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Predictive Relationship Between Study Habits and Mathematical Achievement Among Stem Students: A Learning Style Perspective

Rujube H Hermano*, Adel Grace P Gaudicos

Southern Leyte State University, Main Campus, Philippines. *Corresponding Author's Email: rhermano@southernleytestateu.edu.ph

Abstract

This study aims to examine the influence of study habits on mathematical competencies among Science, Technology, Engineering, and Mathematics (STEM) students focusing on three learning styles: visual, auditory, and tactile. It utilized a quantitative, predictive approach. The research instruments used in the study included adapted questionnaires that explored students' learning preferences and study habits. The collected data were analyzed using both descriptive and inferential statistics. The results indicated that, although the visual learners had a clear preference for taking notes, the least amount of improvement was noted in the case of the tactile learners. Conversely, auditory learners benefited most from all three study habits—time on task, note-taking, and test-taking skills. Therefore, it is evident that classroom practices should incorporate the development of instructional strategies that leverage the learners' strengths to significantly influence student mathematical performances favourably.

Keywords: Learning Styles, Mathematical Competency, Predictive Analysis, STEM Students, Study Habits.

Introduction

Worldwide, student performance is ranked through the Programme for International Student Assessment (PISA). This assessment measures students' skills in reading, science, and mathematics, providing insights into the practical effectiveness of educational systems across different countries (1). The Philippines started participating in PISA in 2018; however, since then, the performance of Filipino students has consistently remained achieved minimum proficiency levels in the three areas, highlighting ongoing problems concerning basic skills. The 2022 results replicated those from 2018, when the Philippines was among the lowest-performing countries in mathematics, science, and reading (2). This consistently poor outcome is disturbing, particularly since mathematics is essential for developing analytical and problem-solving skills that are crucial for the 21st-century workforce. The exploration of mathematics skills in Science, Technology, Engineering, and Mathematics (STEM) programs is typically considered fundamental to the improvement of problem-solving and critical thinking skills. However, the learners in this program commonly manifest varying levels of mathematical proficiency. Research has long indicated that individual learning styles play a part in molding how students absorb and analyze information. Likewise, study habits have been acknowledged as critical factors of academic achievement. Learners display different study habits, which can influence their learning outcomes. Moreover, the interaction between the learners' individual learning styles and their study habits may further influence their academic performance. Consequently, understand -ding these learning styles and study habits could give practical enlightenment on elevating the mathematical performance among Filipino students. Past research has investigated the relationship between learning style and academic performance. A study on the Visual, Auditory, and Kinesthetic (VAK) learning style showed that visual learning had the strongest connection to mathematical ability (3). However, these findings are contrary to another study, which indicated that kinesthetic (also known as tactile) learners performed better than visual and auditory learners in mathematical literacy, particularly in generating and utilizing mathematical reasoning (4). This discrepancy emphasizes that the relationship between learning styles and mathematical

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performance is possibly complex, suggesting that different aspects of mathematics learning (such as literacy versus competency) may be influenced by distinct learning preferences. In addition, study habits involving time management, note-taking, and test preparation have been frequently linked with greater academic achievement. A study on STEM students revealed that test-taking and preparation skills predict the mathematical ability of STEM students (5). Further research emphasizes that effective time management leads to favorable academic outcomes (6), and there is a significant relationship between study-related time management and secondary students' mathematics performance (7). Moreover, note-taking has been identified as a predictor of students' academic performance in mathematics (7). Nevertheless, although these studies have provided valuable insights, they have primarily focused on the general impact of learning styles or study habits on academic achievement rather than examining how these factors specifically relate to STEM students. The gap in the present literature is the need for studies that mainly investigate how study habits vary in accordance with the different learning styles of STEM students and how these dissimilarities affect performance in mathematics. Although some research highlights the significance of study habits in academic achievement, a more detailed understanding is required regarding how these habits relate specifically to the varying learning styles among STEM students. To bridge this gap in the literature, the present study simultaneously examines STEM students' study habits, specifically time management, test preparation, and note-taking, and their preferred learning styles (visual, auditory, and tactile), then models the combined and interactive effects of these factors on mathematics performance. The integration of variables that prior research has typically treated in isolation, this investigation offers a more holistic account of how tailored study strategies can enhance achievement in mathematically intensive disciplines. Hence, the study aims to offer educators practical insights to help them tailor teaching methods that could better support STEM students in enhancing their mathematical abilities.

Conceptual Framework

The conceptual framework integrates results from different studies to elucidate the association between learning styles, study habits, and mathematical performance among STEM students. It is anchored on Fleming's Visual, Auditory, Kinesthetic (VAK) learning style theory, which classifies learners into visual, auditory, and kinesthetic (8), influencing how they engage with and comprehend concepts in mathematics. Research points out those learning styles considerably affect mathematical achievement, with visual learners usually performing better because of their strength in processing information visually (9, 10).

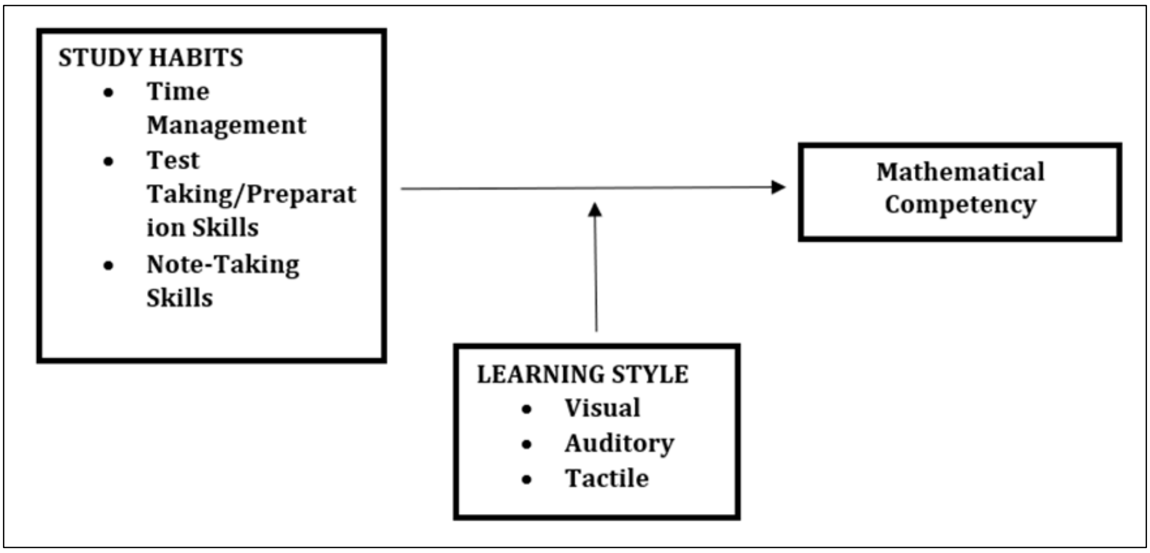

Figure 1: Conceptual Framework of the Study

The framework (Figure 1) examines how certain study habits, such as time management, test preparation, and note-taking, influence academic outcomes. Organized study habits are important and advantageous for academic achievement (11). For instance, previous study found a moderate positive correlation between effective study habits and mathematics performance, showing the importance of aligning study strategies with individual learning styles (12).

The framework also answers how varying learning styles affect study habits. It proposes that while visual learners benefit from organized notes and visual materials, kinesthetic learners may require more interactive and hands-on study methods (13). This underscores the value of educational methods that connect study habits with learning preferences, which in turn leads to improved mathematical performance. Integrating constructivism, cognitive load theory, and self-regulated learning offers a coherent account of how study habits bolster STEM students' mathematics achievement. Constructivism views learning as an active process of constructing knowledge, so disciplined time management, strategic test preparation, and detailed note-taking act as scaffolding to help students build strong mathematical understanding (13). Cognitive load theory adds that such organized routines minimize extraneous mental effort which reserves working-memory capacity for the inherent complexity of problem solving (14). Self-regulated learning theory further emphasizes that students who deliberately plan, monitor, and adjust their approaches, especially when tailoring them to visual, auditory, or kinesthetic preferences, boost metacognitive control, deepen engagement, and ultimately improve performance (15). These lenses not only account for the observed links between high-quality study habits and improved mathematical outcomes but also advance Sustainable Development Goal 4 by illustrating how theoretically grounded, learner-centered practices can make STEM learning more equitable and effective. The framework facilitates more effective and focused education by developing educational strategies for visual, auditory, and kinesthetic learners, which promotes academic success and fairness in learning outcomes. This helps enhance the quality of education and decrease the differences in academic performance. The framework declares that the alignment of learning styles and study habits can increase the student's mathematical performance since it could help increase engagement and, thus, learning effectiveness. Hence, this strategy offers a comprehensive approach to meeting the different needs of STEM students and can help educators make more effective teaching strategies and interventions.

Methodology

This study employed a quantitative, specifically predictive, approach to predict students' mathematical competencies based on their study habits across three learning styles. The respondents were randomly selected Science, Technology, Engineering, and Mathematics (STEM) students from rural areas in the Philippines. Study habits were operationally defined in this study as a multidimensional construct encompassing (1) time management, (2) test-taking and test-preparation skills, and (3) note-taking skills. To quantify these dimensions, the researchers adapted items from University Survey: A Guidebook and Readings for New Students by Virginia Gordon (16). The research instrument consists of three sub-scales—Time Management (TM), Test-Taking/Test-Preparation (TT), and Note-Taking (NT)—with items rated on a five-point Likert scale ranging from 1 (rarely) to 4 (always). In addition, the students' learning styles were assessed using a tool adapted from the University of Texas Learning Center (17, 18). The students' mathematical competency was determined based on their grades in their mathematics subjects.

Data were collected through structured survey questionnaires, and the quantitative data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics, such as means and standard deviations, were computed to summarize participants' responses to the survey items. Inferential statistics, including multiple - correlation and regression analyses, were employed to examine relationships between variables and identify significant mathematics competency predictors among STEM students.

Ethical guidelines were strictly followed throughout the study. Participants provided informed consent after being informed about the study's objectives, procedures, and potential risks. Confidentiality and anonymity were ensured through coded identifiers and secure data storage, and the study received ethical approval from the relevant institutional review board before data collection.

Results and Discussion

Students' Mathematical Competency by Learning Styles

Table 1 displays the mathematical competency scores of the students on the mathematical competency test categorized based on their learning style. The visual learning style was found to have the highest mean score of about 87. 83 (SD = 6. 54), which is clustered under the "Very Satisfactory" level of competency. This was followed by the auditory learning style, with a mean score of 86. 43 (SD=6. 58), also under "Very Satisfactory." Tactile learners scored a mean of 82.92 (SD = 4. 15), and the classification for these was "Satisfactory." These findings indicate a slight variation in the proficiency in mathematics among the visual and the auditory groups of students, but overall, all learning styles fall within a satisfactory range.

Table 1: Students' Mathematical Competency by Learning Styles

Learning Style	Mean	Standard Deviation	Descriptor
Visual	87.83	6.54	Very Satisfactory
Auditory	86.43	6.58	Very Satisfactory
Tactile	82.92	4.15	Satisfactory

Visual learners who demonstrated good spatial graphical aptitude with a capacity for analysis recorded the highest mathematical competency. The same case was seen in work on the VAK (Visual, Auditory, Kinesthetic) learning model learning style that showed visual learning had the highest mathematic connection ability (3). Nonetheless, the results of this study do not agree with the results on mathematical literacy rather than general mathematical competency, as the authors discovered that kinesthetic (also known as tactile) learners performed better than the other two types of learning in mathematical literacy, especially in the generation and use of mathematical reasoning (4). This underlines that the learning styles approach to mathematical performance may be non-simple, demonstrating that various components of learning mathematical (such as literacy versus competency) can result from different learning preferences.

Time Management as Predictor of Students' Mathematical Competency

Time management enables students to master the way and manner through which the available time can best be utilized. To the full-time students, managing their time to ensure they cover every area as prescribed by their study schedule is very essential (19). Looking at the effect that time management skills have on student mathematics performances, the regression model in Table 2 that looks at various dimensions of time management as the independent variable to use for visual leaners, the regression model is able to explain 42.1% of the variance in students' mathematical competency (Adjusted R^2 = 0. 42). The model is statistically significant, as indicated by the Analysis of Variance (ANOVA) results ($F(8, 16) = 16.16$, $p < 0.00$). Visual learners who regularly attend class ($\beta = 0.56$, $p < 0.00$), get at least six hours of sleep each night ($\beta = 0.29$, $p < 0.00$), and complete their assignments on time ($\beta = 0.18$, $p < 0.05$) tend to have higher mathematical competencies compared to those who invest less time in these activities. This implies that dedication to doing coursework, adequate breaks, and timeliness in completing assignments will likely improve the visual learners' mathematical abilities. Generally, most STEM students are likely to attend classes and make study timetables as an ordinary practice, but they are less likely to engage in submitting assignments on time and getting six hours of sleep, among other things (5). Further, research highlights the importance of timetables that include rest and time-out between learning activities to produce favorable academic achievements (6).

Visual learners who are less consistent in adhering to a master schedule ($\beta = -0.41$, $p < 0.00$) and who allocate less time for exercise and socializing ($\beta = -0.17$, $p < 0.05$) also demonstrate higher mathematical competencies. Visual learners who do not adhere strictly to a master schedule might explore alternative strategies and resources that are suitable for them and enhance their mathematical proficiencies. Another observation is that the STEM students tend not to stick to their study schedules, such a finding could mean that an irregular study timetable would be more beneficial to some learners instead (5). This is in contrast to other students for whom a systematic review is generally recommended as it increases the feelings of relaxation and preparedness when undertaking one's examinations (20). Moreover, leisure activities such as exercising and social interactions are recommended, but too many of these activities may imply reducing studying time. Prioritizing academics and balancing their activities can help them achieve better results. As always, STEM students revealed that learning without disruptions, which includes standing up or moving around the classroom, contributes to achieving the desired academic goals (5).

Table 2: Regression Coefficients for Time Management as Predictor of Students' Mathematical Competency

Time Management	Standardized Coefficients		
	Visual	Auditory	Tactile
1. Do you make a master schedule of each quarter?	0.24ns	0.32*	-0.17*
2. Do you update it weekly or daily?	-0.02ns	0.65***	0.06ns
3. Do you stick to it?	-0.41***	-0.56***	-0.06ns
4. Do you allow time for exercise and socializing with friends?	-0.17*	0.47***	0.47***
5. Do you get at least six hours of sleep each night?	0.30***	-0.06ns	-0.11ns
6. Do you study at least two hours for every hour in class?	0.09ns	0.14ns	0.07ns
7. Do you get your assignments done on time?	0.18*	-0.04ns	0.16ns
8. Do you regularly attend your classes?	0.56***	0.72***	-0.12ns
Adjusted R Square	0.42	0.53	0.29
ANOVA	F(8, 159)= 16.16***	F(8,138)= 21.89***	F(8, 120)= 7.47***

***: p-value<0.001 **: p-value<0.01 *: p-value<0.05

The ANOVA results show that the regression model, which investigates different elements of time management as predictors of auditory learners' mathematical competency, is statistically significant ($F (8,138) = 21.89, p < 0.00$). This model explains 53.00% of the variance in students' mathematical competency (Adjusted $R^2 = 0.53$). Regularly attending classes ($\beta = 0.72, p < 0.00$), creating a master schedule for each quarter ($\beta = 0.32, p < 0.05$), updating the master schedule weekly or daily ($\beta = 0.65, p < 0.00$), and allocating time for exercise and socializing with friends ($\beta = 0.47, p < 0.00$) are time management practices that auditory learners who engage in more frequently tend to have higher mathematical competencies. Coming to class and creating a timetable regularly keeps the auditory learners focused and refreshes their study, which enhances their mathematical abilities. Such scheduling helps them learn how to create and update the master schedule, which can be helpful in the management of time and commitment to studying. Students who learn through the auditory modality perform well in settings that allow for verbal interactions, including questioning, discussions, and even listening to lectures and dialogues (21). Hence, it is effective to create a situation where the learner must use words to explain mathematical problems to someone else and hear how his or her peers would explain their solutions. Furthermore, exercising and social activities benefit the students' physical and mental health as they help decrease stress and improve cognitive abilities.

In the same manner, it can be seen that the auditory learners who are comparatively less rigid in following their master timetable ($\beta = -0. 56, p < 0. 00$) possess higher levels of mathematical skills. This means that it is not necessary for the auditory learners to have a tight timetable to the extent that even some extra time for learning and practicing mathematics will mess up everything. Instead, a certain amount of flexibility in time, they may be able to effectively adjust the study habits in accordance to their learning profile. Research shows that the connection between study time and academic achievement becomes stronger when considering additional factors such as the quality of study sessions, class attendance, prior preparation, and student motivation (22). These findings stress the importance of factors beyond the time invested in studying, such as passion and commitment towards the course and the relation of studies to the career. In contrast with the expectation that learning style would affect the amount of time learners spend studying, learners with different learning styles did not very much in the time they spent studying (23). This implies that other components may overshadow learning styles, which are paramount to academic success. Other elements, such as the effectiveness of study habits or the specific requirements of the course material, may be more crucial in determining academic success than learning styles alone.

The regression model examining tactile learners' mathematical competency, with time management as the predictor, accounts for 28.8% of the variance in mathematical competencies (Adjusted R^2 = 0.29). The model's statistical significance is confirmed by the ANOVA results ($F (8, 120) = 7.47$, $p < 0.00$). Tactile learners who regularly allocate time for exercise and socializing with friends (β = 0.47, $p < 0.00$) tend to exhibit higher mathematical competencies compared to those who do so less frequently. Additionally, tactile learners who create a master schedule for each quarter less frequently (β = -0.17, $p < 0.05$) also demonstrate higher mathematical competencies. Tactile learners will likely perform well in learning contexts where they can engage in physical, hands-on activities. Reducing the time spent on strict timetables might enable them to engage in more practical learning activities that build up their mathematical skills. This view is also shared by research studies showing that kinesthetic learners have higher grades in learning activities where much time is spent on practical learning (24). Conversely, their performance typically declines when such activities are reduced (25). Moreover, the limited availability of kinesthetic materials can negatively affect these learners' performance and study time (23). This highlights the importance of hands-on activities for tactile learners and underscores the challenges posed by the scarcity of such resources. Getting ready for a test is essential for success. Having the right attitude for studying is significant, especially when the goal is to have positive results on the day of the exam. Sufficient preparation boosts confidence and promotes improved performance (5). The study investigates the test-taking and preparation skills as the predictor of the mathematical ability of students around different learning styles.

The model indicates that 24.00% of the variation in mathematical competencies among visual learners can be attributed to their test-taking or preparation skills. This model is statistically significant, as evidenced by the ANOVA results ($F (8, 159) = 7.85$, $p < 0.001$). The coefficients indicate that visual learners who start reviewing for major exams at least three days in advance (β = 0.31, $p < 0.00$), predict the types of questions that will be on the test (β = 0.31, $p < 0.00$), complete their tests within the allotted time (β = 0.27, $p < 0.05$), and participate in study groups (β = 0.18, $p < 0.05$) tend to demonstrate higher mathematical competencies compared to those who engage less frequently in these test-taking or preparation practices. The positive correlation between early reviewing for exams and mathematical performance emphasizes the importance of proactive learning approaches. Since visual learners are good at organizing information visually, the early reviewing habit enables them to learn mathematical concepts effectively. Proactive learners, such as visual learners who practice early preparation, show higher educational engagement since the habit reduces last-minute stress, leading to an enhanced understanding of the lessons (26). Proactive students are more likely to persevere, overcome challenges, and handle stressful situations, such as during timed examinations. In addition, visual learners' ability to anticipate the questions of the tests is another strategy that leads to favorable performance (27). This enables them to solve complex tasks. Proactive learners seek opportunities in the environment, and their capacity to predict questions helps them perform better in mathematics (27). On the other hand, joining a study group is another trait of visual learners that leads to mathematical success. Cooperative learning promotes success in mathematics even if it is a heterogeneous classroom (28). The collaborative setting gives diverse ideas or perspectives of the lessons as well as giving support and motivation (29).

Test Taking/ Preparation Skills as Predictor of Students' Mathematical Competency

Test-taking and preparation activities, such as starting review for major exams at least three days in advance (β = 0.74, $p < 0.00$) and predicting the types of questions that will appear on the test (β = 0.70, $p < 0.00$), have a significant positive impact on auditory learners' mathematical competencies as reflected in Table 3. Auditory learners who often practice these activities demonstrate higher mathematics competence. Starting early review before tests gives the learners ample time to organize and internalize the lessons, optimizing their auditory processing strengths. Also, expecting the questions to be asked on the tests enables them to concentrate on studying contents that have higher chances of appearing on the test, which aligns with their capacity to process information by means of auditory processes such as discussing expected questions or listening to discussions. A study also highlighted the same results involving STEM students. It was found out that the STEM students always start to review for exams at least three days in advance and also study every day for each class (5). Also, it was found that the students can predict the types of questions for the upcoming tests. These habits are also observed in another study among Senior high school students, who usually study complex subjects, highlight essential information, begin with teacher's hand-outs, and predict questions on tests (30).

Auditory learners who participate less frequently in study groups (β = -0.27, $p < 0.00$), attend fewer extra help sessions or office hours provided by the instructor (β = -0.36, $p < 0.00$), and have less knowledge about the type of test they will take and how to prepare for different types of tests (β = -0.35, $p < 0.00$) tend to exhibit higher mathematical competencies compared to those who engage in these activities more often. Auditory learners may have a higher level of achievement in self-directed strategies where they can concentrate on their auditory strengths. They can have more advantages in absorbing information through lectures, audio materials, and oral explanations compared to group discussions or support sessions. Furthermore, this type of learner may hold firm general study ability and planning that are effective throughout diverse types of tests. Their capability to master concepts in mathematics does not strongly rely on the format of the test but instead on their general understanding and utilization of material. Auditory learners demonstrate a high degree of self-directed learning preparedness (31). This characteristic allows them to perform well in the absence of group study or other structured planning strategies. In a study, none of the auditory learners displayed low self-directed learning readiness (32), further backing the notion that the learners can manage their learning on their own effectively.

Table 3: Regression Coefficients for Test Taking/ Preparation Skills as Predictor of Students' Mathematical Competency

Test Taking/Preparation Skills	**Standardized Coefficients**		
	Visual	**Auditory**	**Tactile**
1. Do you study for each class every day?	-0.09ns	-0.13ns	-0.08ns
2. Do you start reviewing for major exams at least three days in advance?	0.31***	0.74***	0.11ns
3. Do you belong to a study group?	0.18*	-0.27***	0.07ns
4. Do you attend extra help sessions or office hours provided by the instructor or teacher?	-0.11ns	-0.36***	0.07ns
5. Do you know what kind of test you will take example is a multiple choice and how to prepare for different type of test?	-0.05ns	-0.35***	0.01ns
6. Can you predict what types of question will be on the test?	0.31***	0.70***	0.33***
7. Do you finish your test in the allowed period?	0.27*	-0.01ns	0.31**

8. If you do not do well on test, do you review It or analyze it to see where you had problems?	-0.04ns	-0.07ns	0.24**
Adjusted R Square	0.25	0.66	0.27
ANOVA	F(8, 159)= 7.85***	F(8,138)= 36.31***	F(8, 120)= 7.01***

***: p-value<0.001 **: p-value<0.01 *: p-value<0.05

Tactile learners who frequently predict the types of questions that will appear on the test (β = 0.33, $p < 0.00$), complete their tests within the allotted time (β = 0.31, $p < 0.01$), and review or analyze their tests to identify problem areas (β = 0.31, $p < 0.00$) tend to demonstrate higher mathematical competencies compared to those who engage in these practices less frequently. This shows that active and pondering test-taking approaches are notably beneficial for tactile learners. By predicting the content of the tests, tactile learners can suit their planning to focus on important material that could enhance their comprehension of lessons and examination performance. Furthermore, reviewing and assessing their performance on tests leads to determining areas of complication for continuous refinement. This could be explained by the tactile learner's inclination for hands-on and interactive educational experiences, which can significantly contribute to their mathematical intelligence.

Note Taking Skills as Predictor of Students' Mathematical Competency

The ANOVA results in Table 4 reveal that the regression model, which evaluates different aspects of note-taking skills as predictors of visual learners' mathematical competency, is statistically significant ($F(6, 161) = 33.31$, $p < 0.00$). This model explains 54.00% of the variance in students' mathematical competency (Adjusted $R^2 = 0.54$). Visual learners who are skilled at identifying key information to record and recognizing cues that signify its importance (β = 0.44, $p < 0.00$), as well as those who take extensive notes while reading class materials in addition to highlighting (β = 0.53, $p < 0.00$), exhibit higher mathematical competencies compared to those who engage in these practices less frequently. For these learners, determining and recording vital information and adding note-taking strategies, including extensive note-taking together with highlighting, are helpful practices. Visual learners engage in getting information best by means of visual aids like charts, pictures, and annotated notes, which assist them in highlighting essential points and systematizing ideas (32-34). Their inclination for note-taking and color marking reinforces their perception and memory of materials (32, 35). These approaches reduce the complexity of figuring out and remembering concepts, especially in mathematics subjects.

Visual learners who infrequently convert class notes or notes from texts into their own words (β = -0.20, $p < 0.05$) also show higher mathematical competencies. Converting notes into their own wording might be an advantageous habit for visual learners, but it might not always be necessary to attain high mathematical competencies. Visual learners achieve the highest in mathematics, implying that visual learners may excel by using visual illustrations of concepts as opposed to rephrasing information (3).

The note-taking skills of students account for 54.0% of the variance in the mathematical competencies of auditory learners ($F(6, 140) = 29.62$, $p < 0.00$). Note-taking practices, including reviewing notes immediately after each class (β = 0.27, $p < 0.05$), identifying and recording key information while recognizing cues that signify its importance (β = 0.33, $p < 0.00$), and supplementing highlighting with additional note-taking during the review of class materials (β = 0.86, $p < 0.00$), exert a significant positive effect on students' mathematical competencies. Auditory learners benefit substantially from habits such as immediately reviewing notes after classes, distinguishing key concepts, and incorporating notes along with highlighting. Additionally, auditory learners are the same as visual learners, who are fond of note-taking and augmenting learning. These learners favor listening attentively to the lecture, followed by taking notes or depending on written materials to revisit the information provided orally (21). This approach duplicates the note-taking habits of visual learners, which also make use of written records to aid in their learning. In spite of their primary dependence on auditory inputs, auditory learners acknowledge the value of visual techniques. These approaches assist their learning style by strengthening verbal and auditory processing of material, which supports and enhances their comprehension and retaining of mathematical concepts. Auditory learners who engage less frequently in activities such as taking notes during class, maintaining alignment with the instructor, and simultaneously comprehending concepts (β = -0.19, $p < 0.01$), as well as those who infrequently convert class notes or notes from texts into their own words (β = -0.29, $p < 0.05$), also tend to demonstrate higher mathematical competencies. These propose that while usual note-taking habits and active alignment with the teacher are advantageous, there may be different approaches that are similarly or more beneficial for improving mathematical achievement. Auditory learners who have higher mathematical competencies, even though following or using traditional activities less often, could benefit from combining various learning strategies that harmonize their auditory strengths, for instance, reinforcement techniques or oral review meetings. Auditory students can learn by listening to lectures rather than reading (36). These learners tend to retain details better when listening compared to reading, which could lead to solid memory retention from lessons (37). Integrating auditory-focused procedures could improve their learning and mathematical performance.

Table 4: Regression Coefficients for Note Taking Skills as Predictor of Students' Mathematical Competency

Note Taking Skills	Standardized Coefficients		
	Visual	**Auditory**	**Tactile**
1. Do you take notes in class, keep up with the instructor, and understand the concepts at the same time?	0.03ns	-0.19**	-0.30***
2. Do you have an efficient system of note taking?	0.08ns	-0.13ns	-0.02ns
3. Do you review your notes after each class, preferably in the right after class?	-0.05ns	0.27*	-0.32***
4. Do you know what the important stuff is to write down and what are the cues that this is important stuff?	0.44***	0.33***	0.20*
5. In addition to highlighting, do you make notes as you read class materials?	0.53***	0.86***	0.37***
6. Do you put class notes or notes from text into your own words?	-0.20*	-0.29*	0.14ns
Adjusted R Square	0.54	0.54	0.41
ANOVA	$F(6, 161)=$ 33.31***	$F(6, 140)=$ 29.62***	$F(6, 122)=$ 15.86***

***: p-value<0.001 **: p-value<0.01 *: p-value<0.05

Among tactile learners, note-taking skills account for 41.00% of the variance in mathematical competencies. The model's statistical significance is confirmed by the ANOVA results ($F(6, 122) = 15.86$, $p < 0.00$). The regression coefficients indicate that tactile learners who are adept at identifying key information to record and recognizing cues that signal its importance (β = 0.20, $p < 0.05$), as well as those who take additional notes while reading class materials after highlighting (β = 0.37, $p < 0.00$), demonstrate higher mathematical competencies. Tactile learners benefit from direct contact with learning materials, which includes enthusiastically jotting down main concepts and solutions as they study (38). This active involvement with the learning material not only supports understanding but also aids them in processing and grasping concepts more efficiently, which leads to increased mathematical aptitude. Tactile learners are capable of performing investigations, which start with interpreting the problem according to the mathematical principles involved. They can rewrite the information gathered in the solution. Aside from keeping a record of information, tactile students are able to develop a mathematical model of a particular problem (39). Furthermore, tactile learners have higher mathematical literacy skills than auditory and visual learners (4).

Tactile learners who engage less frequently in activities such as taking notes during class, maintaining alignment with the instructor while simultaneously understanding concepts ($\beta = -0.30$, $p < 0.00$), and reviewing their notes immediately after each class ($\beta = -0.32$, $p < 0.00$) also exhibit higher mathematical competencies. Excessive writing or too much note-taking and constant review may result in information overload for a number of tactile learners. Tactile learners who stand out when physically involved in hands-on performances may undergo decreased cognitive burden and enhanced performance in mathematical activity by concentrating on a more interactive and less constrained learning strategy (40). These learners gain an advantage from a learning atmosphere where they can control materials and be physically functioning, which improves their memory and comprehension of new knowledge. By concentrating on more practical and less structured approaches, they can lower this mental overload and thus execute better mathematical tasks. Tactile learners retain knowledge most efficiently by means of hands-on activities instead of using inactive methods (40).

Conclusion

These findings call on educators and policymakers to diversify classroom practice so that each learning preference is deliberately supported. For auditory learners, who gain the most from strong time management, test preparation, and note-taking skills, teachers should embed think-aloud problem solving, structured peer explanations, and other talk-based routines into mathematics instruction. Visual learners benefit from concept maps, annotated diagrams, and digital sketch-notes that translate abstract ideas into graphic form, while tactile learners need ample opportunities to manipulate materials and engage in hands-on tasks, even though study-habit tweaks had only a modest impact on their performance. A Universal Design for Learning (UDL) framework can weave these modes together by presenting every key concept in multiple formats which offer a choice of practice activities (podcast recaps, sketch-note challenges, lab stations), and using frequent, low-stakes checks to guide real-time adjustments. Blended-learning structures such as station rotation, combined with curriculum “mini-units” that explicitly teach time-management, note-making, and metacognitive reflection, give students repeated, flexible entry points into rigorous STEM content. Furthermore, sustained professional development, clear curricular standards, and targeted resource allocation are essential to ensure these multimodal strategies translate into higher mathematics achievement and more equitable outcomes for every learner profile.

One limitation of this study is that only STEM students participated, which limits the generalizability of results to students from other fields. Future studies should open their participation to non-STEM students to establish their applicability across disciplines. Moreover, future research could analyze other antecedents that mediate the correlation between study practices and performance in math based on learning styles.

Abbreviations

PISA: Programme for International Student Assessment, STEM: Science, Technology, Engineering, and Mathematics, UDL: learning style, Universal Design for Learning, VAK: Visual, Auditory, Kinaesthetic.

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Author Contributions

Both authors worked together on all aspects of the research, from designing the study and collecting data to analyzing results and writing the manuscript. Their collaboration ensured the study’s quality and showed their shared commitment to advancing knowledge in their field.

Conflict of Interest

The authors of this work state that they have no conflicts of interest about its publication.

Ethics Approval

This article is original with unpublished content, and the corresponding author confirms that all co-authors have approved the manuscript and that there are no ethical issues involved.

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