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The Interaction between Spaced Learning breaks and Cognitive Style to enhance Mathematical Problem-Solving Skills for High School Students

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Abstract:

This research aimed to measure the impact of the interaction between the patterns of spaced learning breaks (physical-electronic) and the cognitive style (ambiguity tolerance-ambiguity intolerance) on enhancing mathematics problem-solving skills for high school students in the State of Qatar. The research sample consisted of 60 male and female 12th-grade students from Qatar High School in Al-Kheesa. They were divided into four experimental groups based on their cognitive style and the pattern of spaced learning breaks provided to them, following the quasi-experimental research design. The measurement tools included the Cognitive Style Test (ambiguity tolerance – ambiguity intolerance) and the Mathematics Problem-Solving Skills Test. The results revealed a statistically significant positive interaction effect at the 0.05 level between the spaced learning break pattern (electronic vs. physical) and the cognitive style (ambiguity tolerance vs. ambiguity intolerance) for students in the four groups in the post-test of mathematics problem-solving skills. Additionally, the findings showed statistically significant differences at the 0.05 level in favor of the group that learned through the electronic spaced learning break pattern, as well as in favor of the students with ambiguity tolerance, in terms of their problem-solving skills in mathematics.

Keywords: Spaced Learning Break pattern – Cognitive Style (Ambiguity Tolerance / Ambiguity Intolerance) – Mathematics Problem-Solving Skills – High school– State of Qatar.

1. Introduction:

The High school stage is a critical period in students' lives, marked by various challenges that require effective problem-solving and decision-making skills. Cognitive styles play a key role in how students confront and manage these difficulties by guiding their approach to problem-solving. In mathematics, in particular, many High school students struggle—while some can overcome obstacles through effective strategies, others fail to do so, leading to disengagement from learning activities and a decline in academic performance (Al-Nawasrah & Al-Saqrat, 2023).

The concept of problem-solving skills is considered one of the important concepts in educational science and has received notable attention in recent years, both theoretically and practically. It is especially essential for High school students, as it is not limited to academic success alone but is also crucial for real-life applications. Developing these skills helps students improve their logical thinking and analytical abilities, as well as enables them to deal with challenges in a systematic manner. Students who excel in solving mathematical problems are better prepared to face complex issues in various fields such as science, engineering, and economics. Moreover, enhancing these skills at the High school level boosts students' self-confidence and prepares them for future academic and professional demands (Koskinen & Pitkäniemi, 2022).

Teaching problem-solving skills in mathematics enhances students' creativity, adaptability, and critical thinking by encouraging them to think innovatively and apply diverse strategies to unfamiliar problems (Mohammed, 2019). However, High school students face major challenges in acquiring these skills, including weak critical thinking, limited practice with problem-solving strategies, and overreliance on traditional, rote-based teaching methods, which hinder their ability to apply concepts in real-life contexts. Research underscores the need for curriculum reform and the integration of technology and interactive learning to strengthen mathematical thinking (Chander & Arora, 2021; Gouda, 2018).

To improve students' mathematical problem-solving skills, innovative teaching methods such as spaced learning are recommended, as they enhance learning outcomes by reducing fatigue and boredom through short, spaced-out study sessions (Mohamed & Hassan, 2022). Egara (2022) emphasized that the timing and format of breaks in spaced learning should align with the nature of the content and delivery method, whether traditional or digital. Although these breaks do not involve academic material, the type of activity—whether physical or electronic—can influence students' focus and retention. Therefore, it is important to investigate whether hands-on, device-free activities or digital, non-academic activities during breaks are more effective for sustaining attention and improving learning, highlighting the need for optimal break design (Senior & junior, 2021).

Educational institutions significantly shape students' cognitive development, particularly in their ability to tolerate ambiguity—a cognitive style that influences how they perceive and respond to unfamiliar or complex situations. Students who are more tolerant of ambiguity tend to be open-minded, adaptable, and more effective in problem-solving, especially in dynamic learning environments, while those with lower tolerance prefer structure and familiarity (Al-Masri & Ismail, 2019; Al-Qahtani, 2013; Brown, 2000). Research highlights the importance of recognizing these cognitive differences, as studies have shown that ambiguity-tolerant students exhibit stronger personality development and higher academic achievement compared to their less tolerant peers (Al-Wazir, 2001; Ibrahim, 2011).

Researchers suggest a strong relationship between the type of breaks used in spaced learning and students' cognitive styles—specifically their tolerance or intolerance of ambiguity. Ambiguity-tolerant students benefit from spaced breaks as they provide time for deep analysis and the use of creative strategies to solve problems independently. In contrast, ambiguity-intolerant students require shorter breaks with additional guidance to reduce anxiety caused by uncertainty. Physical breaks offer hands-on, real-world interaction that supports creative exploration for tolerant students and provides structured support for intolerant ones. Meanwhile, electronic breaks promote self-paced learning through digital resources, benefiting tolerant students, but ambiguity-intolerant learners need clear instructions and real-time interaction to minimize confusion. This alignment between break types and cognitive styles enhances students' analytical thinking and helps them develop problem-solving skills in ways tailored to their individual needs, as supported by Carpenter et al. (2012) and Dunlosky & Rawson (2019).

A researcher's observations as a mathematics teacher in Qatar revealed significant deficiencies among twelfth-grade students in problem-solving skills, particularly in abstract units like sequences and series. An exploratory study with 20 students showed that 85% struggled with the abstract nature of content and 90% preferred more interactive teaching methods over traditional approaches. Most students (90%) failed to apply problem-solving strategies effectively, highlighting a gap in instructional design. These findings align with previous studies (e.g., El-Naggar & Hassan, 2018; Chander & Arora, 2021; Gouda, 2018) that report similar issues in High school mathematics education. Cognitive style—especially ambiguity tolerance—plays a crucial role in students' ability to learn and solve problems. Researchers argue that spaced learning, with varied break formats (electronic or physical), can significantly enhance both cognitive and performance aspects of problem-solving skills, especially when aligned with students' cognitive styles (Ibrahim, 2011; Al-Muntasir, 2013; El-Naggar, 2023; Ali et al., 2022; Senior & Junior, 2021). Therefore, the current research aims to explore how different types of spaced learning breaks interact with students' cognitive styles to improve mathematics problem-solving outcomes.

2. Literature review:

In this section, the concept of Spaced Learning breaks pattern and Cognitive Style. In addition, that Mathematical Problem-Solving Skills for High School Students are discussed.

2.1 **Spaced Learning and Cognitive Style**

Spaced learning is a new and innovative instructional strategy in which a series of electronic learning sessions are delivered over spaced intervals, with increasing learner engagement in each session. These sessions are separated by short breaks, during which learners perform activities completely unrelated to the lesson content (Mohammed, 2018, 276).

According to Mohamed and Hassan (2022), spaced learning follows a structured design involving multiple dimensions. In terms of repetition, it incorporates diverse sensory methods—visual, auditory, olfactory, and kinesthetic—using various educational tools like written texts, audio clips, videos, and digital games. Repetition techniques include literal or rephrased repetition, storytelling, examples, illustrations, and retrieval practices such as tests, simulations, case studies, and role-play. Interactive methods like discussions and collaborative learning are also used. The number of repetitions (or entries) typically ranges from two to three: the first introduces the content, and the second reinforces it to enhance memory retention, with more than three entries discouraged to avoid learner fatigue. Regarding timing, the interval between sessions should be close to the optimal retention gap to improve long-term memory, although overly long intervals, while beneficial, may be difficult to apply in instructional design (Mohamed & Hassan, 2022).

Spaced learning consists of two main phases: the learning phase and the testing phase (Mohamed & Hassan, 2022; El-Naggar & Hegazy, 2022; Lotfolahi & Salehi, 2016; Emsley, 2016; Garzia et al., 2016). In the *learning phase*, the first input presents the core content in a simplified manner, typically lasting no more than 20 minutes. This is followed by a first break (10 minutes), involving an unrelated activity to disengage the brain from the lesson content.

Then, in the second input, the material is reviewed with varied methods (e.g., examples or restructured delivery) to reactivate memory pathways. A second unrelated break follows, also lasting 10 minutes. The *third input* focuses on student-centered activities that reinforce and apply the learned content to ensure comprehension. In the testing phase, students are assessed immediately after the learning sessions to evaluate short-term memory, and then re-tested after a delay to measure long-term retention. This structure allows researchers to identify effective intervals, inputs, and assessment strategies to improve mathematical problem-solving skills among High school students (Mohamed & Hassan, 2022; El-Naggar & Hegazy, 2022).

There are two main types of spaced learning breaks: (1) Passive breaks, which involve no activity or educational content between sessions, and (2) Active breaks, which introduce unrelated educational content between the primary learning session and its repetition (Al-Naggar & Hegazy, 2022). Additionally, research categorizes these breaks as either physical or electronic (Ali, El-Naggar & Elharoun, 2022; Al-Naggar & Hegazy, 2022). *Physical breaks* involve interactive, non-digital activities in the classroom, such as general knowledge games, while *electronic breaks* include digital activities conducted via smart devices or computers unrelated to programming skills. Researchers advocate for this classification due to its effectiveness in enhancing mathematical problem-solving skills. For instance, Ali, El-Naggar, and Elharoun (2022) found that mobile-based spaced learning—especially using electronic breaks—was more effective in enhancing knowledge retention among High school students. Similarly, Senior & Junior (2021) highlighted the superiority of electronic breaks when learning digital skills like game design, as these breaks help maintain learners' cognitive focus and improve both knowledge acquisition and practical performance.

Cognitive styles are a significant focus in cognitive psychology, as they reveal individuals' preferred ways of processing, organizing, and retrieving information in various situations, especially educational ones (Qaddouri & Bin Zahi, 2017; Elmaadawy et al., 2025). These styles are considered relatively stable personality traits that help classify individuals—for example, as impulsive, reflective, or ambiguity-tolerant. Among the many classifications, one key dimension is tolerance vs. intolerance of ambiguity. Individuals with high ambiguity tolerance can flexibly handle uncertain or complex situations and view ambiguity as a natural part of learning and decision-making (Budner, 1962). Conversely, those with low ambiguity tolerance prefer clarity and often struggle with vague scenarios, which may result in anxiety or indecision (McLain, 2009; Furnham & Marks, 2013). Understanding these cognitive styles is essential for tailoring educational strategies, especially in teaching problem-solving and decision-making under uncertainty. Cognitive styles generally reflect how people perceive, organize, and respond to stimuli in their environment, encompassing all cognitive processes such as information reception, transformation, and recall (Abdel-Hadi, 2010; Al-Anzi, 2015; Barsoum et al., 2022).

The researchers suggest that integrating the two types of spaced learning breaks—electronic and physical—with students' cognitive styles regarding ambiguity tolerance can enhance mathematical problem-solving skills. For ambiguity-tolerant students, electronic spaced breaks can include complex and ambiguous math problems that foster critical thinking and cognitive flexibility through exploratory digital platforms. For ambiguity-intolerant students, physical spaced breaks can offer structured, clear math problems with tangible and specific tasks, helping reduce uncertainty and support direct, systematic problem-solving. By aligning learning activities with individual differences in ambiguity tolerance, this approach creates a flexible and adaptive learning environment that promotes students' mathematical problem-solving skills.

2.2 Mathematical Problem-Solving Skills

A mathematical problem is a novel situation that the student does not have a ready-made solution for and must engage in mental processes to resolve. It is characterized by three key features: acceptance (the student has a clear goal and willingly engages with the problem), the presence of an obstacle (which prevents the use of routine methods), and the need for inquiry (searching for new, creative ways to reach a solution) (Al-Ersan, 2003). Solving such problems requires the student to apply systematic, non-routine thinking, integrating prior knowledge with new information. Other definitions highlight that a problem involves a challenge or obstacle that triggers student effort and engagement, often in the form of quantitative or symbolic tasks that require persistence (Disqours, 2005; Aziz, 2009). Engelbrecht and Redfern (2020) emphasize that a mathematical problem must be solvable, present a meaningful challenge, and visibly reflect the student's effort to overcome the obstacle and reach a solution.

There are several key strategies for solving mathematical problems, each offering a unique cognitive approach to reaching solutions. One is guessed and check, also known as trial and error, where students make educated guesses and test their accuracy, refining their responses based on outcomes (Abu Zeina & Ababneh, 2010). Another is working backward, where the problem is solved in reverse—from the desired outcome back to the given data (Garofalo & Drier, 2022). The pattern recognition strategy involves identifying consistent sequences or structures (numerical or visual) and using them to form mathematical relationships to solve problems (Abu Zeina & Ababneh, 2010). The elimination strategy involves listing all possible answers and systematically removing incorrect ones to isolate the correct solution (Hegarty & Williams, 2021). Organized listing or creating a table helps in organizing data visually to detect patterns or relationships and can be either a direct solution method or a supportive tool (Abu Zeina & Ababneh, 2010). The simplify the problem strategy involves tackling a less complex version of the problem—such as using smaller numbers or ignoring some conditions temporarily—to gain insights into solving the original, more complex version (Schoenfeld, 2016). Lastly, the draw a diagram strategy uses visual representations (sketches, charts, or models) to clarify relationships and shift problems from abstract to concrete, enhancing understanding and facilitating solution planning (Schoenfeld, 2016).

Problem-solving in mathematics requires a sequence of cognitive operations based on the learner's mathematical knowledge, where selecting the appropriate strategy is key to success (Abu Eisha, 2013). Among the many models developed, Polya's (1957) four-step approach—understanding the problem, devising a plan, carrying out the plan, and evaluating the solution—is the most widely adopted in mathematics education due to its clarity and effectiveness (Al-Amin, 2004; Al-Qaisi, 2005). Other models, such as those by Dewey (1910), Lester (1976), and Arab scholars like Hindam & Gaber (1996), also emphasize sequential steps. However, Polya's model remains the most popular and is used in many modern math textbooks (Al-Sulami, 2013), making it the preferred framework in this research for addressing students' difficulties in solving mathematical problems.

The research was guided by the following question:

RQ. What is the impact of Interaction between Spaced Learning breaks pattern and Cognitive Style to enhance Mathematical Problem-Solving Skills for High School Students?

3. Method:

3.1 Participants

The research sample consisted of 60 randomly selected twelfth-grade students, who were first categorized into two groups based on their cognitive style: tolerance of ambiguity and intolerance of ambiguity. Each of these two groups was then further divided into two experimental subgroups, resulting in a total of four experimental groups: (1) Electronic spaced learning breaks / tolerance of ambiguity, (2) Electronic spaced learning breaks / intolerance of ambiguity, (3) Physical spaced learning breaks / tolerance of ambiguity, and (4) Physical spaced learning breaks / intolerance of ambiguity.

3.2 Instruments

3.2.1 Mathematical Problem-solving list of skills

The process of developing a list of mathematical problem-solving skills for twelfth-grade students focused on algebra began with clearly defining the purpose of the list—to identify and organize the essential skills required for solving algebraic problems at the High school level. To determine the content of the list, researchers reviewed both Arabic and international literature, studies, and references in mathematics education, particularly in algebra and problem-solving. They also consulted High school -level mathematics experts. Based on the gathered information, the skills were categorized into major and sub-skills, each written in clear, procedural terms to ensure they are observable, measurable, and linguistically unambiguous. The structure of the list was aligned with Polya's four-step problem-solving model: understanding the problem, devising a plan, executing the plan, and verifying the solution.

To validate the accuracy and relevance of the list, the initial version was presented to a panel of subject experts in High school mathematics. They evaluated the clarity of wording, the coherence between sub-skills and their main categories, and suggested edits for refinement. Based on their feedback, redundant skills were removed, and some complex ones were divided into simpler components. After incorporating these revisions, the final version of the list was completed. It includes a total of eight main problem-solving skills and thirty-two related sub-skills, providing a structured and validated framework to assess and develop students' algebra problem-solving competencies.

3.2.2 Learning style test

Budner's Tolerance–Intolerance of Ambiguity Test (1962) was adapted and standardized for use with High school students through several steps. The test is designed to measure individuals' tolerance or intolerance toward ambiguity and consists of 16 items—eight positively worded and eight negatively worded. Students respond using a 6-point Likert scale: Strongly Agree, Agree, Slightly Agree, Slightly Disagree, Disagree, and Strongly Disagree. Higher scores indicate greater intolerance of ambiguity. The test was translated and standardized by Abdel-Aal Ajwa (1989) on a sample of 110 students. It was selected for this research due to its simplicity, real-life relevance, and suitability for the High school age group. In administering and scoring the test, positively worded items are scored from 6 (strong agreement) to 1 (strong disagreement), and the reverse is applied for negatively worded items. A total score above 50% indicates intolerance of ambiguity, while a score below 50% suggests tolerance.

To ensure the reliability of the test, Cronbach's Alpha coefficient was calculated using a sample of 10 twelfth-grade students, yielding a statistically significant value of 0.819 at the 0.01 level, indicating strong internal consistency. For validity, the test was reviewed by a panel of experts in educational and cognitive psychology who suggested modifications to item wording and sequence; all recommendations were implemented. Construct validity was further verified through internal consistency, where statistically significant correlations were found between individual item scores and the total test score. This confirmed the test's validity and suitability for use with the main research sample. The estimated average time for completing the test, calculated by measuring the time taken by each participant in a pilot sample, was approximately 20 minutes.

3.2.1 Mathematical Problem-solving test

The Mathematics Problem-Solving Skills Test was developed to assess 12th-grade students' problem-solving abilities in algebra. The test items were constructed based on a list of eight main skills, aligned with George Polya's four-step problem-solving process (understanding the problem, devising a plan, carrying out the plan, and reviewing the solution). The test comprises 32 items related to algebra problems, each requiring students to solve problems following these structured steps. A rubric scoring scale (3-2-1-0) was used to evaluate students' performance on each sub-skill, with a maximum total score of 96 points. Content validity was ensured through expert review of the test items and scoring rubric, resulting in several refinements. Reliability was confirmed by inter-rater agreement using Cooper's formula, applied by trained High school mathematics teachers in Qatar, achieving an agreement rate of 96.25%, indicating high reliability.

Additional psychometric analyses included item difficulty and discrimination indices. Difficulty levels ranged between 0.6 and 0.7, while very easy items exceeded 0.8. Discrimination indices ranged from 0.39 to 0.62, suggesting acceptable discriminatory power. Internal consistency was evaluated by calculating item-total correlation coefficients for a pilot sample of 10 students outside the main research group. These coefficients ranged from 0.730 to 0.854, with the overall internal consistency coefficient reaching 0.909—demonstrating strong coherence among test items. Scoring was based on the rubric, where each sub-skill response received a score between 0 and 3, leading to a total range from 0 to 96. The average time required to complete the test was estimated at 60 minutes, making it practical for classroom use. Overall, the test is both valid and reliable for measuring students' mathematics problem-solving skills.

3.3 Procedures

The preparation for the research experiment involved several key steps. First, necessary approvals were obtained, and the sample of 60 twelfth-grade students was selected and trained to use the Moodle e-learning platform via the provided link. Each student received a username and password, and their ability to navigate the platform was observed. Those who faced difficulties were given special training sessions using both personal computers and the Moodle Classic mobile app. Next, students were categorized based on their cognitive style using Budner's Ambiguity Tolerance test: 30 were identified as ambiguity-tolerant (scores < 48), and 30 as ambiguity-intolerant (scores ≥ 48). Each group was then randomly divided into two subgroups: one learned through temporally spaced (digital interval) learning, and the other through physically spaced learning. Equivalence between the four groups in mathematical problem-solving skills was confirmed using a one-way ANOVA on pre-test scores, ensuring no significant differences before applying the experimental treatment.

After confirming group equivalence, the researchers administered the mathematics problem-solving skills test as a pre-test to all four groups. The experimental treatment was then carried out at Qatar High School in Al-Kheesa, with full cooperation from the school administration and mathematics teachers. The intervention followed the spacing learning strategy, using either electronic or physical intervals based on group assignment. Teachers were briefed on the objectives, procedures, and group structures. During the intervention, students actively engaged in interactive activities during and after each lesson to reinforce skill acquisition. Finally, the post-test was administered using the same math problem-solving test to evaluate the impact of the experimental treatments. The collected scores were analyzed statistically to test the research hypotheses and interpret the outcomes.

4. Results

To answer the RQ, the statistical analysis was conducted to examine the impact of the spaced learning interval type and cognitive style on mathematical problem-solving skills. Table 1. presents the mean scores of the different groups in the post-application of the mathematical problem-solving skills test, along with the standard deviation for each group.

Here is the translation of Table 1. into English, preserving the structure and data:

Table 1.

Means and Standard Deviations of High School Students' Scores in the Post-Test of Mathematical Problem-Solving Skills (Maximum score = 96)

Variable	Spaced Learning Interval Type		Total
Cognitive Style	Electronic	Physical	
Intolerance of Ambiguity	M = 81.47 SD = 2.031 N = 15	M = 70.00 SD = 2.420 N = 15	M = 75.73 SD = 3.231 N = 30
Tolerance of Ambiguity	M = 86.20 SD = 3.342 N = 15	M = 76.93 SD = 2.052 N = 15	M = 81.57 SD = 3.444 N = 30
Total	M = 83.83 SD = 3.630 N = 30	M = 73.47 SD = 3.158 N = 30	M = 78.65 SD = 3.504 N = 60

Table 1. reveals several key findings: students in the electronic spaced learning groups scored higher on average than those in the physical spaced learning groups. Additionally, students with a higher tolerance for ambiguity outperformed those with lower tolerance. The highest average scores were achieved by students who tolerated ambiguity and studied through electronic spaced learning, followed by students who did not tolerate ambiguity but also studied electronically. Next were students who tolerated ambiguity and studied through physical spaced learning, and lastly, students with low ambiguity tolerance who studied using physical spaced learning intervals.

Table 2. provides the necessary data to determine the significance of: (1) the difference in average scores between twelfth-grade students in the electronic spaced learning group and those in the physical spaced learning group in mathematical problem-solving skills; (2) the difference in average scores between students with high ambiguity tolerance and those with low ambiguity tolerance in these skills; and (3) the interaction effect between the type of spaced learning (electronic vs. physical) and cognitive style (ambiguity tolerance vs. intolerance) on the development of mathematical problem-solving skills.

Table 2.

Two-Way ANOVA Analysis of the Effect of Spaced Learning Interval Type and Cognitive Style on the Post-Test of Mathematical Problem-Solving Skills

Source of Variation	Sum of Sruares	df	Mean Square	F	Sig.	Eta^2	Impact
Spaced Learning Pattern (A)	1612.017	1	1612.017	254.242	0	2.25	Large
Learning Style (B)	510.417	1	510.417	80.501	0	1.68	Large
Interaction A*B	28.15	1	28.15	20.863	0.003	1.12	Large
Error	355.067	116	8.34				
Total	2505.65	119					

Table (2) shows that the F-value for the variable *type of spaced learning intervals* is 254.242, which is statistically significant at the 0.05 level. This indicates a significant positive effect of interval type on student performance. Students who learned through electronic spaced intervals scored higher (M = 83.83) than those who learned through physical spaced intervals (M = 73.47). The effect size (Eta squared = 2.25) is large, indicating that electronic intervals had a greater impact on students' mathematical problem-solving skills. Thus, the first hypothesis was rejected.

Similarly, the F-value for the variable *cognitive style* is 80.501, also statistically significant at the 0.05 level. Students with tolerance for ambiguity outperformed those without it (M = 76.93 vs. 70.00), with a large effect size (Eta squared = 1.68). This confirms a positive influence of cognitive style on developing problem-solving skills, leading to the rejection of the second hypothesis.

Lastly, the interaction effect between interval type and cognitive style yielded an F-value of 20.863, which is statistically significant. The effect size (Eta squared = 1.12) is large, indicating that the combination of spaced learning type and cognitive style significantly influenced students' performance, revealing differences among the four experimental groups.

To determine the direction of the differences between the experimental groups, the Scheffé post hoc test was conducted. The results showed that students in the electronic spaced learning group who were ambiguity-tolerant (Group 2) outperformed those in the electronic group who were ambiguity-intolerant (Group 1). Additionally, Group 1 outperformed both the physical spaced learning group of ambiguity-intolerant students (Group 3) and the physical group of ambiguity-tolerant students (Group 4). Furthermore, Group 2 also outperformed both Group 3 and Group 4. Lastly, Group 4 outperformed Group 3. These results indicate that the combination of electronic spaced learning and ambiguity tolerance yielded the highest gains in mathematical problem-solving skills, while physical spaced learning combined with ambiguity intolerance resulted in the lowest performance. This confirms that both the mode of spaced learning and students' cognitive style significantly influence learning outcomes.

5. Discussion

The research demonstrated that students who engaged in electronic spaced learning significantly outperformed those who experienced physical spaced learning. This effectiveness is primarily due to the structured format of spaced learning, which divides content into manageable units with planned breaks. Electronic breaks, unlike physical ones, maintain students' focus by keeping them within the same digital learning environment—crucial when dealing with logically and analytically demanding subjects like mathematics. These digital breaks also provided mental rest and reduced cognitive overload, leading to better comprehension and retention of complex concepts.

Furthermore, electronic breaks were more appealing and engaging to students compared to physical ones. High school learners, being naturally adept with technology, responded positively to interactive educational tools embedded within digital breaks. These breaks not only sustained student interest but also reduced boredom and disrupted routine, which in turn helped students build connections between abstract mathematical ideas and enhanced their problem-solving abilities. The findings align with a range of previous research studies that support the cognitive and motivational benefits of structured digital learning environments.

From a theoretical perspective, the results are well supported by several educational frameworks. Cognitive Load Theory explains how breaking down content and maintaining a stable digital context helps students manage information more efficiently. Retrieval Theory highlights the role of time-spaced intervals in strengthening memory and skill retention. Connectivism underscores the value of continuous interaction with digital content, while Information Processing Theory emphasizes the cognitive advantages of sustained mental engagement during breaks. Altogether, these theories reinforce the importance of well-designed electronic spaced learning strategies in fostering deep understanding and long-term mastery of mathematical problem-solving skills.

The research also, found that students with a high tolerance for ambiguity significantly outperformed those with low tolerance in developing mathematical problem-solving skills. Ambiguity-tolerant students showed a greater willingness to engage with incomplete or unclear information, explore complex concepts, and apply flexible and critical thinking strategies. They demonstrated strong internal motivation, persistence, and enjoyment in tackling cognitively demanding tasks. In contrast, ambiguity-intolerant students preferred direct, familiar solutions, struggled with multi-step or vague problems, and were more likely to feel frustrated and avoid exploration. These differences highlight the need to consider individual cognitive styles when designing educational interventions.

The findings are supported by several educational theories, including Field Theory, Cognitive Dissonance, Piaget's developmental theory, and Ausubel's meaningful learning theory. These theories emphasize that ambiguity-tolerant learners are better equipped to reorganize knowledge, process conflicting information, and build logical, interconnected understanding. Electronic or physical spaced learning activities, when tailored to students' cognitive styles, can enhance engagement, reduce cognitive load, and promote deep, transferable learning. Therefore, incorporating cognitive style awareness into instructional design is essential for effectively supporting diverse learners in mastering complex mathematical skills.

Finally, the research found a statistically significant interaction between the type of spaced learning breaks (electronic or physical) and students' cognitive style (tolerance or intolerance of ambiguity) in developing 12th-grade students' mathematical problem-solving skills. Students with high ambiguity tolerance were more inclined to explore complex and unfamiliar problems, and they benefited from both types of spaced breaks, using them to reflect and connect concepts logically. Meanwhile, students with low ambiguity tolerance, though more comfortable with clear, direct information, also benefited from spaced learning. The structured content and breaks helped reduce their cognitive load and improved their comprehension.

The findings highlight that the effectiveness of spaced learning varies depending on the student's cognitive style. Electronic breaks appeared more stimulating for ambiguity-tolerant students due to their flexibility and rich media content. In contrast, ambiguity-intolerant students found physical breaks more mentally relaxing and easier to manage. This positive interaction between break type and cognitive style supported students' acquisition of complex problem-solving skills by addressing individual learning needs and creating a cognitively supportive environment.

6. Conclusion

This research clearly demonstrated that electronic spaced learning is more effective than physical spaced learning in improving mathematical problem-solving skills among 12th-grade students. The structured nature of spaced learning—dividing content into smaller, digestible units separated by intentional breaks—allowed students to process information more efficiently. Electronic breaks, in particular, maintained continuity within the learning environment and minimized distractions, helping students manage complex mathematical concepts with greater ease and clarity.

Additionally, the research emphasized the importance of students' cognitive styles, especially their tolerance for ambiguity. Students who were more tolerant of ambiguity consistently outperformed their peers, as they were better equipped to deal with uncertain or complex information. These students demonstrated a strong intrinsic motivation, cognitive flexibility, and a deeper engagement with the learning material. In contrast, students with low tolerance for ambiguity often struggled with vague or multi-step problems and preferred clear, direct instructions, showing less willingness to explore unfamiliar concepts.

Crucially, the interaction between the type of spaced learning break and students' cognitive style revealed a statistically significant impact on learning outcomes. Ambiguity-tolerant students benefited from both electronic and physical breaks, using them as opportunities to reflect, analyze, and make connections among mathematical concepts. However, electronic breaks proved more stimulating due to their multimedia elements and interactive nature. On the other hand, ambiguity-intolerant students found physical breaks more relaxing and manageable, helping them re-engage with learning tasks without feeling overwhelmed.

Overall, the findings highlight the importance of aligning instructional strategies with students' cognitive preferences. By integrating electronic spaced learning and considering individual differences in ambiguity tolerance, educators can create adaptive learning environments that enhance engagement, reduce cognitive overload, and promote deeper, more sustainable learning. These insights emphasize the need for personalized educational design informed by cognitive and instructional theories to support all learners in mastering complex mathematical skills.

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