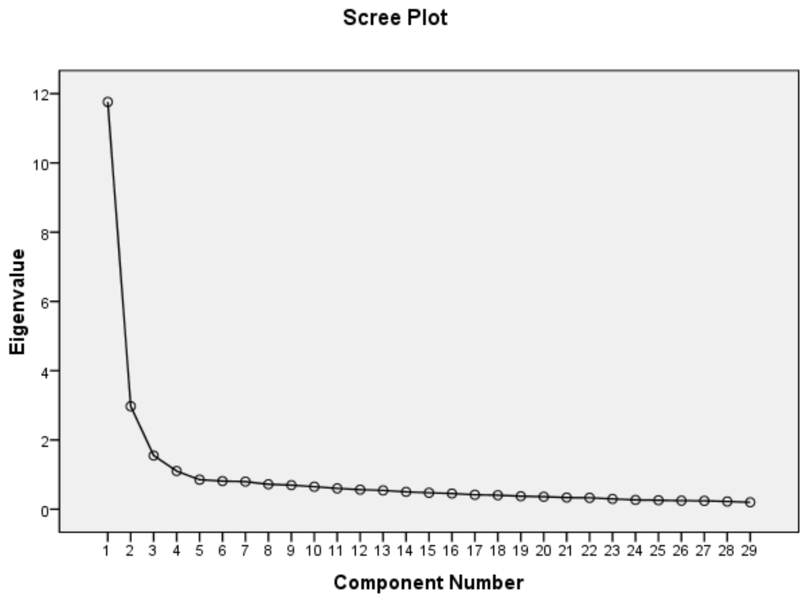

Figure 2. Scree plot

Table 4 shows that four components have eigenvalues greater than 1, suggesting that they are meaningful and should be retained for further interpretation. Specifically, the first four components account for a cumulative variance of approximately 59.939%. Notably, the first component alone explains 40.551% of the variance, indicating a strong underlying component, followed by the second, third, and fourth components contributing 10.252%, 5.338%, and 3.798% respectively. After rotation, the variance is more evenly distributed across these four components, with each explaining between 14% and 16% of the variance, enhancing interpretability.

Meanwhile, the scree plot seen in Figure 2 visually supports these findings. The plot shows a steep drop after the first component, followed by a more gradual decline starting from the fourth component, forming an 'elbow'. This graphical representation affirms the retention of four components, as components beyond the fourth contribute minimally to explaining additional variance.

Table 5. Rotated component matrix

Learning Practices in Mathematics	**Component**			
	1	**2**	**3**	**4**
I listen carefully during discussions and take notes for problem sets and definitions.	0.765			
I take notes during lessons to help me recall key concepts.	0.796			
I write down important details mentioned during discussions.	0.763			
I listen attentively during class discussions to make remembering easier	0.725			

Learning Practices in Mathematics	Component			
	1	2	3	4
I actively listen to the instructor while jotting down key points.	0.756			
I rewrite my notes after class in a separate notebook for better retention.		0.658		
I summarize key takeaways in my own words after each lesson.		0.688		
I highlight or underline important terms in my notes for quick review.	0.577			
I write formulas and examples on a separate sheet for easier review.	0.509	0.472		
I take notes on both whiteboard content and verbal explanations.	0.410			
I prefer handwritten notes over digital for better concentration.	0.572			
I rewrite notes multiple times to reinforce memory.		0.663		
I draw diagrams or concept maps to visualize processes.		0.730		
I create summary notes and concept maps to simplify complex topics.		0.722		
I use flashcards for active recall.			0.756	
I solve practice problems repeatedly until I master the steps.				0.788
I re-solve examples given in class to test my understanding.				.716
I look for additional problem sets online for extra practice.				.694
I write formulas on sticky notes and place them where I'll see them often.		.464	.532	
I recite notes aloud or record myself to reinforce memory.	.408		.453	.694
I employ spaced repetition for long-term retention.	.438		.493	
I test myself using flashcards or self-made quizzes.		.646	.473	
I rewatch lecture videos to reinforce learning.			.526	
I solve problems without notes to assess my recall.			.644	
I set small daily study goals instead of cramming.	.451	.475		
I use Quizlet or Anki for digital flashcards.		.827		
I record voice notes and replay them for auditory learning.		.765		
I connect lessons to real-life applications.		.636		
I revisit past quizzes and re-solve them for practice.			.477	

Table 5 illustrates the structure of the extracted components. Items with factor loadings greater than 0.4 will be included from that component. Based on the loadings:

• Component 1 includes statements 1, 2, 3, 4, 5, 8, 10, 11, and part of 9. These statements load strongly on Component 1, suggesting a coherent underlying theme.

• Component 2 consists of statements 6, 7, 12, 13, 14, and also part of 9, 19, 20, 21, 25. This cluster represents a second distinct dimension of positivist mathematics learning practices.

• Component 3 is composed of statements 15, 19, 21, 22, 25, 26, 27, and 28. Since several of these statements cross-load between Components 3 and 4, further analysis will be conducted to confirm their appropriate grouping.

• Component 4 includes 16, 17, 18, 20, 21, 22, 23, 24 and 29, many of which show strong and exclusive loadings.

For statements that demonstrated more than one component (Statements 9, 19, 20, 21, 22, 23, 25), further analysis will be performed to clarify their final placement. These cases will be examined to ensure conceptual coherence and statistical justification in the component structure. Following the extraction of components, the identified components were analyzed and categorized in alignment with the core principles of positivism.

Table 6. Four key components of PLSM.

Identified Component	Learning Practices in Mathematics
Active Note-taking	1. I listen carefully during discussions and take notes for problem sets and definitions.
	2. I take notes during lessons to help me recall key concepts.
	3. I write down important details mentioned during discussions.
	4. I listen attentively during class discussions to make remembering easier
	5. I actively listen to the instructor while jotting down key points.
	8. I highlight or underline important terms in my notes for quick review.
	10. I take notes on both whiteboard content and verbal explanations.
	11. I prefer handwritten notes over digital for better concentration.
Note Reorganization	6. I rewrite my notes after class in a separate notebook for better retention.
	7. I summarize key takeaways in my own words after each lesson.
	9. I write formulas and examples on a separate sheet for easier review.
	12. I rewrite notes multiple times to reinforce memory
	13. I draw diagrams or concept maps to visualize processes.
	14. I create summary notes and concept maps to simplify complex topics.
Self-Testing and Use of Technology	15. I use flashcards for active recall.
	19. I write formulas on sticky notes and place them where I'll see them often.
	22. I test myself using flashcards or self-made quizzes.
	25. I set small daily study goals instead of cramming.
	26. I use Quizlet or Anki for digital flashcards.
	27. I record voice notes and replay them for auditory learning.
	28. I connect lessons to real-life applications.
Review Techniques	16. I solve practice problems repeatedly until I master the steps.
	17. I re-solve examples given in class to test my understanding.
	18. I look for additional problem sets online for extra practice.
	20. I recite notes aloud or record myself to reinforce memory.
	21. I employ spaced repetition for long-term retention.
	23. I rewatch lecture videos to reinforce learning.
	24. I solve problems without notes to assess my recall.
	29. I revisit past quizzes and re-solve them for practice.

Table 6 demonstrates the four key components of PLSM identified through component analysis. The researcher considered each component's relation to the statements while ensuring alignment with positivist principles of observable, measurable learning behaviors. The interpretation of these components is supported by established educational theories, including cognitive load theory (Sweller, 1988), active learning principles (Freeman *et al.*, 2014), and retrieval practice research (Roediger & Karpicke, 2006). For statements that demonstrated cross-loadings across multiple components (Statements 9, 19, 20, 21, 22, 23, 25), careful consideration was given to conceptual coherence, with each statement ultimately assigned to its most appropriate component.

The analysis revealed four distinct components of mathematics learning practices. The first component, Active Note-Taking, includes learning practices such as attentive listening during class discussion, recording of important notes, and preference for handwritten notes. This finding aligns with Wienecke *et al.*'s (2023) study which identified significant correlations between note-taking frequency and factors including language skills, mathematics interest, and socioeconomic status. These practices support cognitive load theory (Sweller, 1988) by minimizing extraneous cognitive load through structured information processing.

The second component, Note Reorganization, includes post-lecture learning practices like rewriting notes, creating summaries and visual aids, and summarizing important notes in their words. Bloom's (2020) research on active note restructuring demonstrated measurable improvements in mathematics test performance and content comprehension, reinforcing the value of these practices. These reorganization techniques effectively implement dual coding theory (Paivio, 1986) through their integration of verbal and visual information encoding.

Self-testing and the Use of Technology emerged as the third component, highlighting strategies like flashcards, spaced repetition, and digital tools that influence active recall and technological enhancements to learning. Asare *et al.* (2024) established that technology integration in mathematics education significantly improves student performance metrics. These technology-enhanced practices are grounded in retrieval practice principles (Karpicke & Blunt, 2011) and incorporate elements of gamified learning. The final component, Review Techniques, focuses on learning practice methods including repeated problem-solving, self-assessment without notes, revisiting previous materials, reflecting deliberate practice (Ericsson *et al.*, 1993), and metacognitive monitoring.

The finalized placement of cross-loaded statements was determined through an analysis alignment with positivist learning principles. Statement 9, I write formulas and examples on a separate sheet for easier review, was assigned to Note Reorganization due to its emphasis on knowledge restructuring, despite showing some association with Review Techniques. Statement 19, I write formulas on sticky notes and place them where I'll see them often, was placed under Self-Testing and Use of Technology as it represents a strategic approach to active recall. Statement 20, I recite notes aloud or record myself to reinforce memory, was categorized under Review Techniques because it represents a practice method for knowledge reinforcement. Statement 21, I employ spaced repetition for long-term retention, was included in Self-Testing and Use of Technology as it reflects technologically-enhanced learning practices, while Statement 22, I test myself using flashcards or self-made quizzes, was also placed in this component due to its clear alignment with active recall practices. Statement 23, I rewatch lecture videos to reinforce learning, was assigned to Review Techniques as it represents an approach to content review. Finally, Statement 25, I set small daily study goals instead of cramming, was categorized under Self-Testing and Use of Technology. These placement decisions were made to ensure conceptual coherence within the positivist framework.

Section 3. Development of the 21st century positivist learning scale in mathematics (PLSM)

The 21st Century Positivist Learning Scale in Mathematics (PLSM) was developed that combine the positivist approach with the learning practices of undergraduate students when learning mathematics to create a reliable and valid measurement tool for mathematics learning practices. The PLSM identifies four key components that represent learning practices for 21st-century mathematics education. The Active Note-taking component (Items 1-8) focuses on real-time cognitive engagement during class discussion, emphasizing information processing through behaviors like careful listening and systematic note-taking. Note Reorganization (Items 9-14) captures post-lecture learning practices that facilitate deeper learning such as summarizing, visual mapping, and rewriting of notes. The Self-Testing and Technology Use component (Items 15-21) reflects learning practices by integrating digital tools and highlighting strategies like flashcards, spaced repetition, and real-world applications. Finally, Review Techniques (Items 22-29) systematize deliberate practice methods through repeated problem-solving, self-assessment, and strategic review of materials.

This four-component construction was validated through statistical analysis and theoretical alignment, ensuring each component maintains strong internal consistency while representing a comprehensive framework of mathematics learning practices. The PLSM bridges traditional positivist emphasis on observable learning practices with modern educational needs by incorporating both conventional study methods and technology-enhanced learning practices, making it particularly relevant for today's digitally-infused learning environments. By operationalizing these research-based practices into measurable indicators, the PLSM provides educators and researchers with a valuable tool for assessing and improving mathematics learning strategies in alignment with 21st-century educational demands.

21st Century Positivist Learning Scale in Mathematics (PLSM)

Dear Respondent,

Thank you for participating in this survey. This survey instrument, the ***21st Century Positivist Learning Scale in Mathematics (PLSM)***, is designed to assess how different learning practices align with your actual experiences in mathematics education.

You will be presented with a series of statements related to learning practices. Your task is to rate each item based on how well it matches your own learning practices in mathematics.

All responses will be kept confidential and used only for research purposes. There are no right or wrong answers, please answer based on your personal experiences.

Thank you for your time and valuable input!

Figure 3. Introductory part of the PLSM

Figure 3 displays the introductory part of the 21st Century Positivist Learning Scale in Mathematics (PLSM). It explains that the survey aims to assess how students' actual learning experiences align with 21st-century learning practices in mathematics. Respondents are asked to rate a series of statements based on how well each one reflects their personal experiences in learning mathematics. It also assures participants that their responses will remain confidential and will be used solely for research purposes, emphasizing that there are no right or wrong answers.

Table 7. 21st-century positivist learning scale in mathematics (PLSM) instrument

	Learning Practices in Mathematics	**5**	**4**	**3**	**2**	**1**
Active Note-taking	I listen carefully during discussions and take notes for problem sets and definitions.					
	I take notes during lessons to help me recall key concepts.					
	I write down important details mentioned during discussions.					
	I listen attentively during class discussions to make remembering easier.					
	I actively listen to the instructor while jotting down key points.					
	I highlight or underline important terms in my notes for quick review.					
	I take notes on both whiteboard content and verbal explanations.					
	I prefer handwritten notes over digital for better concentration.					
Note Reorganization	I rewrite my notes after class in a separate notebook for better retention.					
	I summarize key takeaways in my own words after each lesson.					
	I write formulas and examples on a separate sheet for easier review.					
	I rewrite notes multiple times to reinforce memory					
	I draw diagrams or concept maps to visualize processes.					
	I create summary notes and concept maps to simplify complex topics.					
Self-Testing and Use of Technology	I use flashcards for active recall.					
	I write formulas on sticky notes and place them where I'll see them often.					
	I test myself using flashcards or self-made quizzes.					
	I set small daily study goals instead of cramming.					
	I use Quizlet or Anki for digital flashcards.					
	I record voice notes and replay them for auditory learning.					
	I connect lessons to real-life applications.					
Review Techniques	I solve practice problems repeatedly until I master the steps.					
	I re-solve examples given in class to test my understanding.					
	I look for additional problem sets online for extra practice.					
	I recite notes aloud or record myself to reinforce memory.					
	I employ spaced repetition for long-term retention.					
	I rewatch lecture videos to reinforce learning.					
	I solve problems without notes to assess my recall.					
	I revisit past quizzes and re-solve them for practice.					

Legende: 5 – Always, 4 – Often, 3 – Sometimes, 2 – Rarely, 1 – Never

5. CONCLUSION

This study developed and validated the 21st Century Positivist Learning Scale in Mathematics (PLSM) to measure observable mathematics learning practices aligned with positivism. Using a mixed-methods approach at Isabela State University-Echague Campus, the researcher:

i. Identified 29 key learning practices through student surveys and expert validation by three PhD specialists

ii. Proved the scale works well with strong results:

- Excellent reliability (a=0.95)

• Excellent sampling adequacy (KMO=0.944)
• Significant component structure (p<.001)
• Clear four-factor solution explaining 59.94% variance

iii. Organized practices into four reliable components via factor analysis:

• Active Note-taking
• Note Reorganization
• Self-Testing & Technology Use
• Review Techniques

The resulting PLSM provides researchers with a valid instrument to assess learning practices that combine traditional techniques with modern technological approaches. Its development process combined statistical analysis with theoretical grounding in cognitive load theory, retrieval practice research, and deliberate practice frameworks. The PLSM offers practical utility for diagnosing students' learning practices while maintaining scientific consistency through measurable, observable behavioral indicators aligned with positivist principles. Future applications could inform targeted interventions and curriculum development in mathematics education.

RECOMMENDATIONS

Based on the findings of the study, the following recommendations are:

i. For teachers

• Implement the 21st-Century Positivist Learning Scale in Mathematics (PLSM) as a diagnostic tool to assess students' strengths and weaknesses in mathematics learning practices.

• Develop intervention programs (like problem-solving workshops) tailored to improve specific PLSM components.

• Integrate PLSM insights into professional development programs to help teachers align instruction with positivist learning principles.

• Encourage other universities or K–12 institutions to validate and adapt the PLSM.

ii. For Future Researchers

• Conduct follow-up studies to examine how PLSM component scores predict long-term mathematics achievement and retention.

• Investigate differences in PLSM outcomes across educational contexts. For example, a comparative analysis of mathematics learning practices in public and private university.

• Test the effectiveness of PLSM-based teaching strategies (like structured problem-solving modules) on student performance.

REFERENCES

Acharya, B. R., Kshetree, M. P., Khanal, B., Panthi, R. K., & Belbase, S. (2021). Mathematics Educators' Perspectives on Cultural Relevance of Basic Level Mathematics in Nepal. *Journal on Mathematics Education, 12*(1), 17-48. https://doi.org/10.22342/jme.12.1.12955.17-48

Andal, S., & Andrade, R. (2022). Exploring Students' Procedural Fluency and Written Adaptive Reasoning Skills In Solving Open-Ended Problems. *International Journal of Science, Technology, Engineering and Mathematics.* https://doi.org/10.53378/352872

Asare, B., Natalie, W., & Yarhands, A. (2024). The Effect Of Using Technology In Teaching And Learning Mathematics On Student's Mathematics Performance: The Mediation Effect Of Students' Mathematics Interest. *Journal of Mathematics and Science Teacher, 4*, em059. https://doi.org/10.29333/mathsciteacher/14309.

Bloom, A. (2020). *Effect Of An Active Note Restructuring Intervention On Developmental Mathematics Students' Test Performance.* Retrieved from: https://shsu-ir.tdl.org/server/api/core/bitstreams/5e71e317-c2ab-40ee-975c-411608712afb/content

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363–406. https://doi.org/10.1037/0033-295X.100.3.363

Ernest, P. (1991). *The Philosophy of Mathematics Education.* New York: The Flamer Press.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the national academy of sciences, 111*(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Hay, I., Stevenson, Y., & Winn, S. (2022). Development of the "Self-Efficacy-Effort" in Mathematics Scale and Its Relationship to Gender, Achievement, and Self-Concept. *Mathematics Education Research Group of Australasia.* Retrieved from: https://files.eric.ed.gov/fulltext/ED623688.pdf

Gurat, M. G. (2018). Mathematical Problem-Solving Strategies among Student Teachers. *Journal on Efficiency and Responsibility in Education and Science, 11*(3), 53-64. https://doi.org/10.7160/eriesj.2018.110302.

Isabel, V., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. *European Journal of Science and Mathematics Education, 11,* 573-588. https://doi.org/10.30935/scimath/13135.

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborate studying with concept mapping. *Science, 331*(6018), 772–775. https://doi.org/10.1126/science.1199327

Mesa, V. (2010). *Student Participation in Mathematics Lessons Taught by Seven Successful Community College Instructors.* Adults Learning Mathematics. Retrieved from https://files.eric.ed.gov/fulltext/EJ1068226.pdf

Odutayo, A., & Fonseca, K. (2023). Making Quadratic Functions Interesting: Students Teams-Achievement Division Instructional Strategy. *Journal of Mathematics, Science and Technology Education, 2024, 20*(1). https://doi.org/10.29333/ejmste/14092

Paivio, A. (1986). *Mental representations: A dual-coding approach.* New York: Oxford University Press.

Pomerantz, E. M., Moorman, E. A., & Litwack, S. D. (2007). The How, Whom, and Why of Parents' Involvement in Children's Academic Lives: More Is Not Always Better. *Review of Educational Research, 77*(3), 373–410. http://www.jstor.org/stable/4624903

Qureshi, M. A., Khaskheli, A., Qureshi, J. A., Raza, S. A., & Yousufi, S. Q. (2023). Factors Affecting Students' Learning Performance Through Collaborative Learning And Engagement. *Interactive Learning Environments, 31*(4), 2371-2391. https://doi.org/10.1080/10494820.2021.1884886

Rambe, H., & Siregar, S. (2022). The Effect of Time Management on Student's Interest in Learning Mathematics. *Jurnal Basicedu, 6*, 2295-2300. https://doi.org/10.31004/basicedu.v6i2.2435.

Roediger, H. L., & Karpicke, J. D. (2006). Test-Enhanced Learning: Taking Memory Tests Improves Long-Term Retention. *Psychological Science, 17*(3), 249-255. https://doi.org/10.1111/j.1467-9280.2006.01693.x

Sintema, E., & Mosimege, M. (2023). High School Students' Beliefs about Mathematical Problem Solving: A Cluster Analysis. *Mathematics Teaching Research Journal.* Retrieved from: https://files.eric.ed.gov/fulltext/EJ1391467.pdf

Sweller, J. (2004). *Cognitive Load During Problem Solving: Effects on Learning*. Cognitive Science. https://doi.org/10.1207/s15516709cog1202_4

Ulusoy, F., & Argun, Z. (2019). Secondary School Students' Representations For Solving Geometric Word Problems In Different Clinical Interviews. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 7*(1), 73-92. https://doi.org/10.18404/ijemst.328341

Wienecke, L. (2024). *The Influence of Note-taking on Mathematical Solution Processes while Working on Reality-Based Tasks.* https://doi.org/10.17877/DE290R-24974.