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The Power of Gamification: How Kahoot! Transforms Motivation and Learning in Primary Science Education

Desembra Sohilait [1]*, Paul Arjanto[2], Seng Tong Chong[3], Maria Imaculada da Conceição Soares[4]

[1] Faculty of Teacher Training and Education, Pattimura University, Ambon, Indonesia
[2] Postgraduate Studies, Pattimura University, Ambon, Indonesia
[3] College of Continuing Education, Universiti Tenaga Nasional, Selangor, Malaysia
[4] Faculty of Education, Instituto Superior Cristal, Dili, Timor-Leste

corresponding author
desembrasohilait@gmail.com [1]

Abstract: This study investigates the impact of Kahoot! on elementary students' motivation and learning outcomes in science education. Using a quantitative experimental one-group pre-test post-test design, 24 sixth-grade students participated, with data collected through a structured motivation questionnaire and a science comprehension test. Statistical analysis, including the Wilcoxon Signed-Rank Test, revealed a significant increase in motivation, with mean scores rising from 62.125 (Pre-Test) to 83.25 (Post-Test) and a p-value of .000 confirming the intervention's effectiveness. The findings align with self-determination theory, emphasizing autonomy, competence, and relatedness in fostering motivation. This study highlights the potential of game-based learning to enhance student engagement and suggests integrating digital platforms like Kahoot! into curricula to maximize learning outcomes. Future research should explore long-term effects and broader applications of gamification in primary education.

Keywords: game-based learning, student motivation, digital education tools, kahoot!, elementary science education

INTRODUCTION

In the modern educational landscape, the integration of technology has become a crucial strategy to enhance student engagement and motivation. The integration of technology in education has emerged as a transformative approach to enhance student engagement and learning motivation, particularly through the use of Digital Game-Based Learning (DGBL) (Thi Van Pham et al., 2021; Tsihouridis et al., 2023). DGBL, characterized by the incorporation of gaming elements into educational activities, aims to create an interactive and engaging

learning environment that aligns with students' interests and cognitive development. One prominent DGBL tool, Kahoot!, leverages gamification to create a dynamic, competitive, and interactive learning experience, fostering both participation and motivation among students (Licorish & Lötter, 2022; Wang et al., 2023). Research demonstrates that gamification not only improves engagement but also facilitates deeper conceptual understanding, particularly in interactive and practical subjects like science (Candan & Başaran, 2024; Hung et al., 2019). Thus, the incorporation of gamification in education, particularly through tools like Kahoot!, has proven to be an effective method for fostering active learning and improving students' conceptual understanding.

Early integration of engaging and interactive learning methods is essential for fostering a strong foundation in elementary science education. While the effectiveness of Kahoot! has been widely explored in diverse educational settings, its impact on elementary science education remains under-researched (Rayan & Watted, 2024). Science education at the elementary level often faces challenges in sustaining student interest, as traditional teaching methods may not effectively cater to young learners' dynamic needs (Zheng et al., 2024). Unlike passive learning approaches, game-based learning tools like Kahoot! allow students to actively engage with learning materials, making abstract scientific concepts more tangible and easier to understand (Pellas, 2024). Furthermore, science education relies heavily on experimentation and problem-solving, which can be reinforced through interactive, game-based platforms that encourage inquiry-based learning.

Motivating students to engage in learning activities is a key challenge in education, and gamification tools like Kahoot! offer innovative solutions to address this issue. The motivational benefits of Kahoot! lie in its ability to provide instant feedback, foster collaboration, and promote a sense of achievement among students (Lin et al., 2014; Yeh et al., 2017). The platform's use of rewards, points, and leaderboards serves as an extrinsic motivator, encouraging students to actively participate and strive for better performance (Thi Van Pham et al., 2021). Additionally, Kahoot! enhances intrinsic motivation by creating an enjoyable and immersive learning environment, which can be particularly beneficial in subjects that students may perceive as challenging, such as science (Liu et al., 2023). However, despite the growing body of research on gamification, there is limited empirical evidence on its specific impact on elementary science education, particularly within the Indonesian context, where integrating digital tools remains a growing but underutilized practice (Rashid & Noor, 2023). Therefore, further research is needed to explore the specific impact of Kahoot! on elementary science education, particularly in Indonesia, to maximize its potential as a digital learning tool.

Moreover, existing studies on Kahoot! have primarily focused on short-term engagement rather than long-term knowledge retention and sustained motivation. Many prior studies have examined its impact on secondary or higher education students, leaving a gap in research concerning younger learners who may respond differently to game-based learning strategies (Chen & Tu, 2021; Huang, 2021). The digital divide, varying levels of access to technology, and differences in pedagogical approaches between elementary and higher education further highlight the need for context-specific studies.

This study addresses these research gaps by examining the influence of Kahoot! on elementary students' motivation and learning outcomes in science subjects. It aims to provide comprehensive insights into how gamification strategies enhance learning experiences, focusing on both short-term engagement and long-term knowledge retention. By evaluating the application of Kahoot! in Indonesian elementary schools, this research contributes to the broader academic discourse on technology integration in primary education, highlighting its potential for creating more effective and engaging science learning environments. Furthermore, it examines how different components of gamification, such as competition, collaboration, and immediate feedback, influence students' attitudes toward science learning. This research investigates the use of Kahoot! to improve students' motivation and learning outcomes in elementary science lessons. The findings are expected to provide valuable implications for educators, policymakers, and instructional designers seeking to optimize digital learning tools for young learners. By addressing the existing research gaps, this study aims to provide empirical evidence on the effectiveness of gamification in fostering young learners' motivation, ultimately contributing to the development of more engaging and effective instructional practices in elementary science education.

METHOD

Research Design

A quantitative experimental approach was employed using a one-group pre-test post-test design, allowing for a systematic comparison of students' motivation levels before and after the intervention (Creswell & Creswell, 2018). This study followed a structured process, beginning with a pre-test to assess baseline motivation levels, followed by the intervention, and concluding with a post-test to evaluate changes. The one-group pre-test post-test design is commonly used to measure the effects of an intervention within a single group, providing insights into changes over time due to the applied treatment (Fraenkel et al., 2019).

Participants and Sampling

The population of this study comprised all sixth-grade students at an elementary school who participated in science learning. The sample was selected through purposive sampling, ensuring that the chosen class had comparable characteristics in terms of initial science knowledge and learning engagement (Etikan, 2016). The final sample included 24 students, all of whom participated in the same intervention without a separate control group.

Intervention and Procedure

The study involved one group of students who received science instruction using the Kahoot application. Before the intervention, the students completed a pre-test to measure their initial motivation levels. The group then participated in Kahoot-integrated science learning, where interactive quizzes reinforced lesson content and encouraged active participation. After the intervention, a post-test was administered to the same group to assess motivation changes and learning improvements. The research procedure was divided into three main phases: 1) Pre-Test Phase: Students completed the motivation questionnaire and the science comprehension test before any intervention. 2) Intervention Phase: Students engaged in Kahoot-based learning, where interactive quizzes reinforced lesson content and encouraged active participation. 3) Post-Test Phase: Students completed the same motivation questionnaire and science comprehension test to measure motivation changes and comprehension improvements.

Data Collection and Instruments

To measure students' motivation, a structured questionnaire was used, assessing intrinsic and extrinsic motivation dimensions, such as interest in the subject, engagement, and competitive drive. A five-point Likert scale was employed to capture students' responses. Additionally, a science comprehension test was administered to examine whether increased motivation influenced learning outcomes. The validity of the questionnaire was established through content and construct validation, ensuring that the instrument accurately reflected the targeted motivation constructs (DeVellis & Thorpe, 2021). Reliability was assessed using Cronbach’s Alpha, with a coefficient threshold of 0.70 indicating high internal consistency.

Data Analysis

The collected data were analyzed using SPSS and Microsoft Excel. Statistical analysis included normality testing to ensure that the data distribution met assumptions for parametric

analysis. A paired t-test was conducted to examine within-group differences in motivation levels before and after the intervention. This analysis helped assess the effectiveness of Kahoot-based learning in enhancing student motivation and science comprehension (Field, 2018).

Hypotheses

This study tests two hypotheses regarding the impact of Kahoot-based learning on student motivation. The null hypothesis (H_0) states that there is no significant difference between pre-test and post-test scores in student learning motivation, meaning that the median difference between pre-test and post-test scores equals zero. Conversely, the alternative hypothesis (H_1) posits that there is a significant difference between pre-test and post-test scores in student learning motivation, indicating that the median difference between pre-test and post-test scores is not equal to zero. These hypotheses guide the statistical analysis in determining whether the intervention had a measurable impact on student motivation levels.

RESULT

Descriptive Statistics of Pre-Test and Post-Test Scores

The range of the Pre-Test scores is 15, which is wider compared to the Post-Test range of 10. This indicates that student motivation levels were more varied before the intervention, while the smaller range in the Post-Test suggests a more uniform increase in motivation across students. The minimum score increased from 55 in the Pre-Test to 78 in the Post-Test, and the maximum score rose from 70 to 88, demonstrating an overall improvement in student motivation after the intervention. Additionally, the sum of all scores in the Pre-Test is 1491, while in the Post-Test, it increased to 1998. The mean (average) score also showed a significant improvement, rising from 62.125 in the Pre-Test to 83.25 in the Post-Test, indicating an overall enhancement in student motivation. Moreover, the standard deviation (4.26627) and variance (18.201) in the Pre-Test are higher compared to the Post-Test values (3.06807 and 9.413, respectively). This suggests that the Pre-Test scores were more dispersed, whereas the Post-Test scores were more clustered around the mean, indicating a more consistent and homogeneous improvement in motivation levels among students.

Table 1. Descriptive Statistics of Pre-Test and Post-Test Learning Motivation Scores

	Pre_Test	Post_Test
Range	15	10

Minimum	55	78
Maximum	70	88
Sum	1491	1998
Mean	62.125	83.25
Std. Deviation	4.26627	3.06807
Variance	18.201	9.413
Skewness	0.199	-0.169
Kurtosis	-0.621	-1.027

Regarding skewness, the Pre-Test has a positive skewness value of 0.199, meaning that more students had scores below the mean before the intervention. In contrast, the Post-Test shows a slightly negative skewness (-0.169), indicating that more students achieved scores closer to the higher end of the scale, confirming an overall improvement in motivation. Similarly, the kurtosis value in the Pre-Test is -0.621, while in the Post-Test, it is -1.027, indicating a platykurtic distribution in both cases, meaning the distribution is flatter than a normal distribution with fewer extreme values. However, the lower kurtosis value in the Post-Test suggests that student motivation scores became more evenly distributed after the intervention. The statistical results indicate a significant improvement in student motivation after using Kahoot! as a learning tool. The higher mean, reduced variability, and positive shift in skewness suggest that students became more engaged and motivated. The intervention effectively narrowed the performance gap, leading to higher and more consistent motivation levels across students. These findings support the notion that integrating digital game-based learning tools into educational settings can have a positive impact on student motivation and engagement.

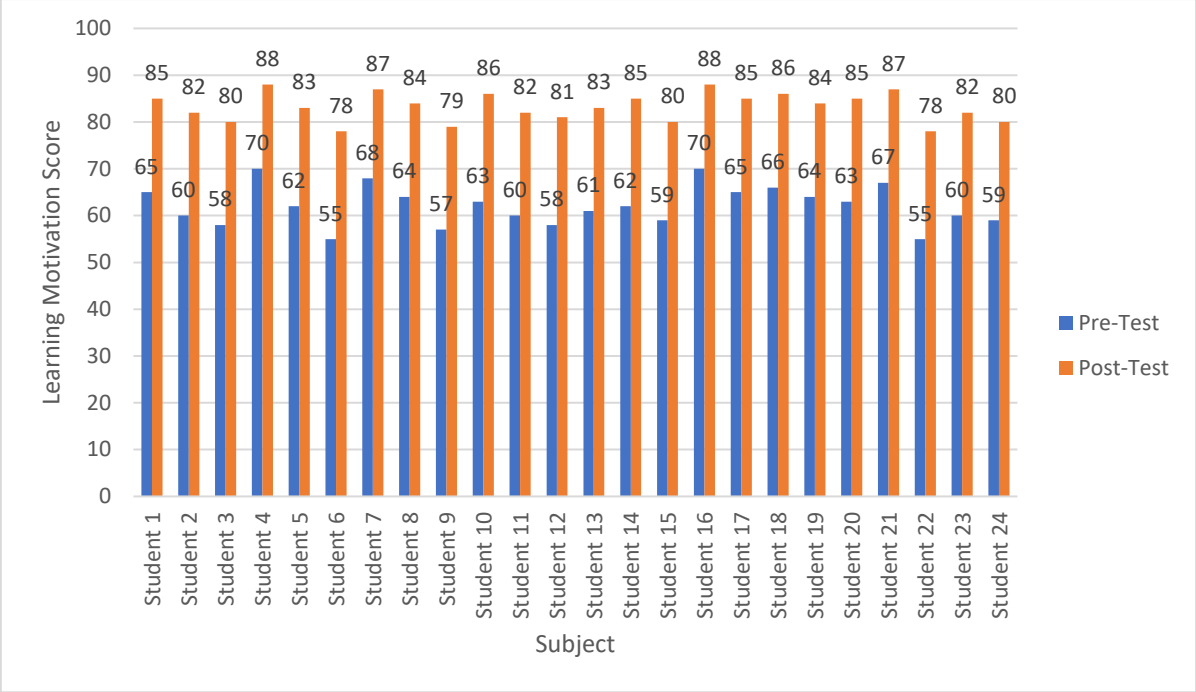

Figure 1. Comparison of Pre-Test and Post-Test Learning Motivation Scores of Students

Figure 1 presents data on student learning motivation before and after the intervention, as measured through pre-test and post-test scores. The table includes 24 students, each of whom was assessed for their motivation levels before the implementation of the Kahoot! learning method (Pre-Test) and after the intervention (Post-Test). The data indicate a consistent increase in motivation scores for all students after participating in Kahoot!-based learning activities. Pre-test scores range from 55 to 70, while post-test scores range from 78 to 88, showing a significant improvement across all students. The highest pre-test score recorded was 70, while the highest post-test score reached 88, demonstrating an increase of 18 points. Similarly, the lowest pre-test score was 55, which increased to 78 in the post-test, reflecting a positive shift in motivation. On average, the post-test scores exhibit a notable improvement compared to the pre-test scores, suggesting that the use of Kahoot! effectively enhanced student motivation in learning science. The increase in motivation scores highlights the potential of gamified learning tools in fostering greater engagement and enthusiasm among elementary school students.

Statistical Test Results

The output presents the results of the Wilcoxon Signed-Rank Test, a non-parametric test used to compare two related samples, specifically the Pre-Test and Post-Test scores. This test is suitable for paired data that do not follow a normal distribution, making it an appropriate choice for evaluating the impact of an intervention on student learning motivation.

Table 2. Wilcoxon Signed-Rank Test Results for Pre-Test and Post-Test Comparison

Null Hypothesis	Test	Sig. (p-value)	Decision
The median of differences between Pre-Test and Post-Test equals 0.	Related-Samples Wilcoxon Signed Rank Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The null hypothesis (H_0) states that "The median of differences between Pre-Test and Post-Test equals 0," which implies that there is no significant difference between the two test scores. The test results indicate a p-value of .000, which is less than the significance level of 0.05. As a result, the null hypothesis (H_0) is rejected, confirming a statistically significant difference between Pre-Test and Post-Test scores. This finding suggests that the use of Kahoot! as an intervention significantly improved student motivation and learning outcomes. The increase in Post-Test scores compared to Pre-Test scores is not due to random chance but reflects a real effect of the intervention. These results are consistent with previous research highlighting the benefits of digital game-based learning (DGBL) in enhancing student engagement and motivation. Therefore, incorporating Kahoot! in elementary science education can be considered an effective strategy to improve student learning experiences and outcomes.

DISCUSSION

Impact of Kahoot! on Student Motivation

The findings of this study demonstrate a significant improvement in student motivation after using Kahoot! as an instructional tool. The mean score increased from 62.125 in the Pre-Test to 83.25 in the Post-Test, indicating a notable enhancement in learning motivation. Additionally, the reduced standard deviation and variance in the Post-Test suggest that motivation levels became more uniform across students. The Wilcoxon Signed-Rank Test results further confirm the significance of this improvement, with a p-value of .000, leading to the rejection of the null hypothesis. This study's results suggest that incorporating game-based learning tools like Kahoot! fosters student motivation and engagement. The data highlight not only a numerical improvement in scores but also a more homogeneous distribution of motivation levels across participants. Such findings reinforce the assertion that digital educational interventions can positively shape students' learning experiences.

Theoretical and Empirical Support for Game-Based Learning

These results align with the initial research hypothesis that integrating game-based learning tools would positively impact student motivation. Previous studies have similarly found that digital game-based learning can enhance student engagement and motivation (Licorish & Lötter, 2022; Thi Van Pham et al., 2021). The findings confirm that gamified learning strategies create an interactive environment that fosters motivation. By making learning more interactive and competitive, game-based learning tools encourage students to be more engaged with their studies, which translates into higher motivation levels and improved learning outcomes. Furthermore, these findings are consistent with self-determination theory, which posits that intrinsic motivation can be enhanced through autonomy, competence, and relatedness (Ryan & Deci, 2000). Kahoot! aligns with these elements by allowing students to participate in an engaging, autonomous, and competence-driven learning process, which ultimately strengthens their motivation.

Distribution and Inclusivity of Motivation Improvement

A key trend observed in the data is the narrowing of the range from 15 (Pre-Test) to 10 (Post-Test), indicating that motivation levels became more consistent among students. The positive shift in skewness from 0.199 to -0.169 and the decline in kurtosis values from -0.621 to -1.027 suggest that students' scores clustered around higher values after the intervention, reflecting improved motivation and engagement. Additionally, the increase in the minimum score from 55 to 78 suggests that even the least motivated students experienced considerable improvement. This finding underscores the inclusivity of game-based learning, as it appears to benefit students across different performance levels. The improvement in standard deviation also suggests that the effectiveness of Kahoot! as a motivational tool was consistent across various learners.

Implications for Future Research and Educational Practice

These findings contribute to the growing body of literature on digital game-based learning, reinforcing its effectiveness in enhancing student motivation (Candan & Başaran, 2024). The study supports the argument that incorporating interactive tools like Kahoot! can create more engaging learning experiences and improve student outcomes (Tsihouridis et al., 2023). The broader implications of this study suggest that educational technology tools should be more widely integrated into curricula to maximize student engagement. In particular, the findings provide empirical support for previous research that emphasizes the importance of

gamification in education, not only as a means of entertainment but as a legitimate pedagogical approach that enhances learning outcomes.

One unexpected finding was the significant increase in the minimum score from 55 to 78, suggesting that even lower-performing students benefited from the intervention. This aligns with prior research indicating that game-based learning provides an inclusive environment that benefits students of varying academic abilities (Rayan & Watted, 2024). A possible explanation for this trend is that students who traditionally struggle with conventional learning methods may find gamified learning more engaging and accessible. Kahoot! introduces an element of fun and competition, which may lower anxiety and increase intrinsic motivation for students who typically experience difficulty in a traditional classroom setting.

Despite the positive results, certain limitations must be acknowledged. The study was conducted on a relatively small sample (24 students), which may limit the generalizability of the findings. Additionally, the use of self-reported motivation scores could introduce bias. Future research should explore larger samples and incorporate multiple assessment methods to validate these findings. Moreover, while the study demonstrates short-term benefits, it does not assess the long-term impact of game-based learning on motivation and academic performance. Future research should consider longitudinal studies to examine whether these improvements persist over time or if motivation levels decline after the novelty of the game-based approach diminishes.

The use of the Wilcoxon Signed-Rank Test adds statistical robustness to the findings, confirming that the improvement in motivation was not due to random chance. The consistency of results with previous studies further supports the reliability of these findings (Candan & Başaran, 2024; Thi Van Pham et al., 2021). Additionally, the alignment of findings with established theories on motivation and gamification further strengthens the credibility of the results. The consistency with self-determination theory, reinforcement theory, and cognitive load theory provides a solid theoretical basis for understanding the effectiveness of Kahoot! as an instructional tool.

These results have significant implications for educational practice and policy. Educators should consider integrating digital game-based learning tools to enhance student motivation. Policymakers can also support initiatives promoting technology-enhanced learning strategies in schools. Future research should investigate the long-term impact of game-based learning interventions on student academic performance and motivation retention. In addition to practical applications, these findings highlight the need for professional development programs that equip teachers with the skills to implement game-based learning effectively. Training

educators on how to use tools like Kahoot! in pedagogically sound ways could further enhance their impact on student engagement and learning outcomes.

While the increase in motivation could be attributed to Kahoot!, other potential factors—such as novelty effects or teacher enthusiasm—should be considered. Future studies should control for these variables to isolate the direct impact of game-based learning tools. Additionally, variations in teaching styles, classroom environments, and subject matter may influence the effectiveness of Kahoot! as a motivational tool. Comparative studies that examine different learning contexts could provide deeper insights into the mechanisms behind gamified learning and its impact on various student populations.

CONCLUSION

The findings indicate a significant improvement in students' motivation after using Kahoot! as an instructional tool. Students demonstrated higher enthusiasm, increased participation, and greater engagement in the learning process. Kahoot! created an interactive and competitive learning environment that encouraged students to be more active and motivated. This study reinforces the effectiveness of digital game-based learning in enhancing student motivation and engagement. Additionally, the results highlight the role of autonomy, competence, and interaction in fostering intrinsic motivation. From a practical perspective, the study emphasizes the importance of integrating game-based learning strategies into curricula to enhance student participation. Moreover, the findings suggest that game-based learning tools like Kahoot! can help bridge motivation gaps among students, promoting a more inclusive learning experience. Overall, this study affirms the potential of Kahoot! as an effective pedagogical tool for fostering student motivation and engagement, supporting its broader implementation in educational settings.

REFERENCE

Candan, F., & Başaran, M. (2024). A meta-thematic analysis of using technology-mediated gamification tools in the learning process. *Interactive Learning Environments*, *32*(7), 3332–3348. Scopus. https://doi.org/10.1080/10494820.2023.2172589

Chen, C.-C., & Tu, H.-Y. (2021). The Effect of Digital Game-Based Learning on Learning Motivation and Performance Under Social Cognitive Theory and Entrepreneurial Thinking. *Frontiers in Psychology*, *12*. Scopus. https://doi.org/10.3389/fpsyg.2021.750711

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (Fifth edit). SAGE.

DeVellis, R. F., & Thorpe, C. T. (2021). *Scale development: Theory and applications*. Sage publications.

Etikan, I. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1. https://doi.org/10.11648/j.ajtas.20160501.11

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th edition). SAGE.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2019). *How to design and evaluate research in education* (Tenth Edition, International Student Edition). McGraw-Hill Education.

Huang, C.-H. (2021). *Explore the Effects of Usefulness and Ease of Use in Digital Game-Based Learning on Students' Learning Motivation, Attitude, and Satisfaction*. *366*, 26–39. Scopus. https://doi.org/10.1007/978-3-030-78448-5_2

Hung, C.-Y., Sun, J. C.-Y., & Liu, J.-Y. (2019). Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds. *Interactive Learning Environments*, *27*(8), 1028–1046. Scopus. https://doi.org/10.1080/10494820.2018.1481103

Licorish, S. A., & Lötter, A. L. J. (2022). When Does Kahoot! Provide Most Value for Classroom Dynamics, Engagement, and Motivation?: IS Students' and Lecturers' Perceptions. *Journal of Information Systems Education*, *33*(3), 245–260. Scopus.

Lin, W.-C., Ho, J.-Y., Lai, C.-H., & Jong, B.-S. (2014). *Mobile game-based learning to inspire students learning motivation*. *2*, 810–813. Scopus. https://doi.org/10.1109/InfoSEEE.2014.6947779

Liu, H., Wu, Z., Lu, Y., & Zhu, L. (2023). Exploring the Balance between Computational Thinking and Learning Motivation in Elementary Programming Education: An Empirical Study with Game-Based Learning. *IEEE Transactions on Games*, *15*(1), 95–107. Scopus. https://doi.org/10.1109/TG.2022.3143701

Pellas, N. (2024). Effects of Kahoot! On K-12 Students' Mathematics Achievement and Multi-Screen Addiction. *Multimodal Technologies and Interaction*, *8*(9), 81. https://doi.org/10.3390/mti8090081

Rashid, N. A. M., & Noor, N. M. (2023). *Enhancing Pre-Schoolers' Learning Motivation in Jawi Subject Through Game-Based Learning Application*. *2023-October*, 426–434. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85179013158&partnerID=40&md5=97b34da1c18ae14a3b6f2cd05b8dbcff

Rayan, B., & Watted, A. (2024). Enhancing Education in Elementary Schools through Gamified Learning: Exploring the Impact of Kahoot! On the Learning Process. *Education Sciences*, *14*(3). Scopus. https://doi.org/10.3390/educsci14030277

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*, 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Thi Van Pham, A., Thi Thao Ho, N., & Duy Nguyen, L. (2021). *An Investigation into Students? Motivation and Learning Effectiveness in Gamified Learning Experiences via Kahoot! At a Higher Education Institution in Vietnam*. 5–10. Scopus. https://doi.org/10.1145/3481056.3481066

Tsihouridis, C., Batsila, M., Vavougios, D., & Tsichouridis, A. (2023). *"In Vivo" Science Learning—Academic Teaching Through a Game-Based Process*. *634 LNNS*, 151–162. Scopus. https://doi.org/10.1007/978-3-031-26190-9_15

Wang, K., Liu, P., Zhang, J., Zhong, J., Luo, X., Huang, J., & Zheng, Y. (2023). Effects of Digital Game-Based Learning on Students' Cyber Wellness Literacy, Learning Motivations, and Engagement. *Sustainability (Switzerland)*, *15*(7). Scopus. https://doi.org/10.3390/su15075716

Yeh, Y.-T., Hung, H.-T., & Hsu, Y.-J. (2017). *Digital Game-Based Learning for Improving Students' Academic Achievement, Learning Motivation, and Willingness to Communicate in an English Course*. 560–563. Scopus. https://doi.org/10.1109/IIAI-AAI.2017.40

Zheng, Y., Zhang, J., Li, Y., Wu, X., Ding, R., Luo, X., Liu, P., & Huang, J. (2024). Effects of digital game-based learning on students' digital etiquette literacy, learning motivations, and engagement. *Heliyon*, *10*(1). Scopus. https://doi.org/10.1016/j.heliyon.2023.e23490