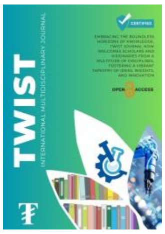
DOI https://doi.org/10.5281/zenodo.10049652#111

TWIST, 2024, Vol. 19, Issue 1, pp. 445-453

TWIST

Journal homepage: www.twistjournal.net



Dimensionality of Strategies in Learning Mathematics among Engineering Students:
An Exploratory Factor Analysis

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Abstract
Understanding how students learn is paramount for educators, as it allows them to tailor their teaching strategies and methodologies to effectively support student learning. In the context of mathematics education, this understanding becomes particularly crucial. Therefore, investigating the strategies employed by students in learning mathematics is of utmost importance. The primary objective of this study is to uncover the underlying strategies utilized by engineering students when learning mathematics. To achieve this objective, the researcher conducted a comprehensive examination of theories of learning mathematics and reviewed relevant literature in the field. Additionally, data were gathered from 50 engineering students regarding their approaches to learning mathematics. Based on the gathered information, a set of statement items was formulated, reflecting the various strategies identified. These statement items underwent validation by a panel of experts to ensure their reliability and relevance. Subsequently, the validated items were administered to a larger sample of 479 engineering students. Utilizing Exploratory Factor Analysis, the study identified five key strategies utilized by engineering students in their approach to learning mathematics. These strategies include *Cognitive Strategies and Metacognition, Social Learning and Feedback, Consistent Practice and Review, Utilization and Self-Directed Learning,* and *Visual and Study Aids.*

Keywords
Engineering Mathematics, Strategies, Exploratory Factor Analysis

INTRODUCTION

Mathematics, widely revered for its foundational role in human cognition and problem-solving, remains indispensable in our daily lives, shaping myriad aspects of our existence (Biswas, 2015; Acharya, 2017). Moreover, its applicability spans diverse disciplines in higher education, ranging from technical fields and engineering to economics, finance, agriculture, pharmaceuticals, and health sciences (Nicholas et al., 2015; Joyce et al., 2017; Gradwohl & Eichler, 2018). Recognized for its role in academic achievement and its provision of essential skills for navigating everyday challenges, mathematics solidifies its status as a fundamental pillar of success (Carey et al., 2017).

However, despite its importance, mathematics poses significant hurdles for many learners, mainly engineering students, who grapple with its abstract concepts and their practical application in technical domains (Greer et al., 2009; Eng et al., 2010; Lopes et al., 2019). Mathematics courses in universities are often cited as significant obstacles, leading to high dropout rates, especially in non-scientific programs where failure rates can exceed 30 percent (Gradwohl et al., A., 2018; Awaludin et al., 2015). Concerns regarding the problem of unsatisfactory mathematics performance have been reported in Malaysia (Eng et al., 2010; Wahid et al., 2014) and the Philippines (Dagaylo-AN & Tancinco, 2016; Manalaysay, 2019). Consequently, gaining a deeper understanding of the nuances of mathematical learning, particularly among engineering students, becomes imperative for educators and policymakers alike.

Recognizing the complexity of learning, it becomes essential to delve into the learning strategies employed by engineering students when tackling mathematical concepts (Simon et al., 2010). Understanding these strategies is crucial for educators to tailor their teaching approaches effectively, catering to student's diverse needs and preferences (Prameswono et al., 2023). Previous studies in related fields shed light on the intricate relationship between learning strategies and academic performance, emphasizing the importance of aligning teaching methods with learners' cognitive processes (Pintrich & De Groot, 1990; Farrington et al., 2012). It is essential to consider various theoretical learning frameworks to comprehensively address the complexities surrounding mathematics education in engineering (Vygotsky, 1978). These theories provide valuable insights into how individuals acquire mathematical knowledge and skills, offering a foundation for developing effective pedagogical strategies.

Given these considerations, the researchers want to explore the learning strategies employed by engineering students by applying Exploratory Factor Analysis. This methodology, informed by a thorough review of existing literature and insights gleaned from a limited number of participants and surveys, has been identified as a valuable approach (Gono et al., 2021; Romero & Gono Jr, 2021; Fuentes & Gono, 2023). To achieve these objectives, our research endeavors to enrich mathematics education for engineering students, thereby nurturing their academic proficiency and facilitating their professional growth.

METHODS

Study Participants

The study participants comprised engineering students from the University of Mindanao. By focusing on a specific group of students, the researchers can obtain insights that are directly relevant to their academic discipline and educational experiences. Prior to conducting the main survey, the researchers conducted a preliminary assessment by interviewing 50 engineering students about their learning strategies in Engineering Mathematics. Subsequently, a sample of 500 engineering students was selected through simple random sampling. This method ensures that each student has an equal chance of being selected, enhancing the representativeness of the sample. Further, this sample size was deemed sufficient for conducting Exploratory Factor Analysis (EFA) to examine the underlying dimensions of learning strategies.

With the data collected from the main survey, the researchers plan to conduct an Exploratory Factor Analysis. EFA is a statistical technique used to identify underlying factors or dimensions that explain the correlations among observed variables. By analyzing the patterns of responses to survey questions, EFA allows researchers to identify and interpret latent factors representing different aspects of learning strategies in engineering mathematics. The researchers aim to uncover the underlying structure of learning strategies employed by engineering students, which can provide valuable insights for educational interventions and curriculum development.

Materials and Instruments

The foundation of this research was built upon an extensive review of literature and theories pertaining to learning mathematics. These readings served as the cornerstone for creation of item statements of learning strategies. The researchers asked with 50 engineering students to explore their approaches to learning mathematics. Audio recordings were frequently utilized to ensure accurate transcription of the interviews (Creswell, 2013). The insights gleaned from both the research participants' responses and existing literature were instrumental in formulating the item statements, thus creating the Item Pool Statements for further analysis. The survey questionnaire was also utilized the 5-scale Likert Scale as shown below:

Scale	Description	Descriptive Interpretation
5	Strongly Agree	The item described means that the respondent strongly agrees to the given statement.
4	Agree	The item described means that the respondent agrees to a certain extent to the given statement.
3	Neither Agree or Disagree	The item described means that the respondent neither agrees nor disagrees with the given statement.
2	Disagree	The item described means that the respondent disagrees to a certain extent to the given statement.
1	Strong Disagree	The item described means that the respondent strongly disagrees with the given statement.

Design and Procedure

This research employs a quantitative research design to delve into the underlying factors influencing the learning strategies utilized by engineering students in Mathematics. To initiate this exploration, the researchers delved into existing literature on Mathematics learning, utilizing it as a foundational framework for the study. By grounding the study in established theories, the researchers aimed to ensure a thorough exploration and comprehension of the theoretical assumptions guiding the research. These theoretical underpinnings formed the basis for crafting the item statements used in the study.

In accordance with ethical standards, the researchers engaged with 50 engineering students to gather insights into their strategies for learning Mathematics. Participation in the study was entirely voluntary, with participants given the autonomy to decline involvement without any repercussions. Confidentiality measures were implemented to safeguard respondents' information, including personal details such as name, age, and program affiliation. Informed consent was obtained from all participants, ensuring they were fully aware of the study's objectives and their rights as participants.

The significant statements derived from both the research participants' responses and the literature review served as the foundation for developing the item statements comprising the Item Pool. Through Exploratory Factor Analysis (EFA), the researchers sought to elucidate the various strategies employed by students in learning Mathematics. EFA facilitated a comprehensive exploration of the data, uncovering patterns, relationships, and latent constructs that contribute to students' perspectives on the subject.

Furthermore, the research paper adheres to rigorous standards of academic integrity and ethical conduct. It is an original work, devoid of any instances of plagiarism or fabrication. Clear guidelines on authorship attribution ensure that credit is attributed solely to those who made substantial contributions to the research process, including conception, design, data analysis, interpretation, drafting, and critical revision of the article. This approach fosters accountability and recognition for individuals who significantly contribute to the scholarly endeavor.

Lastly, the study maintains transparency regarding potential conflicts of interest, affirming that the researcher's institution is not involved in the study. This declaration further underscores the integrity and impartiality of the research process.

RESULTS AND DISCUSSION

Table 1 presents the results of the test conducted to assess the adequacy and suitability of the sample for the exploratory factor analysis (EFA). The Kaiser-Meyer-Olkin (KMO) measure, which evaluates the sampling adequacy, yielded a value of 0.940. This value exceeds the commonly accepted threshold of 0.5, indicating that the data is highly suitable for conducting EFA. According to Kaiser's criteria (1974), such a high KMO value suggests that the dataset is well-suited for identifying distinct factors.

Moreover, Bartlett's sphericity test was employed to determine whether the correlation matrix (R-matrix) differs significantly from an identity matrix. The results of this test revealed statistical significance ($p<0.01$), indicating that the variables in the dataset are not independent and exhibit patterned relationships. This supports the notion that the dataset contains meaningful relationships between variables, making it conducive to factor analysis.

Table 1 Sampling adequacy and multidimensionality tests for Strategies in Learning Mathematics

Test		Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.94
Bartlett's Test of Sphericity	Approx. Chi-Square	451.379
	df	248
	Sig.	<0.001

Figure 1 illustrates the scree plot generated from the second Exploratory Factor Analysis (EFA) conducted in this study. As elucidated by Cattell (1966), the scree plot utilizes eigenvalues derived from either the input or reduced correlation matrix. The plot itself is a graphical representation wherein the eigenvalues are plotted along the vertical axis, while the factors are plotted along the horizontal axis. By visually inspecting the plot, analysts can discern the point at which there is a significant decline in the magnitude of the eigenvalues, often referred to as the "elbow" of the plot. The scree plot is a valuable tool for determining the number of significant factors extracted from the data and the variance explained by each factor. Specifically, analysts look for the point on the plot where the slope of the line connecting the plotted eigenvalues changes abruptly, indicating a substantial drop in eigenvalue magnitude. This point signifies the number of factors that are deemed meaningful for further analysis. In the context of the presented scree plot, it is observed that the instrument under study exhibits a multi-dimensional structure. This observation is supported by the discernible drop in the plotted line after the fifth factor. As noted by Gorsuch (1997), the scree test performs effectively under certain conditions, particularly when the sample size is large and when the underlying factors in the data are well-defined.

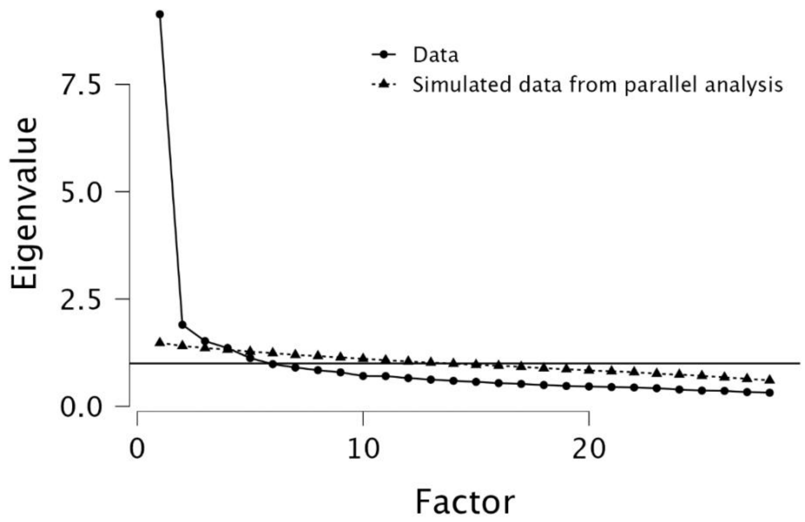

Fig. 1 Scree Plot of Strategies in Learning Mathematics among Engineering Students

Rotated Component Matrix

In table 2, the researchers present the factor loading and thematic analysis findings concerning the strategies employed by engineering students in learning mathematics. Following the exploratory factor analysis, the researchers identified a set of 23 items, which were then grouped into five distinct factors or dimensions reflecting different aspects of learning mathematics among engineering students namely *Cognitive Strategies and Metacognition*, *Social Learning and Feedback*, *Consistent Practice and Review*, *Utilization and Self-Directed Learning*, and *Visual and Study Aids.* To ensure the reliability of our analysis, we systematically removed any items with factor loadings below 0.4, consistent with the rigorous criteria established by previous studies (Costello & Osborne, 2005). Additionally, the researchers eliminated any factors with fewer than three item statements, as recommended by MacCallum et al. (1999) and Raubenheimer (2004). As a result, the researchers identified five distinct factors that characterize the strategies utilized in learning mathematics among engineering students.

The factor of *Cognitive Strategies and Metacognition* plays a crucial role in shaping the learning experiences of engineering students in mathematics. The item statements provided reflect a diverse range of cognitive and metacognitive approaches that students may utilize to enhance their understanding and retention of mathematical concepts (Conley, 2014; Alzahrani, 2017). Strategies such as repetition and spaced repetition highlight the importance of regular practice and reinforcement in consolidating learning, while problem-solving heuristics like working forwards underscore the value of strategic thinking and pattern recognition in tackling mathematical problems efficiently (Mevarech & Fan, 2018; Lawanto et al., 2013). Additionally, the use of mnemonic devices and analogies demonstrates students' ability to leverage memory aids and contextualization to make abstract concepts more accessible and memorable (Bransford et al., 2012)

Engaging in interdisciplinary learning and teaching others are indicative of metacognitive strategies that foster deeper understanding and application of mathematical concepts (Pradhan, 2019). By seeking out opportunities to explore how mathematics intersects with other fields of engineering, students gain valuable insights into the practical applications of theoretical concepts, thereby enhancing their comprehension and appreciation of the subject matter (Drushlyak et al., 2021) Similarly, teaching mathematical concepts to others not only reinforces students' own understanding but also encourages them to articulate and clarify their knowledge, fostering a deeper level of conceptual mastery (Ben-Hur, 2006; Schoenfeld, & Kilpatrick, 2008).

Reflecting on mistakes and employing active reading strategies demonstrate students' metacognitive awareness and self-regulation in their learning process (Nash-Ditzel, 2010). By analyzing errors and identifying areas for improvement, students develop resilience and problem-solving skills, ultimately enhancing their ability to overcome challenges and succeed in their mathematical endeavors (Lee, & Johnston-Wilder, 2017). Furthermore, active reading strategies such as summarizing and annotating texts encourage students to actively engage with course materials, promoting deeper comprehension and critical thinking skills essential for success in engineering mathematics (Johnson, Archibald, & Tenenbaum, 2010).

The factor of *Social Learning and Feedback* is instrumental in understanding how engineering students engage with mathematical concepts within a collaborative and supportive learning environment (Ariani et al., 2017). The item statements provided highlight various ways in which students seek assistance, feedback, and diverse perspectives to enhance their understanding and proficiency in mathematics (Barana, Marchisio, & Sacchet, 2021). Seeking help from professors or teaching assistants when encountering challenging topics demonstrates students' recognition of the value of expert guidance and support in overcoming academic hurdles (Hattie & Timperley, 2007). This proactive approach fosters a sense of accountability and encourages students to address their learning needs effectively.

Utilizing online forums or discussion boards to ask questions and exchange ideas with peers represents a collaborative learning approach that capitalizes on the collective knowledge and experiences of fellow students (Rafaeli & Kent, 2015). Engaging in such virtual communities not only provides immediate assistance but also cultivates a sense of camaraderie and shared learning among participants. Moreover, seeking out diverse perspectives by collaborating with students from different cultural or academic backgrounds enriches the learning experience by exposing students to alternative problem-solving approaches and fostering cross-cultural understanding and collaboration (Barkley, Major & Cross, 2014; Yoon et al., 2020).

Seeking feedback from professors or peers on mathematical work is essential for continuous improvement and skill development (Boud, & Molloy, 2013). By soliciting constructive criticism and identifying areas for improvement, students actively engage in self-assessment and reflection, leading to enhanced learning outcomes (Rezk, 2021). Feedback from professors provides expert insights and guidance, while peer feedback offers diverse perspectives and encourages collaborative learning and growth.

The factor of *Consistent Practice and Review* is pivotal in understanding how engineering students approach their mathematical studies (Avvisati & Borgonovi, 2020; Liebendörfer et. al, 2022). The item statements provided exemplify the importance of regular and deliberate practice in mastering mathematical concepts. By setting aside dedicated time each day for studying mathematics, students demonstrate a commitment to consistent learning and skill development. This disciplined approach not only ensures regular engagement with the subject matter but also cultivates a habit of prioritizing mathematics amidst other academic responsibilities (Cunningham & Carlsen, 2014).

Engaging in a variety of mathematical problem-solving activities is instrumental in honing students' problem-solving skills and enhancing their mathematical proficiency (Andrade, Fortes & Mabilangan, 2020). By tackling diverse problems across different mathematical topics, students broaden their understanding and develop versatile problem-solving strategies. This experiential learning approach enables students to encounter and overcome various challenges, ultimately strengthening their mathematical abilities (Bradshaw & Hazell, 2017).

Table 2 Factor Loading and Thematic Analysis of Strategies in Learning Mathematics Among Engineering Students

Cognitive Strategies and Metacognition	
Item Statements	**r-value**
I use repetition and spaced repetition techniques to reinforce learning and retention of mathematical material.	0.595
I use problem-solving heuristics such as working forwards or identifying patterns to approach mathematical problems strategically.	0.586
I employ the ""chunking"" technique by breaking down complex mathematical problems into smaller, more manageable parts.	0.545
I practice explaining mathematical concepts in my own words to ensure comprehension.	0.524
I use analogy or metaphor to relate abstract mathematical concepts to more familiar ideas.	0.522
I use mnemonics or memory aids to remember mathematical theorems or proofs.	0.507
I seek out opportunities for interdisciplinary learning to see how mathematics is applied in other fields of engineering.	0.445
I teach mathematical concepts to others to solidify my own understanding.	0.443
I review and reflect on my mistakes to learn from them and avoid repeating them in the future.	0.433
I practice active reading strategies such as summarizing paragraphs or annotating mathematical texts..	0.403
Social Learning and Feedback	
Item Statements	**r-value**
I seek help from professors or teaching assistants when I encounter challenging mathematical topics.	0.624
I use online forums or discussion boards to ask questions and exchange ideas with other students.	0.62
I seek out diverse perspectives on mathematical problems by collaborating with students from different cultural or academic backgrounds.	0.586
I seek feedback from professors or peers on my mathematical work to identify areas for improvement.	0.566
Consistent Practice and Review	
Item Statements	***r-value***
I set aside dedicated time each day for studying mathematics.	0.606
I practice solving a variety of mathematical problems to enhance my skills.	0.597
I regularly review my class notes and textbook material to reinforce mathematical concepts.	0.58
Resource Utilization and Self-Directed Learning	
Item Statements	***r-value***
I use online tutorials or video lectures to supplement my understanding of difficult mathematical topics.	0.639
I seek out additional resources such as online tutorials or textbooks to supplement my learning.	0.553
I utilize online resources such as Khan Academy or Coursera to access additional instructional material on mathematical topics.	0.43
Visual and Study Aids	
Item Statements	***r-value***
I use color-coding or highlighting techniques to emphasize important information in my mathematical notes.	0.647
I create flashcards or summary sheets to help me memorize key mathematical formulas and definitions.	0.422
I create study guides or summaries of key mathematical concepts to aid in exam preparation.	0.421

In the realm of learning mathematics among engineering students, the factor of *Resource Utilization and Self-Directed Learning* holds paramount importance in learning Mathematics (Kleden, 2015). The item statements provided underscore the proactive approach of students in seeking supplementary resources to enhance their understanding of challenging mathematical topics. By utilizing online tutorials or video lectures, students demonstrate a commitment to leveraging diverse learning materials beyond traditional classroom settings (Dinmore, 2019; Tisdell, & Loch, 2017; Nabayra, 2022). Video tutorials from youtube and other online tutorials helps engineering students understand mathematics subjects (Masouros & Alpay, 2010; Kinnari-Korpela, 2015). This strageties in learning was also true with students in the rural area (Hiwarekar, 2023). These resources offer alternative explanations and perspectives, catering to individual learning styles and preferences (Kanninen, 2009; Al-Shdaifat, Obeidat, Mabdeh, Alzoubi, & Al-Khazaleh, 2023).

Furthermore, students' inclination to seek out additional resources, such as online tutorials or textbooks, reflects their proactive engagement in self-directed learning (Zhu, Bonk, & Berri, 2022; Arigiyati et al., 2023). Recognizing the limitations of classroom instruction, students take initiative in expanding their knowledge base by accessing a plethora of educational materials available online (Goodnough, 2006). This self-directed approach empowers students to take ownership of their learning journey and tailor their learning experiences to meet their specific needs and goals (Nasri, Halim, & Abd Talib, 2020).

In the realm of learning mathematics among engineering students, the factor of *Visual and Study Aids* plays a significant role in facilitating comprehension and retention of complex mathematical concepts (Phillips, Norris & Macnab, 2010). The item statements provided highlight various strategies that students employ to enhance their study materials and optimize their learning experiences. Utilizing color-coding or highlighting techniques to emphasize important information in mathematical notes serves as a visual cue, aiding students in identifying key concepts and relationships amidst a sea of information (Ekman & Waliullah, 2019).This method not only enhances organization and clarity but also reinforces memory retention through visual reinforcement (Sedig, Rowhani, Morey, & Liang, 2003).

Additionally, the creation of flashcards or summary sheets serves as an effective mnemonic device, enabling students to condense vast amounts of information into concise and digestible formats (Fernández & Araya, n.d). By summarizing key mathematical formulas and definitions, students engage in active recall and retrieval practice, promoting long-term retention and mastery of essential concepts (Murata, 2008).. Furthermore, the act of creating study guides or summaries of key mathematical concepts fosters deeper understanding and comprehension. Through the process of synthesis and summarization, students consolidate their knowledge and identify connections between various mathematical principles, thereby enhancing their ability to apply these concepts in problem-solving scenarios.

Latent Roots Criterion of the Extracted Factors

Shown in Table 3 is the latent roots criterion of the extracted factors depicting the percentage of Variance. The first factor has an initial eigenvalue of 8.585 and a variance of 13.60%. The second factor has an initial eigenvalue of 2.798 and a variance of 10.00%. The third factor has an initial eigenvalue of 2.059 and a variance of 7.40%. The fourth factor has an initial eigenvalue of 2.057 and a variance of 7.30%.the last factor has an initial eigenvalue of 1.561 and a percentage variance of 5.60. Overall the factors explain 43.90 percent of the strategies in learning Engineering Mathematics.

Table 3 Latent Roots Criterion of the Extracted Factors

	Eigenvalues	**% Variance**	**Cumulative Variance**
Factor 1	3.810	13.60	13.60
Factor 2	2.798	10.00	23.60
Factor 3	2.059	7.40	31.00
Factor 4	2.057	7.30	38.30
Factor 5	1.561	5.60	43.90

CONCLUSION

The Exploratory Factor Analysis unveiled five key strategies utilized by engineering students in learning Mathematics. These strategies encompass Cognitive Strategies and Metacognition, Social Learning and Feedback, Consistent Practice and Review, Utilization and Self-Directed Learning, and Visual and Study Aids. These findings shed light on the diverse approaches employed by engineering students to tackle mathematical challenges and enhance their understanding of complex concepts. By recognizing and understanding these strategies, educators and institutions can tailor their teaching methodologies and support systems to better meet the needs of engineering students and promote more effective learning outcomes in the field of Mathematics.

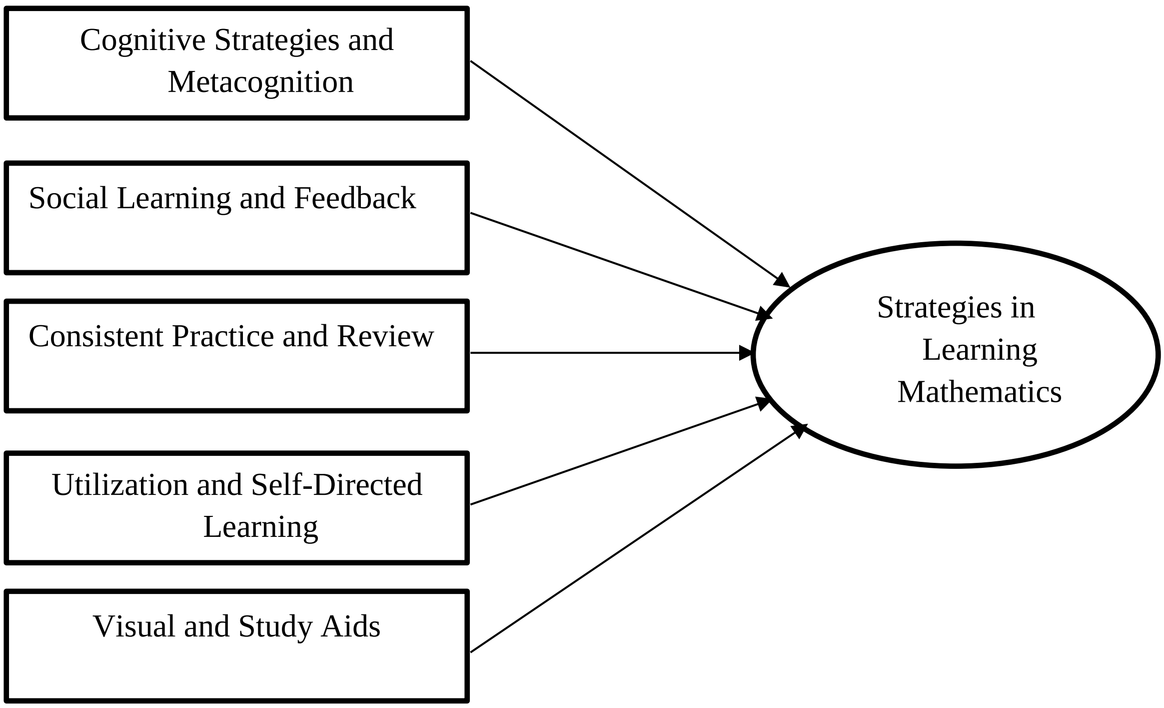

Fig. 3 Dimensions of Strategies in Learning Mathematics among Engineering Students

Drawing from the conclusion regarding the diverse strategies employed by engineering students in learning Mathematics, it is advisable for educational institutions to embrace a holistic approach to pedagogy. To accomplish this, educators should integrate a variety of instructional methods and support systems tailored to the unique needs of engineering students. To begin with, educators should place a strong emphasis on nurturing *Cognitive Strategies and Metacognition* among students. This involves encouraging critical thinking and problem-solving abilities through hands-on workshops, practical problem-solving scenarios, and opportunities for self-reflection. By providing such avenues, students can enhance their confidence and creativity in approaching mathematical challenges.

Additionally, fostering a culture of *Social Learning and Feedback* is paramount in creating a supportive academic atmosphere. This entails incorporating group discussions, peer review sessions, and mentorship initiatives to encourage knowledge exchange and constructive feedback. Such collaborative efforts foster a sense of community among students, promoting collective learning and growth. Furthermore, promoting *Consistent Practice and Review* is indispensable for reinforcing learning and retention of mathematical concepts. Assigning regular homework, quizzes, and review sessions ensures active engagement with course material, leading to long-term mastery of mathematical principles. Moreover, empowering students with opportunities for *Utilization and Self-Directed Learning* allows them to personalize their educational journey. By providing access to a variety of learning resources and support services, students can explore alternative methods and tailor their study approaches to suit their individual learning preferences. Lastly, integrating *Visual and Study Aids* into teaching strategies can enrich students' comprehension and memory of mathematical concepts. Incorporating visual aids, mnemonic devices, and interactive tools in lectures makes abstract concepts more tangible and engaging, facilitating deeper understanding and retention of knowledge.

FUNDING INFORMATION
No funding involved

DECLARATION OF CONFLICT
We have no personal, financial, or other interest that could, or could be seen to, influence the decisions or actions we are taking or the advice we are giving during my research for this study.

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