

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH

2026, Vol. 7, No. 4, 1626 – 1636

<http://dx.doi.org/10.11594/ijmaber.07.04.13>

Research Article

A Meta-Analysis of the Impact of Game-Based Approaches on Affective and Psychomotor Learning Outcomes in Mathematics Education: Evidence from the Davao Region, Philippines

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Article history:

Submission 27 January 2026

Revised 30 March 2026

Accepted 23 April 2026

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ABSTRACT

Although there is a growing interest in the implementation of game-based learning within mathematics education due to its promise of promoting affective and psychomotor learning, research has predominantly concentrated on reported cognitive gains. It is therefore essential to explore further the impact of such approaches on learners in order to ensure that all domains of learning are addressed. The current study therefore aims to synthesise findings from within the Davao Region, Philippines, focusing specifically on affective and psychomotor learner outcomes associated with the use of games. An ex post facto meta-analytic design was used to explore the impact of game-based approaches on affective and psychomotor learner outcomes. A comprehensive search strategy was used to identify relevant published and unpublished quasi-experimental studies that had reported effect sizes pertaining to affective and psychomotor learning from a range of educational settings within the region, including higher education institutions and Department of Education repositories. Four studies met the inclusion criteria, with six effect sizes being incorporated into the analyses. Findings from the meta-analyses revealed a large positive effect associated with the use of games for affective learning, with no studies detected which specifically reported on psychomotor learner outcomes. High levels of between-study variance prompted the use of random-effects models, while no publication bias detected assessed through statistical and graphical techniques. The findings from the current study support the use of game-based approaches as a promising pedagogical strategy to enhance affective learner outcomes within mathematics education, supporting constructivist-based theory relating to a holistic approach to teaching and learning. Implications for future research include a need to explore psychomotor learner outcomes within game-based approaches in greater depth,

How to cite:

Evardo Jr., O. J. & Gaylo, D. N. (2026). A Meta-Analysis of the Impact of Game-Based Approaches on Affective and Psychomotor Learning Outcomes in Mathematics Education: Evidence from the Davao Region, Philippines. *International Journal of Multidisciplinary: Applied Business and Education Research*. 7(4), 1626 – 1636. doi: 10.11594/ijmaber.07.04.13

using both quantitative and qualitative research methodologies and in a variety of contexts.

Keywords: *Affective Learning, Educational Games, Learner Engagement, Mathematics Instruction, Meta-analysis, Psychomotor Domain*

Introduction

While the cognitive domain is the most traditionally addressed area in mathematics education, there are two other dimensions which represent important aspects of learning: the affective and the psychomotor domain. The affective domain influences learner's emotional interaction with the mathematical content which deals with students' attitudes, motivation, emotions, values, interests and beliefs towards mathematics. On the other hand, the psychomotor domain is concerned on how learners develop bodily coordination and perform tasks involving fine or gross motor skills. Recent studies point that innovative strategies such as game-based approach (GBA) can enable holistic learning by simultaneously promoting emotional engagement and embodied learning.

GBA offers opportunities to address these identified educational gaps. The game-based approach combines cognitive and psychomotor activities with emotional experiences. Mas et al. (2018) used learning games to engage students in movement-based tasks, while Plass et al. (2013), Ramli et al. (2020), and Chen et al. (2020) showed that math games can promote students' mathematics learning motivation by increasing situational interest and mastery goal orientation. By manipulating elements such as collaboration, competition, challenges, and curiosity, educational games can foster engagement and encourage learning. Interventions of extended duration set within supportive learning environments, and delivered in a developmental stage and culturally appropriate manner, can enhance learners' engagement and investment in learning (Lu et al., 2022; Tsai & Tsai, 2018; Mao et al., 2021). As for outcomes, well-designed math games can not only facilitate learning experiences, but also foster innovation in mathematics instruction, such as by delivering game-based e-books or implementing microworld-based learning environments that help alleviate math anxiety and enhance students' self-efficacy to attain long-term math

learning success (Hung et al., 2014; Wang et al., 2017; Juric et al., 2021).

In addition to enhancing affective gains, GBA can potentially aid learners in attaining psychomotor skills. Psychomotor skills include fine and gross muscle movements, manipulation of objects, eye-hand coordination, balance, and reaction time (Mas et al., 2018). Games present many situations that require learners to respond through physical movement, thereby enhancing these psychomotor skills. Research has also identified motion-based games and virtual reality applications that aid learners in gaining gross motor skills such as physical activity and movement, spatial awareness, and balance (Gagnon, 1985; Sumarsono et al., 2018; Jain, 2022; Craypo, 2024). Outcomes, however, are dependent upon many factors, including game design, intensity of intervention duration, and settings in which the intervention occurs (Chen et al., 2020; Lu et al., 2022; Tsai & Tsai, 2018). While there is little research into psychomotor gains in mathematics specifically, available evidence indicate potential of GBA in capitalizing on physical engagement for learning mathematics, particularly areas like geometry that incorporate a substantial spatial and object-manipulation component (Plass et al., 2015).

Despite the growing evidence on the benefits of games on affective and psychomotor outcomes, there has been no meta-analytic synthesis specifically focussed on learners of the Davao Region, Philippines. Thus, there is a need for a meta-analytic study to synthesize existing evidence and generate information for evidence-based practice and decision-making among teachers and policymakers. The study is significant as it identifies effective techniques that can promote holistic learning in mathematics beyond mere cognitive acquisition of concepts and information. It fosters knowledge on effective and engaging mathematics instruction that promotes motivation, engagement, and psychomotor learning among learners.

Targeting Sustainable Development Goal 4-Quality Education specifically, the study looks into inclusive, equitable, and meaningful learning opportunities for all learners through effective and participatory teaching and learning of mathematics. The results of this study can inform curriculum and instruction, teacher education, and innovation for effective mathematics education for all learners in the Philippines.

Materials and Methods

Research Design

This quantitative study utilized *ex post facto* design particularly employing meta-analysis. According to Ganeshkumar & Gopalakrishnan (2013), meta-analysis refers to the statistical analysis of the data from separate empirical studies which answers the same research question. The goal of meta-analysis is to produce a numerical estimate of the phenomenon being studied, such as the success of an intervention. Meta-analysis provided a technique to determine the overall effect size by simultaneously analyzing all available studies (both published and unpublished) (Sugano & Nabua, 2020). The meta-analytic approach is appropriate for this study since the goal of the study is to synthesize existing research about game-based mathematics instruction on affective and psychomotor learning outcomes.

Research Locale

Data were collected from higher education institutions (HEIs) and the Policy, Planning, and Research Division (PPRD) of the Department of Education (DepEd) across the five provinces of Region XI (Davao Region), with a focus on HEIs offering undergraduate and graduate programs in mathematics education and PPRDs with completed Basic Education Research Fund (BERF) studies. These institutions were selected for their significant contributions to educational research in the region,

warranting a comprehensive assessment of GBA across different educational contexts. The researcher used a systematic search for studies to ensure a comprehensive database for analysis. A manual search was conducted on the libraries of selected HEIs and PPRDs for completed studies that meet the inclusion criteria. Additionally, a comprehensive online search was done in databases and other peer-reviewed journals that store academic studies. Combining the manual and digital search ensured a thorough and systematic collection of studies that can be used for analysis.

PRISMA Flowchart

The PRISMA flowchart is a standardized tool created to illustrate the process of identifying, screening, and incorporating studies in a systematic review or meta-analysis. Figure 1 shows the PRISMA flowchart that was used in this study.

A total of 235 empirical studies in mathematics education were initially collected from theses, dissertations, and journal articles, both published and unpublished, sourced from higher education institutions (HEIs) and the Policy, Planning, and Research Divisions (PPRDs) across Region XI. After the removal of duplicates, 202 unique studies remained for eligibility screening. Several exclusion criteria were applied during this process: five (5) studies were excluded due to not involving any form of game-based implementation, 96 studies report cognitive learning outcomes, 23 studies were non-experimental in nature, 62 studies employed only pre-experimental designs, and 12 studies lacked sufficient statistical information to compute effect sizes. Following this rigorous screening, a total of 4 studies met all inclusion criteria and were retained for meta-analysis, from which 6 effect sizes were extracted and synthesized.

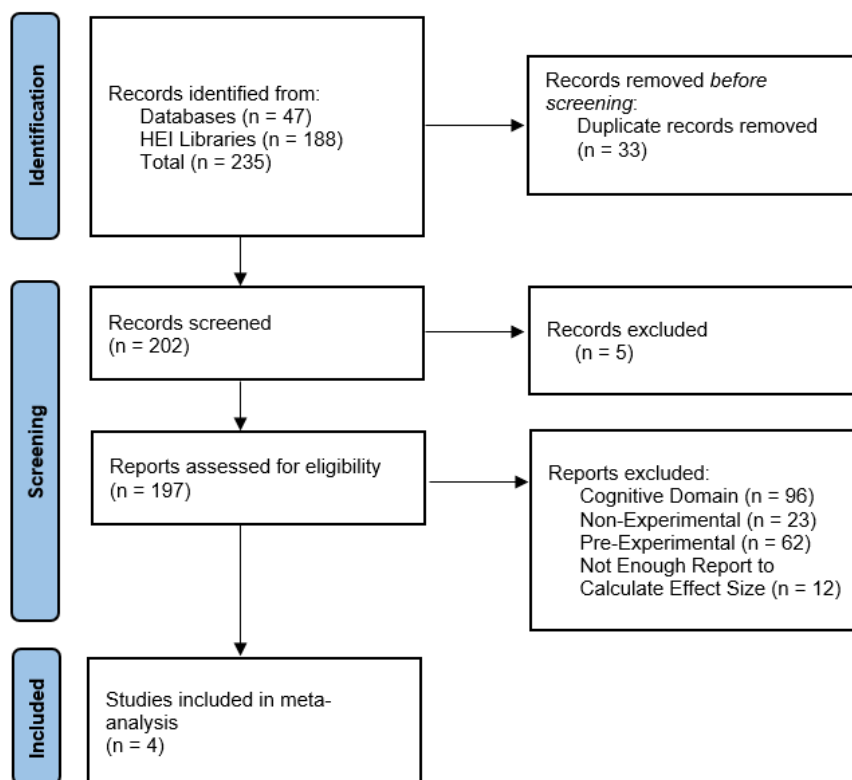


Figure 1. The Study PRISMA flowchart

Data Analysis

For data analysis, a meta-analytic approach was employed to combine results from multiple studies and determine the overall effectiveness of the game-based approach (Higgins et al., 2024). Effect size was used to measure the effectiveness of the GBA intervention on the dependent variable. Conversions and calculations of effect sizes was conducted in RStudio when not directly reported in the manuscript. The Cochran’s Q test determined whether or not there was significant heterogeneity between the studies. Forest plot, used to visualize the individual and pooled effect size alongside the 95% confidence interval for the effect sizes were then created, and funnel plot determined the degree to which publication bias may have impacted the findings. Symmetry in the plots generally indicated little bias, while asymmetry indicated the presence of bias (Higgins et al., 2024).

Ethical Considerations

Although no human participants were included in the study, relevant ethical considerations were strictly observed to ensure the

integrity and credibility of the research process. Prior to the manual search of libraries in HEIs and PPRDs, approval and permission were obtained from the concerned authorities. The approval was also established to ensure that no breach of confidentiality and violation of intellectual property rights of the materials to be analysed will be committed.

Result and Discussion

Meta-Analytic Findings on the Affective Domain

The meta-analysis included six (6) effect sizes from four studies. Although the number of studies was limited, the study highlights a growing body of studies focused on this domain. The meta-analysis offered first look at the effect of GBA on affective learning outcomes which are measures that are crucial for long-term academic success and can predict a student’s disposition toward mathematics. Table 1 summarizes the meta-analytic estimation of the average effect size, the associated confidence intervals, and the heterogeneity among studies.

Table 1. Effect sizes and heterogeneity test results for Affective Domain

Estimation Model	k	Effect Size	[95% CI]	p	Heterogeneity		
					Q	p	I ²
Random	6	1.38	[0.43, 2.33]	.005	66.94	<.001	95.48%
Fixed	6	1.13	[0.94, 1.34]	<.001			

The random-effects meta-analysis, as seen in Table 1, revealed a statistically significant overall effect size of 1.38 ($p = .005$; 95% CI [0.43, 2.33]) pointing to a very large positive effect of GBA on students' affective outcomes. In comparison, the fixed-effects analysis indicated a somewhat reduced effect size but still a very large positive effect of 1.13 ($p < .001$; 95% CI [0.94, 1.34]). Given the presence of significant

between-studies variance, $Q = 66.94$, $p < .001$, $I^2 = 95.48\%$, a random-effects model should be preferred over the fixed-effects counterpart (DerSimonian & Laird, 1986).

The forest plot in Figure 2 visually illustrates the effect sizes reported across studies, all of which show positive estimates, further reinforcing the consistent affective benefits of GBA implementations.

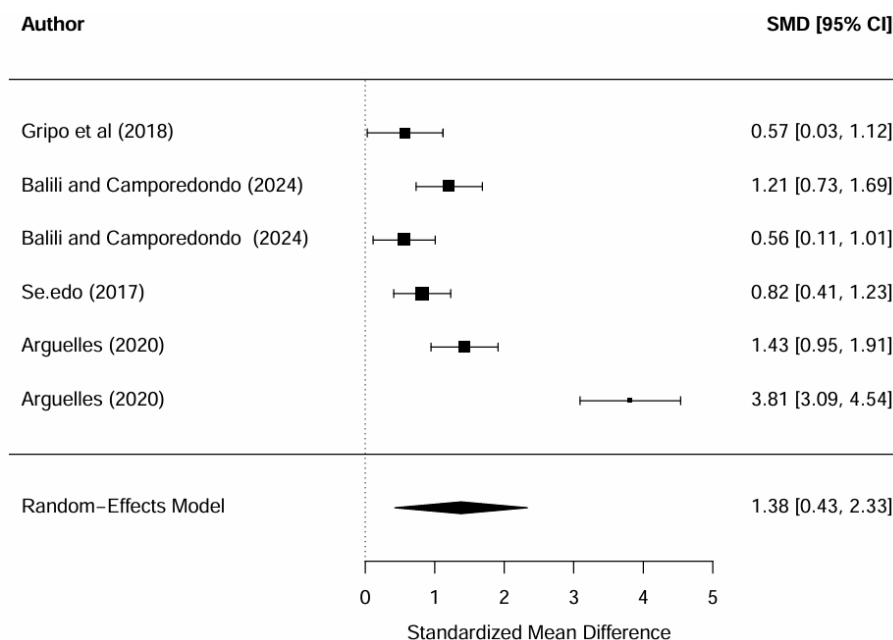


Figure 2. Forest Plot for Affective Outcomes

Table 1 and Figure 2 show that GBA can be associated with students' positive affective outcomes in mathematics, if used appropriately and applied thoughtfully. This is in line with previous studies indicating the use of game-based interventions to obtain positive affective outcomes, including students' emotional regulation, self-esteem, and socio-emotional competencies. While many meta-analyses and systematic reviews found small to moderate effect sizes for affective-motivational gains (Barz et al., 2023; Eve et al., 2023; Lau et al., 2017), there are also more positive results regarding affective learning outcomes for games with a

therapeutic focus or that intend to teach emotional skills (Gómez-León, 2025; Villani et al., 2018). Such games may include strategies rooted in cognitive-behavioral therapy (CBT) or rational-emotive perspectives.

While games with emotional aspects can increase student's emotional engagement and affective outcomes, casual/active video games can improve a student's mood (Wols et al., 2024). Serious/applied games, like those using biofeedback, emotion recognition and/or social-emotional training, are more effective in attaining affective outcomes than generic

games that are mostly for entertainment (Ahmed, 2024). This supports the idea that games should be intentional and thoughtful in mathematics education to obtain desired results. These findings point towards the possibility of GBA increasing students' emotional engagement and even their mental wellbeing in mathematics. Moreover, the study emphasizes the need for more research and intentional game

design is needed to establish the effectiveness of GBA and maximize the affective benefits.

Publication Bias

To assess the potential for publication bias, a funnel plot was generated and visually inspected. Figure 2 presents the funnel plot for the six effect sizes included in the affective domain analysis.

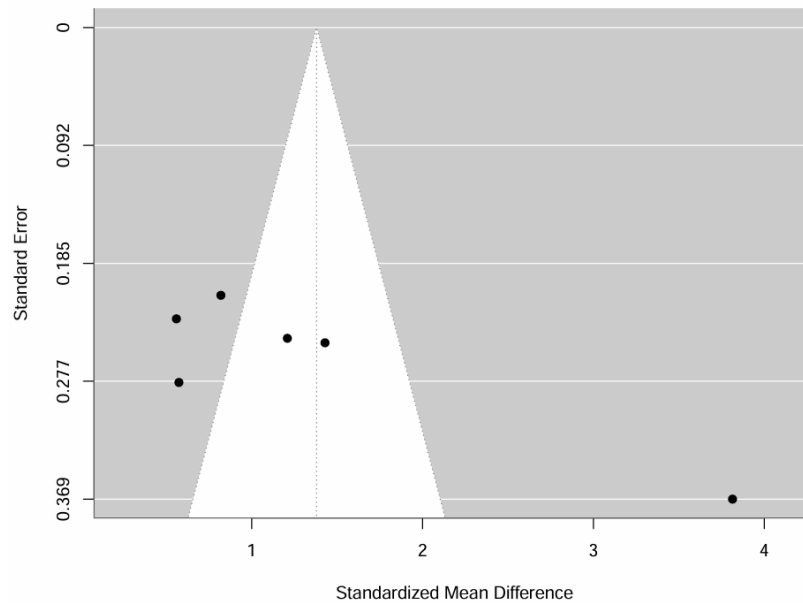


Figure 2. Funnel Plot for Affective Outcomes

Funnel plots are commonly used in meta-analytic research to assess for potential bias due to the lack of publication of small or non-significant studies (Egger et al., 1997). Ideally, in the absence of publication bias, the distribution of the effect sizes would resemble a symmetrical inverted funnel with its apex at the average effect (Sterne et al., 2011).

The funnel plot (Figure 2) displays an obvious asymmetry, with all but one of the effect sizes plotted to the left of the mean. This pattern could suggest the presence of publication bias, possibly resulting from the under repre-

sentation of smaller studies that report less desirable or non-significant findings. However, it is important to interpret this pattern with caution due to the small number of effect sizes ($k = 6$). As recommended by Sterne et al. (2011), funnel plots are more reliable when at least 10 studies are included. With fewer data points, asymmetry may arise by chance alone or due to sampling variability rather than actual bias.

To complement the visual inspection of the funnel plot and provide a more robust assessment of publication bias, a trim and fill analysis was performed, the result is shown in Figure 3.

```
> # Performing Trim and Fill
> trimandfill <- trimfill(overallresult)
> trimandfill

Estimated number of missing studies on the left side: 0 (SE = 1.1381)

Random-Effects Model (k = 6; tau^2 estimator: REML)
```

Figure 3. Trim and Fill Analysis Result

The results indicated that zero (0) studies were estimated to be missing on the left side of the funnel plot. This suggests that no evidence of publication bias was detected in the current meta-analysis of affective domain outcomes

using this method. To further examine the robustness of the meta-analytic results against publication bias, Rosenthal's Fail-Safe N was calculated, as seen in Figure 4.

```
> # Calculating Fail Safe N using Rosenthal's Approach
> fsn(yi, vi, dat=dat2)

Fail-safe N Calculation Using the Rosenthal Approach

Observed significance Level: <.0001
Target Significance Level: 0.05

Fail-safe N: 317
```

Figure 4. Fail-Safe N Analysis Result

The analysis yielded a Fail-Safe N of 317, which indicates that it would require 317 additional unpublished or null-effect studies to bring the overall effect size to a statistically non-significant level. This number greatly exceeds the commonly accepted benchmark suggested by Rosenthal (1979), which is calculated as $5k + 10$, where k is the number of studies included in the meta-analysis. For the present study, $5(6) + 10 = 40$. Since $317 > 40$, the findings are considered robust against the threat of publication bias. This substantial margin suggests that the positive effects of game-based approaches (GBA) on affective outcomes in mathematics are unlikely to be due solely to the selective publication of significant results.

Psychomotor Domain

According to Cooper and Harrow (1973), the psychomotor domain refers to the development of physical skills, movement coordination, and the ability to perform tasks that require fine or gross motor skills, often demonstrated through actions such as manipulating objects, responding reflexively, or executing motor routines. In the context of mathematics education, psychomotor outcomes may include students' ability to model concepts using manipulatives, interact with physical or digital learning tools, or engage in hands-on, movement-based activities.

Despite the extensive search of online databases and repositories in HEIs and PPRDs conducted, no relevant studies were found that focused on using game-based interventions to

improve students' psychomotor outcomes in the specified geographic location and time frame. The absence of research in this area may be attributed to several reasons.

First, there is a lack of research into the psychomotor outcomes in mathematics education due in part to the long-established dominance of cognitive processes to mathematics learning and teaching such as symbolic reasoning, conceptual understanding, and problem-solving (Cui et al. 2024). Often, researchers focus on learner knowledge acquisition and learner affect. However, a number of recent studies have started to challenge the notion of mathematics as a 'mental activity only' and increasingly indicate that there is value in embodied cognition, physical activity, and hands-on tasks to enhance both mathematical knowledge acquisition and physical skills in mathematics (Son, 2025; Tran et al. 2017).

Second, typical mathematics classrooms are structured around desk-based, cognitive tasks, making it difficult to integrate and observe psychomotor skills naturally. This limits opportunities for students to exhibit mathematical understanding via movement or hands-on activities, which are requirement for psychomotor evaluation (Magistro et al., 2022; Viscione et al., 2017). Furthermore, assessing psychomotor skills requires direct observation. In class settings, several logistical considerations (e.g., limited class time, presence of other students), however, limit the extent to which teachers are able to directly and effectively observe their students' development in this

regard. Moreover, as Brata et al. (2025) pointed out, from a practical perspective, direct observation might necessarily be a subjective process. Although the use of checklists or rubric-based assessment is common in many areas of classroom observation (Kurniati et al., 2022), their development can be challenging, above all in those subjects, such as mathematics, where unique combinations of physical, motor, and cognitive processes come together in complex coordination in order to complete a particular task.

Lastly, implementation of psychomotor assessments requires further planning, movement space, and resources to support psychomotor assessment implementation (e.g., manipulatives, technology, etc). Even teachers need specific training and time to build psychomotor assessments and to carry out the assessment. Some classroom conditions do not support psychomotor activities. Those limitation cause that there are few studies related with psychomotor approach in mathematics education study.

It is important to note that although this study did not found any studies which specifically attempted to measure some aspect of psychomotor outcomes as a result of using GBA, the psychomotor domain, nevertheless, is a fundamental aspect of how GBA is put into practice. While some of the studies found focused more on reported gains in cognitive or affective aspects of learning, most GBA strategies in some way embodied physical processes such as moving objects, manipulating information on a screen, role playing out a scenario, or carrying out other forms of kinesthetic learning.

In this sense, the psychomotor domain acts as an enabling condition or prime mover within the GBA framework. The learner must be able to perform the physical manipulations of materials or procedures necessary to achieve an end. These manipulations form a scaffolding or embodied facilitator for higher-level cognitive and affective learning. Through physical activity, learners process, internalize, and apply information via embodied cognition (Nathan & Walkington, 2017). Thus, when outcomes are framed primarily in terms of cognitive or affective gains, one must not overlook the psychomotor domain because, fundamentally, it is the

learner engaging with the content, the tools, and the learning environment.

The absence of direct assessment of psychomotor outcomes should not be misunderstood as a lack of relevance. Rather, it points to a gap in methodological focus, where researchers prioritize observable knowledge gains or motivational shifts without accounting for the sensorimotor engagement that makes such outcomes possible. A more holistic view of GBA would recognize the linkage of learning domains, where psychomotor involvement supports affective engagement and deepens cognitive processing. Future research should explore this intersection, possibly through multimodal assessments that include observation checklists, motion tracking, or video analysis; to better understand how physical engagement contributes to learning.

Conclusion

This meta-analysis provides evidence of the large and positive effect of game-based approaches (GBA) on affective learning outcomes in mathematics education. Theoretical constructs from constructivist, motivational, and embodied cognition theories reveal that students' affect and motivation play a critical role in engaging in meaningful mathematics learning. While cognitive skills are typically considered to be the primary outcomes of mathematics learning, this study found that there are no studies that have assessed students' psychomotor skills in relation to mathematics learning with GBA. Nonetheless, psychomotor engagement is an inherent yet unexamined feature of GBA, and serves as an enabling mechanism that enhances affective and cognitive learning in mathematics. These findings translate to positive outcomes for student learning, suggesting that incorporating games into mathematics instruction can increase students' motivation, attitude, and emotional engagement with mathematics, leading to more inclusive and holistic learning environments. These findings can inform teachers, curriculum developers, and policymakers as to how to design and implement effective mathematics education that fits within a framework of inclusive and holistic education.

However, the study has several limitations including a small number of included studies, high levels of study heterogeneity, and a lack of psychomotor-focused studies within the region. Future research should undertake more experimental studies that measure the psychomotor dimension of learning as well as affective and cognitive domains, employing a range of multimodal measures within a valid framework. Future studies should also attempt to generalize findings to other regions, educational levels, and different types of interventions, as well as investigate long-term effects and moderators of effect.

Acknowledgement

The authors wish to thank all concerned for their help in the completion of this work.

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