Learn Mathematics through Games: Prospects and Concerns: Comprehensive Mini Review

Indirani Munusamy[1], Mohd Faizal Nizam Lee Abdullah[2*], Shahrul Amri Mohamad[3]

[1,2]Mathematics Department, Faculty of Science and Mathematics, Sultan Idris Education Universiti, Malaysia

[3]School of Educational Studies, Universiti of Science Malaysia

[*]Corresponding Author

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ABSTRACT

Mathematics is a core discipline essential for problem-solving, science, and technology. Nonetheless, it is frequently perceived by learners as abstract, complex, and disconnected from real-world applications. In response, researchers have increasingly explored game-based learning as a strategy to enhance motivation, engagement, and conceptual understanding. Evidence highlights the potential of both traditional and digital games to foster persistence, collaboration, and critical thinking. However, concerns remain regarding superficial learning, over-reliance on extrinsic rewards, and limited evidence of long-term gains. Correspondingly, this mini-review synthesizes research published between 1985 and 2025, encompassing 597 Scopus-indexed articles that examine mathematics games across manipulative-based, digital, and serious three-dimensional(3D) formats. In particular, three thematic areas are addressed: the role of games in enhancing learner motivation and engagement, their effectiveness in supporting mathematical understanding, and the challenges of implementation, assessment, and equity. Findings suggest that games, when carefully designed and aligned with curricular goals, can complement traditional instruction by making abstract concepts more accessible and meaningful. Nevertheless, persistent issues related to scalability, teacher facilitation, and inclusivity highlight the need for further empirical research, particularly longitudinal studies, to establish the durability of learning outcomes. Moreover, this review concludes that while games are not a panacea, they are a powerful pedagogical tool that, when strategically implemented, can enrich mathematics education and foster the development of 21st-century skills.

Keywords: Digital, Science, Technology, Engineering, and Mathematics (STEM), Game-based learning

INTRODUCTION

Mathematics is a foundational discipline that underpins scientific, technological, and everyday problem-solving skills (Yifan et al., 2024). Still, for many learners, mathematics is often perceived as abstract, complex, or disconnected from real-world applications (Aremu & Adebagbo, 2021). In recent years, educational researchers have sought innovative strategies to address this challenge, with game-based learning emerging as a promising approach (Vankúš, 2023). Notably, both digital and traditional games have been demonstrated to foster engagement, motivation, and active participation, making them particularly relevant in an era where interactive, learner-centered pedagogies are increasingly emphasized.

The integration of games into mathematics education, however, is not without debate. While numerous studies highlight their benefits in improving conceptual understanding and retention, others question whether games merely enhance short-term motivation without producing lasting gains in mathematical proficiency. Divergent perspectives also exist regarding the types of games most effective for learning. Some advocate digital and adaptive platforms that personalize instruction, while others emphasize the collaborative and critical-thinking benefits of traditional board and card games (Pawa et al., 2020). Together, these debates reflect broader

unresolved questions in the field, including the extent to which games align with curricular standards, the role of teacher mediation, and the scalability of game-based interventions across diverse learning contexts.

The primary aim of this mini review is to synthesize current evidence on the integration of games into mathematics learning, highlighting both their pedagogical potential and limitations. Specifically, it addresses three key thematic areas: (1) the impact of games on learner motivation and engagement, (2) the effectiveness of game-based approaches in developing mathematical understanding, and (3) the challenges and limitations, including issues of assessment, implementation, and accessibility. By critically examining these dimensions, this review seeks to clarify the current state of knowledge, identify gaps warranting further investigation, and offer insights into how games can be strategically integrated into mathematics education.

Ultimately, the review argued that, while games are not a panacea, they can be a valuable complement to traditional teaching methods when thoughtfully designed and implemented (Su et al., 2025). In essence, the conclusions drawn here emphasize the need for continued research on long-term outcomes, adaptive learning technologies, and the role of teacher facilitation in maximizing the educational benefits of mathematics through games.

The integration of games into mathematics education offers promising opportunities to enhance student engagement and motivation (Anggraeni, 2021). Gamification techniques, such as incorporating problem-based digital activities, can significantly enhance students' game-like experiences and their intrinsic drive to actively participate in learning, addressing common issues such as passivity and a lack of interest in traditional math instruction (Pawa et al., 2020). Furthermore, these approaches foster improved knowledge retention, personalized learning paths, and the development of cognitive skills such as critical thinking and problem-solving. It also reduced mathematics anxiety through enjoyable, repetitive practice in a relaxed environment. Additionally, games encourage collaborative teamwork, creative exploration of concepts, and self-initiated learning, potentially leading to better academic performance and 21st-century skill development such as perseverance and independence (Mohd et al., 2020).

However, several concerns arise regarding the use of games in mathematics education (Tee & Song, 2024) that warrant careful consideration. One major issue is the risk of superficial learning, in which students may prioritize achieving rewards, scores, or rankings over genuine understanding of mathematical concepts. This potentially leads to addiction-like behaviors tied to game mechanics rather than educational depth. Implementation challenges also include the necessity for robust pedagogical design. Without it, gamification may fail to motivate effectively or align with curriculum goals, leading to boredom, reliance on extrinsic rewards, or distractions from core content. Moreover, there is a noted lack of comprehensive empirical evidence on long-term effects, alongside potential issues such as resource limitations (e.g., technology access) and the possibility that not all students benefit equally. All these could exacerbate inequalities or hinder broader applicability across diverse classroom settings.

METHODS

A comprehensive literature search was conducted in Scopus, selected for its wide coverage of peer-reviewed publications across education, technology, and Science, Technology, Engineering, and Mathematics (STEM) disciplines. The search combined controlled vocabulary and free-text terms using the following Boolean string:

("mathematics" OR "math" OR "numeracy" OR "arithmetic") AND ("education" OR "learning" OR "instruction" OR "teaching") AND ("games" OR "play" OR "gamification" OR "simulation") AND ("engagement" OR "motivation" OR "participation" OR "interaction") AND ("assessment" OR "evaluation" OR "feedback" OR "performance")

The search was restricted to studies published between 1985 and 2025, reflecting four decades of research development. This process initially retrieved 597 articles. Consequently, all records were screened against eligibility criteria to ensure relevance and methodological rigor.

Inclusion Criteria

Studies were included if they:

1. Examined mathematics-related games in any form, including manipulative-based, digital/virtual, or 3D serious games.
2. Focused on the use of game-based approaches in mathematics or broader STEM education.
3. Provided an analysis of the benefits, limitations, or pedagogical potential of game-based learning in mathematics.
4. Were published in peer-reviewed journals and written in English.

Exclusion Criteria

Studies were excluded if they:

1. Were published in languages other than English.
2. Addressed mathematics education without explicit incorporation of a game-based learning or gamification component.
3. Consisted of grey literature (e.g., conference abstracts, dissertations, unpublished reports), in order to ensure methodological rigor and reliability of findings.

DISCUSSION AND RESULTS

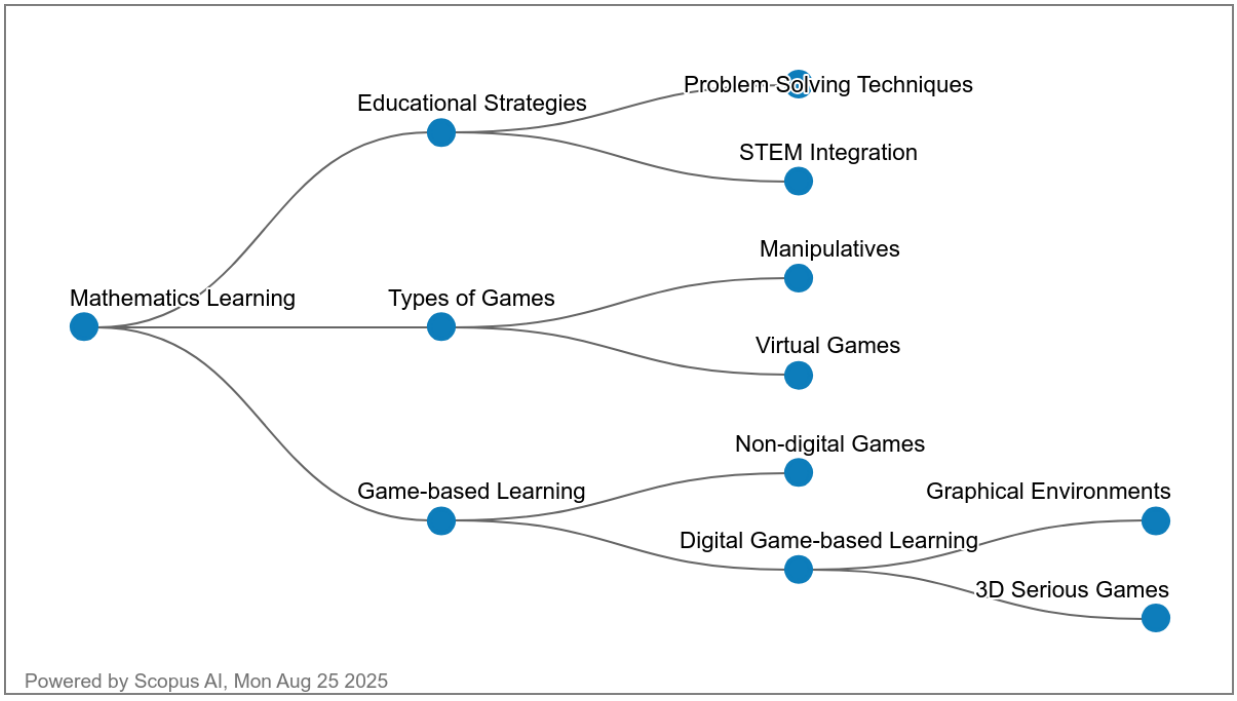

Figure 1 : Learn Mathematics through games generated by Scopus AI Analyzer

Current Status of Learning Mathematics Through Games : Educational Strategy Themes

Learning mathematics through games has gained increasing attention as an educational strategy to foster engagement, enhance problem-solving skills, and strengthen STEM integration (Moral-Sánchez et al., 2022). Notably, games provide structured challenges that encourage logical reasoning, pattern recognition, and creative problem-solving. At the same time, digital simulations and coding or robotics-based games highlight the real-world applications of mathematics across STEM disciplines. Thus, by situating learning in interactive, low-stakes environments, games promote persistence, collaboration, and systems thinking, skills essential for 21st-century learners. However, challenges remain, including variability in game design quality, unequal access to digital resources, limited teacher training, and difficulties in assessing the depth of learning outcomes. Despite these limitations, evidence suggests that when thoughtfully designed and aligned with curricular objectives,

game-based learning can complement traditional instruction. This ultimately makes mathematics more meaningful and equips students with transferable skills for STEM-related contexts.

Current Status of Learning Mathematics Through Games : Types of Games

Furthermore, learning mathematics through games has emerged as an effective educational strategy to enhance engagement, conceptual understanding, and skill development by combining play with structured learning. In particular, two major types of games are widely discussed: manipulative-based games and virtual games. Manipulatives, such as board games, puzzles, and card activities, provide tactile, hands-on experiences that support the visualization of abstract concepts and encourage collaboration and problem-solving in classroom settings. Conversely, virtual games, including digital simulations, adaptive platforms, and interactive apps, offer dynamic environments where learners can explore mathematical relationships, receive instant feedback, and progress at personalized levels of difficulty. While both approaches demonstrate strong potential for fostering motivation and deeper learning, challenges such as uneven access to technology, variability in design quality, and the need for teacher guidance remain critical considerations. Overall, integrating manipulative and virtual games within the curriculum can provide complementary pathways that make mathematics more engaging, accessible, and applicable to real-world problem-solving.

Current Status of Learning Mathematics Through Games : Game-based Learning

In addition, game-based learning has become a promising approach in mathematics education, offering innovative ways to enhance engagement and conceptual understanding beyond traditional methods (Kaymakci Ustuner et al., 2023). For example, non-digital games, such as board games and puzzle-based activities, create interactive graphical environments in which learners visualize mathematical ideas, develop problem-solving strategies, and collaborate with peers in hands-on contexts (Setambah et al., 2023). Complementing these are 3D serious games, which simulate immersive scenarios that allow students to apply mathematical reasoning in lifelike situations, promoting spatial awareness, logical thinking, and experiential learning. Together, these approaches highlight the potential of games to bridge abstract concepts with tangible experiences, though challenges such as resource availability, alignment with curricula, and assessment of learning outcomes persist. When effectively designed and integrated, both graphical non-digital environments and 3D serious games serve as powerful tools to foster deeper learning and make mathematics more engaging and meaningful (Castaneda et al., 2025).

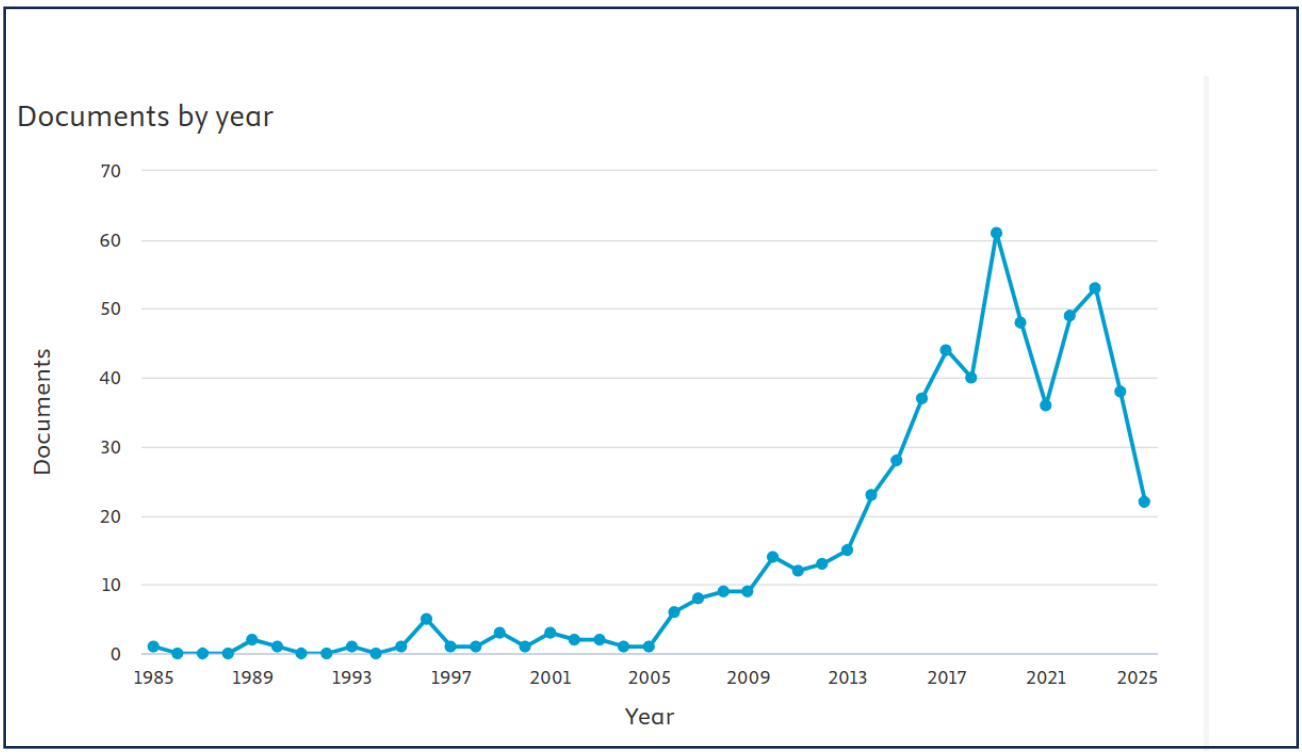

Figure 2 : Documents of Learn Mathematics through games generated by Scopus

Figure 2, titled "Documents by year generated by Scopus about learning mathematics through games," illustrates the publication trend in this research area over time. It reveals a steady increase in the number of articles published, with only a few contributions in the earlier years, followed by a marked rise in output in recent years. Moreover, this growth suggests that integrating games into mathematics education has gained increasing attention among researchers, reflecting a growing recognition of its potential to enhance student engagement, problem-solving skills, and learning outcomes. Additionally, the upward trend indicates that the field is evolving into a significant area of educational research, with expanding opportunities for further studies and practical applications in classrooms.

Authors	Year	Contribution Area
Castaneda J.A.C.; Lin P.-C.; Hung P.C.K.; Zhong H.-X.; Tseng H.-A.; Huang Y.-F.; Ahmad R.	2025	Designing inclusive, playful STEM solutions for visually impaired learners using audio games and tactile 3D blocks.
Al-Nawaiseh S.J.	2025	Investigating the impact of digital educational game blogs on enhancing mathematical concepts among sixth-grade students.
Martinez J.S.G.; Maza E.J.R.; Meza A.J.N.; Huamaní E.L.; Meyluz P.C.	2025	Implementation of academic software with educational games to support mathematics and reading comprehension in children (6–8 years old).
Taraldsen L.H.	2025	Introducing escape rooms as a didactic, game-based tool in mathematics teacher education.
Jeong J.; Frye D.A.	2025	Studying how children (ages 3–6) judge appropriate levels of counting games, linked to the Zone of Proximal Development (ZPD).
Li J.; Shin J.; Xue J.; Dawson K.; Antonenko P.D.	2025	Exploring effects of visuospatial rich math games on anxiety and performance in children with different working memory capacities.
Rastpour A.; Amini A.	2025	Designing a spreadsheet-based game ("Age Guessing") to teach fundamental statistical concepts in undergraduate education.
Pathania M.; Singh C.P.; Kaur D.P.; Mantri A.	2025	Developing a self-adaptive iterative game-based framework to improve performance and satisfaction in elementary mathematics education.
Fang X.; Ng D.T.K.; Tam W.T.; Yuen M.	2025	Designing mobile computational thinking-integrated mathematics lessons using the 5E model for primary school students.

Table 1 : Recent 10 articles in the field of learning mathematics through games

Table 1 highlights recent 2025 contributions to learning mathematics through games, showcasing a wide range of innovative approaches across different educational contexts. As such, researchers have explored inclusive solutions, such as audio games and tactile 3D blocks for visually impaired learners, and digital game blogs to strengthen sixth graders' mathematical concepts (Castaneda et al., 2025). For instance, several studies focus on integrating educational games into software and mobile platforms to support early childhood learning (ages 3-8) in both mathematics and reading (Martinez et al., 2025). Meanwhile, others emphasize novel didactic strategies such as escape rooms in teacher education (Taraldsen, 2025) and spreadsheet-based games for teaching statistics at the undergraduate level (Rastpour & Amini, 2025). Additionally, scholars investigated cognitive and affective dimensions. This includes how children assess counting games in relation to their developmental stage, the impact of visuospatial-rich math games on anxiety (Fang et al., 2025), performance depending on working memory (Li et al., 2025), and adaptive frameworks designed to enhance performance and satisfaction in elementary mathematics (Pathania et al., 2025). Collectively, these contributions underscore the growing diversification and sophistication of game-based learning as a tool for engaging learners, addressing diverse needs, and fostering deeper mathematical understanding.

CONCLUSION

Games extend beyond mere panacea for mathematics education. Instead, they are a powerful complement to traditional pedagogies when strategically embedded in the curriculum and supported by teacher facilitation. The growing body of research demonstrates their capacity to increase motivation, deepen conceptual understanding, and foster collaborative and critical-thinking skills. However, persistent challenges in assessment, scalability, equity, and sustainability remain unresolved. Therefore, future work should prioritize longitudinal studies to evaluate lasting impacts and investigate adaptive and inclusive technologies. This includes refining frameworks for teacher mediation to ensure that game-based learning translates from short-term engagement to durable mathematical proficiency. Ultimately, realizing the full potential of games in mathematics requires balancing innovation with rigor, ensuring that playful learning experiences are engaging, educationally meaningful, and accessible to all learners.

REFERENCES

1. Anggraeni, G. (2021). Recreational Mathematics Activities to Enhance Students' Mathematics Achievement and Learning Motivation. In S. M.W. (Ed.), Journal of Physics: Conference Series (Vol. 1823, Issue 1). IOP Publishing Ltd. https://doi.org/10.1088/1742-6596/1823/1/012019
2. Aremu, A., & Adebagbo, A. (2021). Digital games for teaching and learning of mathematics in nigeria schools. In Research Anthology on Developments in Gamification and Game-Based Learning (Vols. 3–4, pp. 1242–1255). IGI Global. https://doi.org/10.4018/978-1-6684-3710-0.ch058
3. Castaneda, J. A. C., Lin, P.-C., Hung, P. C. K., Zhong, H.-X., Tseng, H.-A., Huang, Y.-F., & Ahmad, R. (2025). Designing inclusive tech playful educative solutions for visually impaired learners in STEM education. Smart Learning Environments, 12(1). https://doi.org/10.1186/s40561-024-00358-x
4. Fang, X., Ng, D. T. K., Tam, W. T., & Yuen, M. (2025). Design mobile computational thinking-integrated mathematics lessons based on the 5E instructional model for primary students. Educational Technology Research and Development. https://doi.org/10.1007/s11423-025-10513-x
5. Kaymakci Ustuner, K., Law, E. L.-C., & Li, F. W. B. (2023). Digital Educational Games with Storytelling for Students to Learn Algebra. In A. N. J., K. L. M., P. H., P. A., & W. M. (Eds.), Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 14145 LNCS (pp. 459–463). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-42293-5_54
6. Li, J., Shin, J., Xue, J., Dawson, K., & Antonenko, P. D. (2025). Visuospatially Rich Math Games Increase Anxiety in Children With Lower Visuospatial Working Memory Capacity. Mind, Brain, and Education. https://doi.org/10.1111/mbe.70012
7. Martinez, J. S. G., Maza, E. J. R., Meza, A. J. N., Huamaní, E. L., & Meyluz, P. C. (2025). Implementation of an Academic Software for Children from 6 to 8 Years Old for Easy Learning in Basic Mathematics and Reading Comprehension. Journal of Advanced Research in Applied Sciences and Engineering Technology, 45(2), 38–55. https://doi.org/10.37934/araset.45.2.3855
8. Mohd, C. K. N. C. K., Shahbodin, F., Sedek, M., & Samsudin, M. (2020). Game based learning for autism in learning mathematics. International Journal of Advanced Science and Technology, 29(5), 4684–4691.https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084646610&partnerID=40&md5=d970ee49db038060ffe80146c3974803
9. Moral-Sánchez, S. N., Sánchez-Compaña, M. T., & Romero, I. (2022). Geometry with a STEM and Gamification Approach: A Didactic Experience in Secondary Education. Mathematics, 10(18). https://doi.org/10.3390/math10183252
10. Pathania, M., Singh, C. P., Kaur, D. P., & Mantri, A. (2025). Effects of Self-Adaptive Approach of Iterative Game Based Learning on Performance and Satisfaction of Elementary School Students in Mathematics: An Action Research Field Experiment. SN Computer Science, 6(5). https://doi.org/10.1007/s42979-025-04071-5
11. Pawa, S., Laosinchai, P., Nokkaew, A., & Wongkia, W. (2020). Students' conception of set theory through a board game and an active-learning unit. International Journal of Innovation in Science and Mathematics Education, 28(1), 1–15. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85091358882&partnerID=40&md5=ba57256ed714d94e536814d5902d6c64

12. Rastpour, A., & Amini, A. (2025). Age Guessing: A Game to Introduce Fundamental Statistical Concepts. Journal of Statistics and Data Science Education, 33(1), 62–67. https://doi.org/10.1080/26939169.2024.2319152
13. Setambah, M. A. B., Rajoo, M., Othman, M. S., Shuib, T. R., & Ibrahim, M. A. (2023). Non-digital gamification: Effects of teaching on mathematics achievement and student behavior. Nurture, 17(4), 504–515. https://doi.org/10.55951/NURTURE.V17I4.388
14. Su, Y.-S., Chang, C.-J., Li, J.-H., & Chen, S.-Y. (2025). Integrating STEM Teaching into Digital Game Aids to Explore Non-Technical Students' C# Programming Learning Outcomes and Perceptions. Journal of Internet Technology, 26(4), 435–442. https://doi.org/10.70003/160792642025072604002
15. Taraldsen, L. H. (2025). Introducing Teacher Education Students to Escape Room as a Didactic Tool in Mathematics. Mathematics Teaching-Research Journal, 17(3), 261–288. https://www.scopus.com/inward/record.uri?eid=2-s2.0-105012042441&partnerID=40&md5=8a17bc7b1933a0006a25ab387ea44444
16. Tee, E. B., & Song, I. (2024). Game Theme Prediction for Smart Mobile Online Educational Games. In Y. X.-S., S. S., D. N., & J. A. (Eds.), Lecture Notes in Networks and Systems: Vol. 1013 LNNS (pp. 537–553). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-97-3559-4_44
17. Vankúš, P. (2023). Game-Based Learning and Gamification Technologies in the Preparation of Future Mathematics Teachers. International Journal of Interactive Mobile Technologies, 17(11), 53–67. https://doi.org/10.3991/ijim.v17i11.39227
18. Yifan, Y., Gopalan, V., Supli, A. A., Kumaran, S. R., & Alnagrat, A. J. A. (2024). Enhancing Primary School Students' Motivation in Mathematics Through Game-Based Learning (GBL). In B. S., V. A., & T. O. (Eds.), Advances in Science, Technology and Innovation (pp. 261–271). Springer Nature. https://doi.org/10.1007/978-3-031-52303-8_19