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ORIGINAL ARTICLE

The Influence of Recreational Mathematics on the Development of Mathematical Connections: A Mixed- method Study

Rey M. Sanchez[1], Jobell B. Jajalla, PhD[2]

[1]*Student Researcher-Bachelor of Secondary Education Major in Mathematics at Kapalong College of Agriculture, Sciences, and Technology-Maniki, Kapalong, Davao del Norte, Philippines*
[2]*Instructor II, Institute of Teacher Education, Kapalong College of Agriculture, Sciences and Technology-Maniki, Kapalong Davao del Norte, Philippines*

Corresponding Author's Email: reys00554@gmail.com

ABSTRACT

This study explored the influence of recreational mathematics on the development of mathematical connections among first-year students enrolled in the teacher education program at a local college in Davao del Norte. Utilizing a mixed-methods approach with a convergent parallel design, the research involved 117 students randomly selected for the quantitative phase and 14 purposively selected participants for the qualitative phase—seven for in-depth interviews and seven for focused group discussions. Quantitative data were gathered through validated Likert-scale survey questionnaires, while qualitative insights were derived from transcribed and thematically analyzed interviews. The results showed a high level of influence of recreational mathematics on students' mathematical connection development. Furthermore, thematic analysis of qualitative data revealed that recreational mathematics created a positive learning environment that fostered deeper conceptual understanding. The integration of both data sources confirmed that the use of recreational mathematics enhances students' ability to form meaningful mathematical connections. These findings suggest the need for curriculum designers and mathematics educators to integrate recreational activities to improve student engagement and learning outcomes.

Keywords: *Recreational Mathematics, Mathematical Connections, Problem-Solving, Creativity, Critical Thinking*

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INTRODUCTION

Making mathematical connections plays an important role in assisting students to have a greater understanding of concepts and their application to real life. Students who can look at the relations between ideas in math will reason and find solutions better. Not only does this reinforce their learning but it also brings math to life. This notwithstanding, several students, mainly those in elementary school, struggle to relate concepts across subjects and this may cause confusion, as well as discontinuities in meaning (National Council of Teachers of Mathematics, 2024).

In global perspective, particularly in Indonesia many elementary students find it difficult to relate the new information on math with what they already know and thus, cause confusion and errors to arise particularly when faced with novel or real-life problems. This cripples their capacity to select and apply the proper strategies. There are instructional strategies that can be used to enhance such relationships but they are not always used in classrooms (Putri & Wutsqa, 2019). Likewise, in the San Francisco Campus of Cebu Technological University, learners tend to excel in their learning at the lower level of math but not so at the higher level of thinking, indicating that the problem also extends to college students (Guinocor et al., 2020).

Recreational mathematics and mathematical connections have been investigated with reference to enhancing the learning among students in several studies. Nevertheless, they tended to dwell on historical practices, restricted target groups of students or broad ideas rather than providing and discussing exact strategies such as recreational math (Zelbo, 2019; Haerudin et al., 2021). The given study fills this gap because it considers the mechanism with which recreational mathematics can be assimilated in order to enable college students to develop stronger mathematical associations, lower any anxieties, and, finally, make learning be enjoyable.

Research Questions

1. What is the effectiveness of recreational mathematics in fostering development of mathematical connections among students enrolled in board program courses?
2. What are the lived experiences of students enrolled in board program courses concerning recreational mathematics and the development of mathematical connections?
3. To what extent does the quantitative data corroborate with the qualitative data?

METHODS

Study Design

The researcher applies the convergent parallel method of the mixed method research in this research. This incorporates the quantitative and the qualitative. It is convergent parallel since the process of data collection, as well as the analysis of the quantitative and qualitative methods is happening concurrently. The findings in every approach are then compared to deepen the knowledge on the subject. This method can help in dealing with the shortfall of one of the available methods that the strengths of the other will facilitate and will enable quantitative data to enrich the quantitative data (Creswell, 2003).

The descriptive approach will be used to describe the participants in a proper manner. It describes the features of an undergoing investigation of a population or a phenomenon. The characteristics that are employed to explain the situation or population normally belong to certain groups and these categories are called descriptive categories.

Population and Sample

This study specifically examined the influence of recreational mathematics on the development of mathematical connections at Kapalong College of Agriculture, Sciences, and Technology. The participants were required to be enrolled in the board program courses in the first semester of the 2024–2025 academic year, ensuring that all students, regardless of their enrollment status (regular, irregular, or on probation), were included. This approach aimed to gather a diverse range of perspectives and experiences to enhance our understanding of the phenomenon under investigation.

In the quantitative phase of the study, 117 first-year students from the Institute of Teachers' Education (ITED) participated, selected through stratified random sampling based on Milroy and Gordon's (2008) method. These participants, drawn from BEED, Mathematics, English, and Filipino programs, provided valuable insights into their experiences, practices, and challenges related to recreational mathematics. To avoid bias, those who answered the survey were not included in the qualitative interview phase. The total teacher education population was 167 students, and the final sample includes 24 BEED, 29 Mathematics, 54 English, and 10 Filipino students. This approach ensured balanced representation across programs while focusing on how recreational math supports students' development of mathematical connections.

Furthermore, the study used stratified random sampling to ensure both randomness and accuracy by dividing the population into subgroups and randomly selecting participants from each, ensuring all segments were represented (Nguyen et al., 2021). This method suited the study well as it included a diverse range of voices from first-year Teacher Education students at KCAST during the first semester of 2024–2025. Students—whether regular, irregular, or on probation—had equal chances to participate, allowing the research to gather meaningful insights on how recreational mathematics influences mathematical connections. By capturing varied student experiences, the study offered relevant findings for the field of education.

In the qualitative phase, seven students were selected for a focus group discussion and were assigned codes FGD-1 to FGD-7 (Participants 8–14), while seven were selected for in-depth interviews IDI-1 to IDI-7 (Participants 1–7). These students identified for their potential to offer insights that would address the research questions and enhance understanding of the topic. As in the quantitative phase, the selection of participants was guided by research questions, relevant theories, and supporting evidence (Sergeant, 2012).

In contrast, qualitative research typically involves purposeful subject selection. For this phase, a non-probability sampling method, specifically purposive sampling, was used. Participants were chosen based on their ability to provide valuable insights that would inform the research questions and deepen the understanding of the phenomenon under study (Kuper et al., 2008). A total of 14 students participated in this phase: seven (7) were selected for in-depth interviews, and the remaining seven (7) were chosen for the focus group discussion. All participants were required to be the first year of first semester of the 2024–2025.

The sample size was considered adequate to achieve thematic saturation, as participants were chosen based on predefined criteria directly relevant to the study's objectives. All participants were first-year students from the Institute of Teachers' Education (ITED), ensuring a focused yet diverse set of perspectives. The division between focus group and interview participants helped to capture a range of experiences and opinions. In qualitative research, small, carefully selected samples are widely accepted when the group is relatively homogeneous and the research goals are clearly articulated. This approach supports the depth and richness of the data while ensuring that key themes are adequately explored and represented.

Instrumentation

Two survey questionnaires were adapted by the researcher to collect data from the participants in the quantitative phase. The first survey gathered information on recreational mathematics, focusing on three components: problem-solving skills, creativity skills and critical thinking skills. The second survey focused on mathematical connection, covering four areas: different representation, part-whole relationship, connections between mathematical concepts and interrelationship between mathematical procedures. Participants rated their answers on a scale from 1 to 5, where 1 meant "never" and 5 meant "always", with the full scale defined as follows: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, and 5 = Always. Moreover, Likert Scale was good for measuring constructs, attitudes and stimuli which are not readily perceivable by human senses. Despite the questionnaire being adapted, it was subjected to expert validation. Additionally, Cronbach's Alpha was employed, with values ranging from .70 to .80, indicating that the surveys had acceptable reliability.

In the qualitative phase, the researcher developed a set of open-ended grand tour questions, which were reviewed and validated by a panel of experts. These questions were crafted based on the findings from the survey and served as a guide for the in-depth interviews (IDIs). Out of the participants who completed the survey in the previous phase, seven individuals will be purposively selected for the IDIs, and another seven for the focus group discussion (FGD). Interviews were chosen as the method for gathering insights, personal stories, experiences, opinions, and other valuable information that could not be captured through quantitative data alone.

To derive the qualitative themes, the researcher employed a thematic analysis approach following a series of group discussions and interviews. Audio recordings were transcribed verbatim, and interview notes were compiled to capture both verbal and non-verbal data. Thematic analysis was conducted manually by systematically coding the transcribed texts, identifying recurring patterns, and grouping similar codes to generate initial themes. To ensure the reliability of the findings, a peer coder independently reviewed a portion of the data; discrepancies in coding were discussed and resolved collaboratively, enhancing intercoder reliability. The final themes were grounded in the collected data and supported by the qualitative outputs, including interview questions, transcripts, coded texts, and thematic summaries.

Data Analysis

In analyzing the quantitative data, the researcher used descriptive statistics to summarize participants' responses. The mean determined the average response, while the standard deviation measured the variability in responses. This approach revealed both general trends and differences in opinions. Inferential statistics further showed a very strong positive correlation ($r = 0.934$) between recreational mathematics and the development of mathematical connections. The relationship was statistically significant ($p < .001$), indicating a very low probability that the result occurred by chance.

Additionally, Cohen's d was calculated at 5.18, indicating a very large effect size, which confirms that the influence of recreational mathematics on students' ability to form mathematical connections is both statistically and practically significant.

In the qualitative data analysis, participant responses were transcribed and organized before being categorized into themes through coding and grouping similar ideas and the results were presented in tables. The researcher closely examined the detailed responses, using coding to structure the data and identify patterns. The goal is to create themes that capture the experiences of the participants, specifically the students from different program of Institute of Teachers' Education (ITED) of Kapalong College of Agriculture, Sciences and Technology. This analysis is iterative, involving continuous review of the data to refine and develop the themes.

RESULTS

Shown in Table 2 is the response of teacher education students to the influence of recreational mathematics in Kapalong Agriculture of Sciences and Technology. It obtained an overall mean score of 3.63 with a description of high and interpreted as oftentimes manifested. This means that the teacher education students often show the effects of recreational mathematics through their learning behavior and performance.

Among the three indicators, Creativity Skills obtained the highest mean score (3.65), closely followed by Problem-Solving Skills and Critical Thinking Skills, both with a mean of 3.61. While all three indicators fall within the "High" descriptive category, suggesting that recreational mathematics fosters essential cognitive competencies, the results also highlight subtle distinctions in students' strengths. Learners exhibited imaginative and flexible thinking, alongside the consistent use of logical reasoning and analytical decision-making. Although the overall findings are favorable, the comparatively lower scores in problem-solving and critical thinking indicate areas where instructional interventions may be refined to further strengthen these specific competencies.

According to these results, Anggraeni and Budiharti (2021) also confirmed that recreational mathematics establishes a student-focused atmosphere in which math games and play-based tasks facilitate pleasure and active involvement. Anggraeni (2021) also emphasized the fact that employing recreational math in the classroom is a sure way of increasing student achievements and motivation. All these activities and exercises are meant to make students familiar with mathematical concepts and develop confidence as well as curiosity in them in low-stress conditions. Our results correspond well to those studies—the mean scores of creativities, problem-solving, and critical thinking were high and again depict that the students felt engaged, motivated, and confident when they learn math in interesting and playful manners. This can be further explained through Csikszentmihalyi's Flow Theory, which suggests that students are more likely to reach a state of deep engagement and intrinsic motivation when they are presented with tasks that balance challenge and skill—an effect often triggered by recreational mathematics. This implies that recreational mathematics facilitates meaningful worthwhile matrices of learning experiences tremendously successfully.

Table 2. Influence of Recreational Mathematics

Variables and indicators	Mean	Description
A. ***Problem-Solving Skills***		
1. **Breaking down complex mathematical problems into manageable steps.**	3.79	High
2. **Persisting in finding a solution, even when faced with difficulties.**	3.59	High
3. **Feeling comfortable using various strategies to approach mathematical challenges.**	3.59	High
4. **Finding solutions to problems I have not encountered before.**	3.56	High
5. **Enjoys solving mathematical puzzles and problems just for fun.**	3.54	High
Category Mean	**3.61**	**High**
B. ***Creativity Skills***		
1. **Thinking of unique ways to approach mathematical problems.**	3.68	High
2. **Enjoys creating new math games or challenges.**	3.53	High
3. **Feeling that recreational mathematics enhances my ability to think creatively.**	3.79	High
4. **Exploring different methods to solve the same mathematical problem.**	3.62	High
5. **Enjoys brainstorming multiple solutions to mathematical challenges.**	3.62	High
Category Mean	**3.65**	**High**
C. ***Critical Thinking Skills***		
1. **Evaluating the reasoning behind different mathematical solutions.**	3.62	High
2. **Identifying assumptions in mathematical arguments.**	3.53	High
3. **Enjoys discussing the logical steps involved in solving math problems.**	3.61	High
4. **Assessing the strengths and weaknesses of various problem-solving approaches.**	3.59	High
5. **Reflecting on my thought process after solving a mathematical problem.**	3.73	High
Category Mean	**3.61**	**High**
Overall Mean	**3.63**	**High**

Mathematical Connections

Shown in Table 3 is the status of development of mathematical connections among teacher education students in Kapalong College of Agriculture, Sciences and Technology. It obtained an overall mean score of 3.70 with a description of high and interpreted as oftentimes manifested. This means teacher education students often demonstrated well-developed mathematical connections in their learning experiences.

Interrelationship Between Mathematical Procedures (M = 3.73, *High*) yielded the highest mean among the four indicators, indicating that students can associate and apply various procedures when solving problems. Different Representation followed closely (M = 3.72, *High*), reflecting students' frequent use of graphs, tables, and equations—demonstrating their adaptability in approaching mathematical tasks. Part-Whole Relationship (M = 3.68, *High*) suggests students recognize how smaller concepts contribute to a broader understanding, while Connections Between Mathematical Concepts (M = 3.66, *High*) indicates their ability to link and integrate different mathematical ideas. Overall, the results show students' strong capacity to make meaningful connections across mathematical content and processes.

Table 3. Mathematical Connections

Variables and Indicators	Mean	Description
A. ***Different Representation***		
1. Finding it helpful to use various representations when solving mathematical problems.	3.91	High
2. Switching between different representations of mathematical concepts to deepen my understanding.	3.64	High
3. Believing that using visual aids enhances my problem-solving abilities in mathematics.	4.02	High
4. Feeling confident in translating between different mathematical representations.	3.44	High
5. Enjoys exploring how different representations can convey the same mathematical idea.	3.61	High
Category Mean	**3.72**	**High**
B. ***Part-Whole Relationship***		
1. Understanding how parts of a mathematical problem relate to the whole concept.	3.63	High
2. Breaking down complex problems into smaller parts to better understand them.	3.68	High
3. Finding it easy to identify how changes in one part of a problem affect the overall solution.	3.60	High
4. Believing that recognizing part-whole relationships improves my mathematical reasoning.	3.79	High
5. Using part-whole thinking when approaching word problems in mathematics.	3.69	High
Category Mean	**3.68**	**High**
C. ***Connections Between Mathematical Concepts***		
1. Seeing clear connections between different mathematical concepts I have learned.	3.62	High

2. Enjoys finding ways to relate new mathematical ideas to previously learned concepts.	3.66	High
3. Believing that understanding the connections between concepts enhances my overall mathematical comprehension.	3.69	High
4. Using my knowledge of one mathematical concept to solve problems in another area.	3.74	High
5. Finding it valuable to discuss different mathematical interrelate.	3.62	High
Category Mean	**3.66**	**High**
D. Interrelationship Between Mathematical Procedures		
1. **Recognizing how different mathematical procedures can be applied to solve the same problem.**	3.82	High
2. Reflecting on the connections between different procedures I use in mathematics.	3.68	High
3. Believing that understanding the interrelationships between procedures makes me a better problem solver.	3.73	High
4. Enjoys exploring multiple methods to arrive at the same mathematical solution.	3.67	High
5. Finding it helpful to compare different mathematical procedures when solving complex problems.	3.77	High
Category Mean	**3.73**	**High**
Overall Mean	**3.70**	**High**

The results correspond with Mohammad and Faris (2021) who demonstrated that mathematical relationships are not only theoretical and are highly associated with practical thinking. In their research, they discovered that students who had a high capacity of mathematical connection skills also had an increased capacity in terms of strategic intelligence which enables them to think more clearly and be able to solve their problems. Similarly, this research study exposed the fact that learners that had the ability to connect mathematical concepts had excellent problem-solving skill. This implies that the process of building mathematics ties does not only increase the depth of study but also assists in further ameliorating general mental capacity. This led to high rate of mathematical connection as exhibited by the students in this study.

Lived Experiences of Students Relative to Recreational Mathematics and Mathematical Connections

Qualitative research involving focus group discussions and in-depth interviews was used to tabulate the data and the results showed four major themes that were gathered as per the experiences that the students had lived in relation to recreational mathematics. Prior to treating these themes, Table 4 gives the profiles of the purposively sampled respondents the participants; all first-year students at KCAST; but pursuing the teacher education program, broken down by sex and program. The responses to the first research question provided these five themes that were about the experience and understanding of recreational math by students in their academic lives.

The first theme was the idea that enrolment in a board program courses in the field of education also gives students exposure towards recreational mathematics. Puzzles and games were perceived as fun and useful means of increasing learning interaction, developing more insightful knowledge, and influencing how the students plan to approach creative teaching. This is in favor of Dweck Growth Mindset, which presupposes that ability is to be achieved through utilizing strategies and effort; recreational math promoted perseverance, intellectual reasoning, and an optimistic attitude toward progress. Equally, Alqahtani and Powell (2021) revealed that in the logic puzzles and interactive games, pre-service teachers took part in, an increase in problem-solving abilities and confidence in use of creative pedagogy were attained. Such activities facilitated the building of a growth mindset and the ability to withstand in learners.

Table 4. Lived Experiences of Students Relative to Recreational Mathematics and Mathematical Connections

Issues Probed	Core Ideas	Code/ Categories	Essential Themes	Theoretical Support
Increased Engagement and Reduced Anxiety in Mathematics	• Stimulating interest in logic. • Improving problem-solving skills by having recreational activities. • Boosting confidence and engagement through recreational mathematics. • Having the boosts in motivation and enthusiasm for learning through recreations.	Having Enjoyment while Learning	Experiencing the Benefits of Recreational Mathematics' Activities	Resilience Theory and Growth Mindset (Dweck,2000s)
	• Overcoming difficulty and found enjoyment in the process. • Having frustration in math leads to learning and growth. • Facing challenges positively lead to perseverance and rewarding solutions. • Struggling in math	Overcoming Frustrations into Motivation		

	• but being persistent to learn. • Making the frustration felt as fuel for persistence in solving problems.			
Used of Unique Recreational Activities for Mathematica	• Using activities such as Rubik's cube and kenken puzzle which enhance cognitive skills • Having logic puzzles, sudoku and riddles to develop critical thinking and creativity. • Dealing more with puzzle games which can enhance the memory and techniques in problem solving.	Making Use of Puzzles and Patterns for Mathematical Experience	Having an Overall Enriching Experience in Mathematical Instruction	Experiential Learning Theory (Kolb,1984)
	• Integrating games such as Rubik's cube to enhance techniques in solving problems. • Having Rubik's cube as one of the instructional activities to develop critical thinking. • Using Rubik's cube is challenging yet encourages deep remembering of patterns.	Utilizing Recreational Activities for Critical Thinking		
Varied Difficulties in Engaging with Recreational Mathematics	• Having difficulty in solving patterns with large numbers like in kenken puzzle. • Struggling with the combination of different	Battling with Difficult Mathematical		

	operations in order to solve the puzzle.	Patterns		
	• Dealing with complex puzzles with unclear explanations. • Dealing with problem solving without having the knowledge on how to finish the solutions.		Facing Learning Hindrances in Mathematical Activities	Metacognition (Flavell,1979)
	• Experiencing exhaustion for doing trial and error in solving. • Facing frustrations in wasting time having long method in solving.	Having Negative Thoughts with Mathematical Problems		
Shaping Mathematical Understanding through Recreational Activities	• Using teamwork for challenges in math lead to enjoyment and enlightenment. • Revealing math as strategy in improving patience. • Having real-world patterns in math revealed its presence everywhere.	Dealing on Recreational Mathematics' Real-Life Implications	Relating Mathematical Concepts in Real-Life Context	Situated Learning Theory (Lave & Wenger,1991)
	• Dealing with math is challenging but relevant to all aspects of life. • Thinking that math is fun and creative which made challenges easier to face. • Helping to improve memory and problem-solving skills. • Enhancing mathematical	Making Real-Life Connection of Math Concepts		

	skills especially in math majors.	

The second theme highlighted how students felt enriched by their participation in the board program courses, particularly in developing mathematical knowledge and teaching skills. Through recreational math, they practiced designing interactive and meaningful lessons that bolstered their confidence and positive attitudes toward teaching mathematics. This aligns with Kolb’s Experiential Learning Theory, which underscores learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation. Supporting this perspective, Olawale (2024) investigated pre-service mathematics teachers within a teacher education program and found that hands-on, experiential components of their training significantly deepened subject knowledge, enhanced teaching practices, and increased classroom confidence—though some challenges remained in implementing differentiated instruction.

The third theme considered how the educational program supported students in overcoming challenges in mathematics. Participants noted that recreated math activities and peer cooperation helped them manage confusion, fear of misunderstanding content, and the threat of failure. This reflects Flavell’s Metacognition Theory, which highlights the importance of monitoring and controlling one's own thinking process. Students developed self- regulation and resilience through reflective and structured efforts. In support of this, Çini et al. (2023) demonstrated that higher levels of metacognitive awareness—at individual, social, and environmental levels—enhanced performance in collaborative problem- solving tasks by enabling strategic regulation and mutual monitoring among group members. Complementing that, Kusaka (2025) found that during mathematics collaborative problem- solving, learners who actively engaged in metacognitive planning, monitoring, and evaluation managed cognitive load more effectively and solved complex tasks with greater confidence.

Finally, the fourth theme focused on the way students had learned to make connections between mathematical expressions and objective cases in real life, including budgeting, measuring and practical problem solving. This connection was promoted by the board program courses and its practice and fun-related ideas with math activities that allow students to recognize the applicability of math outside school. This conforms to the Situated Learning Theory by Lave and Wenger which assumes that learning is most appropriate when connected to real-life settings. It has also been discovered that context-based math instruction enhanced pupil motivation and capacity to apply math to real life, reinforcing engagement and conceptual ideations with the same (Andres and Villanueva, 2021).

In conclusion, these themes show that recreational mathematics, when embedded in a well-designed teacher education program, not only enriches students' mathematical understanding but also prepares them to become confident, reflective, and innovative future educators.

Insights of Students on Recreational Mathematics Enhancing Mathematical Connections

The results of the interviewees concerning their views on math relationships can be observed in Table 5. The identification of three critical themes resulted in three key themes based on in-depth interviews and focus group discussions and are tabulated in specific codes that bring out important issues brought out by students. The themes show how mathematical recreations can be a useful aid to teaching students to think more clearly about the ideas of math and to make connections between ideas and to apply the knowledge in the real world via the use of stimulating and relevant concepts.

The first theme showed that alternative strategies and creative learning are encouraged through participation in the board course program in education. Students reported that they learned beyond conventional methods by engaging with games and puzzles, enhancing both communication and comprehension. These findings align with Bruner and Piaget's Constructivist Theory, which emphasizes active exploration and social interaction as key to knowledge building. Similarly, Wang, Huang, and Han (2024) found that an online, constructivist-guided peer- assessment approach significantly increased students' creative self- efficacy, critical thinking tendencies, and learning performance in maker- based activities. Furthermore, Fontes et al. (2024) distinguished that puzzle- based learning activities promote deeper thinking and link abstract mathematical concepts to real- life contexts, fostering both creativity and conceptual understanding.

Table 5. Insights of Students on Recreational Mathematics Enhancing Mathematical Connections

Issues Probed	Core Ideas	Code/Categories	Essential Themes	Theoretical Support
Introduction to New Mathematical Strategies and Techniques	• Having recreational math encourages creative thinking and deeper understanding. • Using recreational math improves creative and strategic problem-solving. • Deepening understanding of geometry and real-life measurements.	Using the Thinking Outside the Box	Allowing the Use of Alternative Strategies and Creative Approaches	Constructivist Theory (Bruner & Piaget,1960)
	• Interactive activities deepen understanding of math concepts. • Hands-on activities enhance understanding of math concepts. • Learned to simplify	Utilizing Hand-On Activities to Problem Solving		

	problems and think creatively.			
Increased Understanding and Real-World Applications	• Building perseverance and self-belief through recreational mathematics. • Having challenges as opportunities for self-development and mathematical connections. • Improving the critical thinking through recreational math challenges. • Encouraging playful learning, social interaction, and collaboration. • Developing patience and critical thinking solving real-life problems. • Allowing pressure-free exploration and easier understanding of mathematical concepts. • Building perseverance and resilience in facing real-world challenges. • Enhancing patience,	Having the Pros of Recreational Activities towards Mathematical Connections Reducing Performance Pressure through Real-Life Applications	Valuing the Benefits of Recreational Activities with Mathematical Connections	Affective Filter Hypothesis (Krashen,1986)

	creativity, and problem-solving strategies.			
Enhancement of Instructional Approaches with Differentiated Activities	• Enhancing problem-solving and various skills through different recreational activities. • Maximizing mathematical understanding and problem-solving skills through games, puzzles and projects. • Strengthening problem-solving through diverse instructional approaches. • Focusing with basic concepts to establish mathematical connections. • Relating mathematical concepts to real-world problems to encourage creativity. • Placing in instruction with enjoyment while students are learning.	Revising Curriculum with Mathematical Activities Establishing Foundation in Mathematical Concepts	Maximizing the Integration of Differentiated Activities with Basic Concepts among Stakeholders	Critical Thinking Theory (Paul & Elder, 2001)

The second theme highlighted that students had a positive experience participating in recreational math activities, perceiving games and puzzles as instrumental in reducing anxiety and boosting motivation through exposure to the board program. This aligns with Krashen's Affective Filter Hypothesis, which emphasizes that emotional comfort and reduced affective barriers facilitate the absorption of new information. Supporting this, Saccardo et al. (2024) examined the impact of positive emotions and the use of interactive tangible tools in primary mathematics learning. They found that when children experienced positive emotional states—especially when engaging with tangible activity-based tools—task performance in symbolic number comparison improved significantly. Their results suggest that creating emotionally supportive and interactive learning environments enhances engagement and conceptual understanding in math

Finally, the third theme highlighted the necessity of incorporating differentiated activities alongside foundational mathematical concepts to accommodate diverse student needs. Participants explained that the board course program equipped them with strategies to adapt instruction to different learning styles, fostering a more inclusive and effective mathematics environment. This aligns with Paul and Elder's Critical Thinking Theory (2001), which asserts that analyzing and evaluating information enhances learners' decision-making skills. Consistently, Salazar and Gumanoy (2025) found that differentiated learning activities—such as learning centers and flexible grouping—increased students' motivation, engagement, and involvement in mathematics tasks significantly more than traditional methods. Similarly, Vacalares et. al. (2024) reported that differentiated instructional practices in mathematics had a significant positive correlation with students' academic performance, improved comprehension, and heightened engagement by addressing individual readiness levels, interests, and learning preferences.

Data Integration of the Salient Quantitative and Qualitative Findings

The proposed study investigates the contribution of recreational mathematics towards building mathematical relationships among Education students of a local college via a mixed methods study, that is, convergent parallel research approach. The third research question is aimed at comparing and validating the outcomes of both the qualitative and quantitative phases. The most important findings in both sets of data are summarized in Table 6: the first column shows the key areas of focus to be identified, the second and third ones show the quantitative and qualitative findings respectively. Quantitative findings present indicators that had the highest means whereas qualitative responses either confirm or oppose these. The fourth column gives the method of integrating the values in the data sets and the fifth column gives the data or the implications of the combined results.

The quantitative data in problem- solving skills within recreational mathematics showed a high mean score, indicating that students felt confident decomposing complex problems into smaller steps. Qualitative feedback supported this, describing how leisure activities enabled students to simplify problems and "think with their hands." These reproducible findings represent a merging- integration. In line with this, Yıldız and Şimşek (2022) demonstrated that students who engaged in educational game- integrated cooperative learning applications significantly improved their problem- solving strategies, academic achievement, motivation, and retention compared to traditional methods. The study emphasized constructivist-based interactive group learning, giving learners opportunities to experiment with different approaches and gain deeper conceptual understanding—leading to greater independence in tackling higher- order problems.

In a similar vein, Liu, Zhang, Lin, Jia, and Peng (2025) explored the impact of adaptive, Socratic-style, and guided feedback on students' mathematical problem- solving behaviors in digital learning environments. Their personalized conversational tutoring system—called PACE (Personalized Conversational tutoring agent)—models individual students' learning styles using the Felder–Silverman framework and delivers tailored Socratic prompts and illustrative breakdowns to guide learners through problem deconstruction. This directive feedback approach promoted deeper cognitive engagement and demonstrated how formal scaffolding enhances mathematical reasoning and solution processes in online settings.

The quantitative findings showed that students believed recreational mathematics improved their creative thinking. This aligned with qualitative insights, where learners described “thinking outside the box” and deeper conceptual understanding—demonstrating a linking-combining convergence that underscores the value of creativity in mathematical exploration. Supporting this, Bayore and Cajandig (2025) investigated instructional strategies in Grade 7 mathematics classrooms and found that activities like logic puzzles, Math Olympics, and inquiry-based tasks significantly fostered students’ creative thinking and critical reasoning, particularly when teachers used interactive, student-centered approaches.

Regarding the area of critical thinking skills, the quantitative data revealed that students liked using several solutions to solve mathematical problems. This reflects a strong self-reported inclination toward flexible thinking and multi-step reasoning, as indicated by the high mean score in the quantitative results. Qualitative responses, however, indicated a bit of difficulty associated with combining operations in solving puzzles, a diverging-connecting trend. This contradiction between quantitative enthusiasm and qualitative struggle suggests that while students value critical thinking and aspire to engage in it, they may lack the deeper procedural fluency or strategic planning needed to confidently execute such tasks in practice. This implies that students are receptive to critical thinking, but they continue to experience barriers in implementing the skills.

This aligns with findings from Noviyanti, Wiryanto, and Mariana (2025), who emphasized the importance of differentiated instruction in enhancing students’ critical thinking. Their systematic review found that when learning experiences are matched to student readiness, interests, and learning styles, learners become more engaged in higher-order reasoning. However, the authors also highlighted the necessity of scaffolding for those who struggle with complex tasks—ensuring that all learners are supported in achieving deep comprehension. This reinforces the *connecting-diverging* trend in Table 5: alignment with learning styles boosts engagement (connection), but foundational skill gaps hinder full application (divergence).

Table 6. Joint Display of Salient Quantitative and Qualitative Findings

ASPECT OR FOCAL POINT	QUANTITATIVE FINDINGS	QUALITATIVE FINDINGS	NATURE OF DATA INTEGRATION	AXIOLOGICAL IMPLICATIONS
Recreational Mathematics	On the Table 2.1 under the indicator of problem-solving skills with an overall mean of 3.61 specifically in item number 1 - *breakdown complex mathematical problems into manageable steps* (3.79; High).	In the Table 4.2, with the essential theme - *Allowing the Use of Alternative Strategies and Creative Approaches* under the code of *Utilizing Hands-On Activities to Problem Solving*	Connecting-Merging	The high rating for problem-solving skills indicated that students highly value the recreational mathematics activities as an effective teaching strategy for enhancing students creative and strategic way in solving problem in a simpler way as well

		specifically in the core idea 3 – *learned to simplify problems and think creatively*.		as in a step-by-step manner towards fostering positive mathematical connections.
	On the Table 2.1 under the indicator of creativity skills with an overall mean of 3.65 specifically in item number 3 - *feel that recreational mathematics enhances my ability to think creatively* (3.79; High).	In the Table 4.2, with the essential theme – *Allowing the Use of Alternative Strategies and Creative Approaches* under the code of *Using the Thinking Outside the Box* specifically in the core idea 1 - *having recreational math encourages creative thinking and deeper understanding.*	Connecting-Merging	The high-rating for creativity skills indicated that students positively viewed recreational mathematics as beneficial in enhancing their way of thinking creatively in different mathematical concepts and contexts.
	On the Table 2.1 under the indicator of critical thinking skills with an overall mean of 3.61 specifically in item number 6 – *enjoy brainstorming multiple solutions to mathematical challenges* (3.73; High).	In the Table 4.1, with the essential theme – *Facing Learning Hindrances in Mathematical Activities* under the code of *Battling with Difficult Mathematical Patterns* specifically in the core idea 3 – *struggling with the combination of different operations in order to solve the puzzle.*	Connecting-Diverging	The high rating for critical thinking skills in quantitative data indicated that students are making use of multiple problem-solving process for difficult mathematical concepts. However, the responses of the students contradicted the high rating since it was being shared that they still struggled to solve puzzles and other board games through the use of different mathematical operations.
Mathematical	On the Table 2.2 under the	In the Table 4.2, with the	Connecting-Merging	The high rating for different

Connections	indicator of different representation with an overall mean of 3.72 specifically in item number 3 - *believe that using visual aids enhances my problem-solving abilities in mathematics* (4.02; High).	essential theme – *Maximizing the Integration of Differentiated Activities with Basic Concepts among Stakeholders* under the code of *Revising Curriculum with Mathematical Activities* specifically in the core idea 3 - *strengthening problem-solving through diverse instructional approaches*.		representation indicated that students problem-solving skills believed to be enhanced through the maximization and integration of varied instructional approaches. One of these approaches is the utilization of visual aids in relation to the concepts of mathematics. .
	On the Table 2.2 under the indicator of part-whole relationship with an overall mean of 3.68 specifically in item number 2 – *believe that recognizing part-whole relationships improves my mathematical reasoning* (3.79; High).	In the Table 4.2, with the essential theme - *Allowing the Use of Alternative Strategies and Creative Approaches* under the code of *Utilizing Hands-On Activities to Problem Solving* specifically in the core idea 3 – *learned to simplify problems and think creatively*.	Connecting-Merging	The high rating for part-whole relationship indicated that students understand best in hands-on activities to problem-solving when simplifying complex problems and breaking it into manageable parts for effective mathematical reasoning and learning.
	On the Table 2.2 under the indicator of connections between mathematical concepts with an overall mean of 3.66 specifically in item number 4 - *use my knowledge of one mathematical concept to solve*	In the Table 4.2, with the essential theme - Relating *Mathematical Concepts in Real-Life Context* under the code of *Making Real-Life Connections of Math Concepts* specifically in the core idea 3	Connecting-Merging	The high rating for connections between mathematical concepts indicated that students recognize the significance of mathematical knowledge and its connection to the different aspects or areas in real-life context while fostering the

	problems in another area (3.74; High).	*– dealing with math is challenging but relevant to all aspects of life.*		experiences and use it to solve essential problems.
	On the Table 2.2 under the indicator of interrelationship between mathematical procedures with an overall mean of 3.73 specifically in item number 1 - *recognize how different mathematical procedures can be applied to solve the same problem* (3.82; High).	In the Table 4.2, with the essential theme - *Relating Mathematical Concepts in Real-Life Context* under the code of *Dealing on Recreational Mathematics Real-Life Implications* specifically in the core idea 3 - *having real-world patterns in math revealed its presence everywhere.*	Connecting-Merging	The high rating for interrelationship between mathematical procedures indicated that students acknowledge the importance of mathematics and its corresponding procedures knowing that it can be used in real-life scenarios as related to the concepts present everywhere.

In relation to the part–whole relationship, students recognized its central role in mathematical reasoning. Qualitative responses confirmed that practical exercises enabled them to deconstruct challenging tasks by understanding how parts relate to the whole—a linking- fusion integration. This aligns with the findings of Çibukçiu (2025), who reported that third-graders taught through constructivist methods showed significant gains in mathematical problem-solving by actively exploring how components connect within problems. Complementing this, Mukuka and Alex (2024) investigated cooperative learning using the STAD model among Grade 11 students and found that collaborative problem-solving activities significantly strengthened students' mathematical reasoning and conceptual understanding—especially when learning tasks emphasized relationships among parts and wholes. Together these studies reinforce the view that constructivist, cooperative, and game- based interventions help learners grasp the structure of problems by appreciating how individual parts contribute to overall mathematical sense making.

Similarly, active learning approaches—particularly those centered on exploration and peer-to-peer collaboration—have been shown to significantly enhance students' understanding of part–whole relationships. Vale and Barbosa (2023) studied the use of active learning strategies in primary mathematics, including paper folding, gallery walks, and math trails. They found that collaborative tasks helped learners engage in reasoning about decomposition and problem structure, supporting more ambitious, step-wise problem solving in complex contexts. Students working together constructed meaning about how parts relate to wholes, becoming more confident in analyzing and tackling unfamiliar problems—mirroring the outcomes described in your original summary.

Students rated highly the connection between mathematical concepts, acknowledging that understanding in one area supported problem-solving in another. Qualitative feedback reinforced this, showing how participants perceived real-life relevance of mathematics—demonstrating a connecting- merging integration between domains. This aligns with findings from Noviyanti, Wiryanto, and Mariana (2025), who found that differentiated and individualized instructional strategies significantly enhanced students' ability to transfer knowledge flexibly across contexts. Their systematic review showed that when tasks are tailored to student readiness, interests, and learning styles, learners more readily apply mathematical concepts to varied, unrelated situations—supporting better cognitive transfer and adaptive reasoning.

In the same way, differentiated and targeted instructional interventions have been shown to help students make stronger connections across mathematical domains. A recent action research study by Insorio and Librada (2025) revealed that when differentiated instruction—using varied content, process, and product strategies—was implemented in mathematics classes, learners were better able to identify patterns and correlations among concepts. As a result, their logical reasoning and problem-solving abilities improved appreciably.

On the indicator of the interrelationship between mathematical procedures, the mean on the quantitative was high, with students attesting that several processes exist to solve the same problem. This was backed by qualitative responses, with students expressing their thoughts on identifying math patterns in everyday lives, which manifested connecting–merging integration. According to Mavrikis, Holmes, & Noss (2022), offering students feedback in various forms—such as Socratic questioning, guided cues, and procedural support—together with differentiating tasks, enables them to learn multiple strategies and select appropriate methods for improved fidelity in mathematics instruction.

In the meantime, Pacheco- Velázquez, Rodés, & Salinas- Navarro (2024) demonstrated that embedding mathematical procedures in real- world contexts significantly improves students' understanding and motivation. Their study used interactive game- based simulations (e.g. using the LOST logistics simulator) that placed mathematical tasks in daily life scenarios. They found that learners became more engaged and better able to transfer classroom concepts to real-world situations, motivationally inclined to apply multiple strategies when solving practical problems—thereby deepening conceptual comprehension and procedural flexibility.

CONCLUSION

This research study utilized a convergent parallel mixed research design to explore the associations between student engagement in recreational mathematics and their growth of mathematical connections. Quantitative results indicated a high level of student engagement—especially in problem-solving, creativity, and thinking—and strong mathematical connection skills in the use of representations, identification of relationships, and combination of concepts. These two constructs were found to be positively and significantly correlated, meaning that recreational activities involving math motivate students to better understand how to relate mathematical concepts to various contexts.

However, while creativity scored slightly higher (mean = 3.65) than critical thinking (mean = 3.61), this gap, though modest, aligns with prior findings. For example, Kuşcu and Erdoğan (2024) found that pre-service mathematics teachers had above-average creative thinking skills but only slightly lower critical thinking dispositions, with creativity explaining around 23% of the variance in critical thinking. This suggests that recreational mathematics may more readily stimulate divergent and imaginative thinking (creativity) through playful, flexible tasks, while critical thinking—which involves evaluation, synthesis, and combining operations—may require more procedural fluency or instructional scaffolding to reach comparable levels of performance. Therefore, although students show strong engagement and high scores overall, the slightly lower critical thinking mean indicates a potential instructional gap that could be addressed through targeted scaffolding and deeper focus on analytical reasoning.

These findings were supported by qualitative results that pointed toward enhanced learning experiences enriched by games, puzzles, and their real-life relevance among students. Other emergent themes like the adoption of alternative strategies, the importance of differentiated tasks, and difficulties associated with unfamiliar activities provided deeper insight into students lived experiences. This emphasizes the need to design recreational tasks that are varied and responsive to students' levels of readiness and learning styles.

Together, the integration of both data strands confirms that recreational mathematics not only supports mathematical understanding but also builds learner confidence and engagement. These outcomes support the practical inclusion of low-cost, accessible, and varied recreational tasks in instruction. To operationalize these findings, it is recommended that teacher education programs develop curriculum-integrated lesson plans that include recreational mathematics components such as puzzles, math games, and real-world problem scenarios. Additionally, faculty development programs and training workshops should be conducted to equip educators with the necessary pedagogical tools to integrate recreational math effectively into classroom instruction.

Despite these promising outcomes, this study has several limitations. The use of self-reported data may introduce bias, as participants might overestimate or underestimate their actual engagement and skill development. Additionally, the sample was drawn from a single institution, which limits the generalizability of the findings. To address these issues, future research could adopt longitudinal designs to track students' growth over time and include multiple institutions for broader insights.

Finally, while the study focused on teacher education students, the application of recreational mathematics may also benefit learners in other academic tracks or cultural settings. Future studies should investigate how recreational mathematics can be adapted for non-teacher-education students, as well as how cultural context influences students' engagement and interpretation of such tasks. Doing so can inform more inclusive, scalable educational strategies that make mathematics more engaging and meaningful across diverse learning populations.

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