INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES
Vol 14, Issue 9, (2024) E-ISSN: 2222-6990

Gamification and its Impact on Learning Fundamental Physics: A Meta-Analysis

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To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v14-i9/22701 DOI:10.6007/IJARBSS/v14-i9/22701

Published Date: 20 September 2024

Abstract

The objective of this meta-analysis is to methodically evaluate the efficacy of gamification in enhancing students' understanding of fundamental principles in the field of physics. Through an extensive exploration of scholarly databases, a significant body of research on the implementation of gamification in the context of physics education was discovered. This rigorous process led to a final sample of physics gamification studies that were included in the meta-analysis. The effect sizes were computed for each individual study and subsequently combined using meta-analytic methods to assess the overall influence of gamification on the results of physics learning. The meta-analysis reveals a statistically significant positive effect size (ES = 25.32, 95% CI: 1.75 to 48.89) indicating that gamification has a beneficial impact on students' understanding of fundamental physics concepts. Subgroup analyses further explore the moderating factors, such as the type of games employed and duration of intervention, shedding light on the specific conditions under which gamification is most effective. This meta-analysis shows a significant impact on the student's performance in the event gamification elements are introduced in the learning environment (P = 0.04). The present meta-analysis offers empirical data supporting the positive influence of the subject under investigation, and proposes potential directions for future research and the development of instructional design.

Keywords: Comprehension, Fundamental Physics, Gamification, Meta-Analysis

Introduction

Teaching physics through the use of games looks very radical at first sight, but there is more to a game concept. Gamification can be defined as the use of game characteristics in other contexts like the classroom in order to improve motivation. In order for a learning environment to be considered as gamified, it must contain five components of a game; levels, rules, leaderboard, badges and points (Zainudin & Zulkiply, 2023; Tolentino & Roleda, 2017). Due to the novelty of such approaches, however, how these elements of game environments influence comprehension and help to answer different types of basic questions is discussed in contemporary studies. In their research, Tolentino & Roleda (2017) examined the impact of a gamified learning environment that belongs to the transformative learning model on the students' high school physics performance. In this study, the findings showed an enhancement in performance hence supporting the assertion that gamification affects students' performance in physics (Tolentino & Roleda, 2017). It is, thus, while the data is traced with a considerable degree of academic keenness in this study, this rigor is not enough to provide the degree of certainty that would allow for drawing conclusions. Hence, more studies have been carried out with the aim of establishing the relevance of Self-Determination Theory (SDT) in students' learning processes in different subjects including physics and other subjects.

Self-Determination Theory (SDT) stems from human motivation and personality in social environment. It asserts that people are inherently energetic, autonomous, and looking for information even when receiving no incentives (Deci & Ryan, 2012). Jung et al. (2010) and Mekler et al. (2013) justified that gamification elements enhance an individual's motivational behavior, when they conducted the study on the motivational perspective of gamification. This is however possible in the short run only and the continuation of this form of behavior is only possible if the gamified system remains up. Such gamified systems change the rewards paradigm originated from internal motivators to the external stimulus to a certain extent (Brühlmann et al., 2013). Brühlmann (2013) notion of three factors which make it possible to link the given shift in motivation from an internal to the external source with self-determination theory. These were all identified to be physical factors, situation factors and context factors. Ryan and Deci (2000) explained SDT as the orientation that is cause oriented and activity oriented motivational orientations. consequently, according to the findings, SDT defines the landscape of the concept of gamification in order to design, organize and implement it.The growing body of research is increasingly using SDT as the starting point for gamification studies for non-game environments. With the successful application of SDT in the context of video games, the theory begins to clarify how gamification can work in a non-game environment (Ryan et al., 2006). Brühlmann (2013), further expand the idea of gamification by discussing the motivational concept of flow. In motivation, flow is referred to as the state of utter concentration and absorption in the task at hand (Brühlmann et al., 2013). To ensure flow in the task, the task designers should ensure that the user experience of the gamification facilitates the occurrence of flow.

Previous studies have looked at the realistic possibility of physics gamification through primary observations in this area. In their study, Rose (2016), sought to understand the possibilities of using gamified online undergraduate physics content as a way of improving the students' learning outcomes and boost motivation. The studied used points, streaks, the concept of a leaderboard, achievements, graphical rewards and enhanced feedback that are common in game-based environments. Rose (2016), linked techniques that were game related to greater interaction with content and classroom procedures. Carefully designed gaming techniques have a place in keeping students engaged in the classroom content even when doing distance learning. Platforms such as Google Classroom, Prodigy, Kahoot, and Nearpod, among others, form a plethora of gamified applications currently available for learners. Henukh and Guntara (2020), observed how learners responded to using Kahoot to learn physics. The researchers calculated for reliability and validation using the KR-20 formula and product moment formula, respectively. The average score obtained from this test was 87.28%, which is within the select category (Henukh & Guntara, 2020). However, perhaps the most elaborate trial conducted under this domain is by Vieyra (2020): Gamified physics challenges for teachers and the public. In this article, the authors developed and deployed an Android gamified component that can engage children and adults through curated concepts under the fundamentals of physics. The app disseminated a wide range of content to primary, secondary, and undergraduate students. The investigation revealed that students completed challenges through the app and demonstrated growth in their understanding of physics (Vieyra et al., 2020).

Introducing physics-oriented challenges to learners and their educators through gamified platforms is one of the methods proven effective in the gamification of learning environments. However, most studies have only provided observations that cannot fully cement the potentialities of gamification. Moreover, the current body of literature does not present a wide range of works from international literature that investigate a standardized method of teaching that is gained through this learning methodology. Therefore, the current study aims to explore the efficacy of gamification when teaching physics by checking whether gamification physics can solve the misunderstanding in fundamental physics.

Methodology

Study Design

This is a meta-analysis in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The meta-analysis probes the potentiality and efficacies of game techniques in teaching physics and how the whole game structure can help solve the misunderstandings that occur in fundamental physics.

Literature Search

Science Direct, IEEE Xplore, and ACM Digital Library were used to search for relevant articles to be included in this analysis. Articles used in the present study were identified through indexed searches that ensured sufficient and credible literature materials were available for review. Gray literature from Google Scholar was also incorporated to ensure that the study covered a large scope of studies. For the study search, various techniques were employed. The primary search method used was keyword combinations which formed a basis for building an elaborate search. Other incorporated elements were field tags such as text-word [tw] and title-abstract [tiab]. The study further incorporated the use of Boolean operators "OR" and "AND" to broaden the reach. Truncations were also used to complete the search queries. The search process used two base keywords: game AND physics. These were built into other combinations such as ('gamification' OR 'gamified') AND 'physics learning' OR 'physics education' OR 'physics fundamentals.' All base keywords were searched as [tiab] field tags ('game' [tiab] AND 'physics' [tiab]) while everything else was searched as a [tw] field tag ('physics fundamentals' [tw] AND 'gamification' [tw]). The study search was executed in July 2022, and the Mendeley reference manager managed references.

Eligibility Criteria

For this meta-analysis, a PECOS inclusion/exclusion criterion was adopted to sieve through the discovered studies. The population (P) was not a major consideration in terms of their education level, provided that the learners observed were physics learners. The exposure (E) was key for this meta-analysis since we needed to observe gamification employed in a physics learning environment. The studies included had to have compared (C) this exposure to a standard physics learning environment. Key outcomes (O) for this study were the learners increased ability to understand concepts of physics which were considered a step towards solving the misunderstandings about fundamental physics. Accepted study designs (S) were case-controlled observational, longitudinal, randomized, or cohort studies. All included studies had to have been published in English. Two reviews applied these criteria, and their results were compared to iron out any existing incongruences.

Data Extraction

Data were extracted into a standardized excel sheet with data elements pre-set by the researchers. Two reviewers were independently involved in the process to provide a comparison of results and point out any potential extraction mistakes. For this meta-analysis, the information extracted was the study's first author and year of publication, the game elements used, and gamified education activities. The extraction shall also identify the setting of each experiment and the outcomes measured. Finally, the results of the experiment shall be collected and arranged into three distinct outcomes of interest; performance, attitude, and engagement.

Statistical Analysis

The extracted data, comprising relevant information from various sources, was forwarded to the dedicated analytical team for comprehensive statistical analysis. The team utilized STATA Version 17.0 (Stata V.17.0), a widely recognized statistical software package, to conduct the analysis.

To assess the degree of heterogeneity among the included studies, the team employed the Q and I2 statistics. The aim was to understand the variability and diversity of the data across different studies. It was considered more appropriate if the level of heterogeneity fell within the range of 25% < I2 < 50% or below, indicating a moderate level of heterogeneity.

Finally, while estimating the magnitude of the outcomes, the team used meta-analysis and specifically the random-effects model. This model is useful as it provides more modest measures of the effect size, which not only allows for the consideration of variation within each of the studies involved, but also looks at the inter-study differences. Namely, the odds ratio was computed to measure the associations between study variables of interest.

Therefore, in assessing the level of association or correlation between variables, P – values were used. A P-value of P ≤ 0 does therefore deliver the intended statement of significance differences between the two groups. 0.05 was taken as the level of significance for the analysis and 0. The analysis of the results would be then carried out and where the P-value obtained was equal or less than this figure of merit, it could be concluded that the result obtained was significant and therefore it was concluded that the relationship obtained was not likely to be by chance.

As an output of the meta-analysis, forest plots were generated. These plots offer a neat and precise depiction of the effect sizes and learners' intervals for each study contained in the analysis. Also, funnel plots were created to determine the publication bias. By examining the symmetry of the funnel plot, insights can be gained into any potential bias in the selection and reporting of studies, thereby providing further credibility to the established relationships. Overall, this thorough statistical analysis using appropriate methodologies and visualization techniques allowed for drawing meaningful conclusions and providing valuable insights based on the extracted data.

Results and Findings

Study Selection

We identified 1233 articles from the entire literature search. Duplicates 312 were eliminated before the screening, and 921 articles were brought forward for inclusion consideration. The screening reviewers removed 647 articles for being incompatible with the purpose of the systematic review and meta-analysis. This step was actualized through title and abstract screening, where studies were checked for general methodological eligibilities. The remaining 274 studies went ahead for full-text screening, and 264 studies were eliminated, leaving 10 included in the meta-analysis. Fig. 1 below represents a PRISMA flow-chart diagram that shows the study selection process.

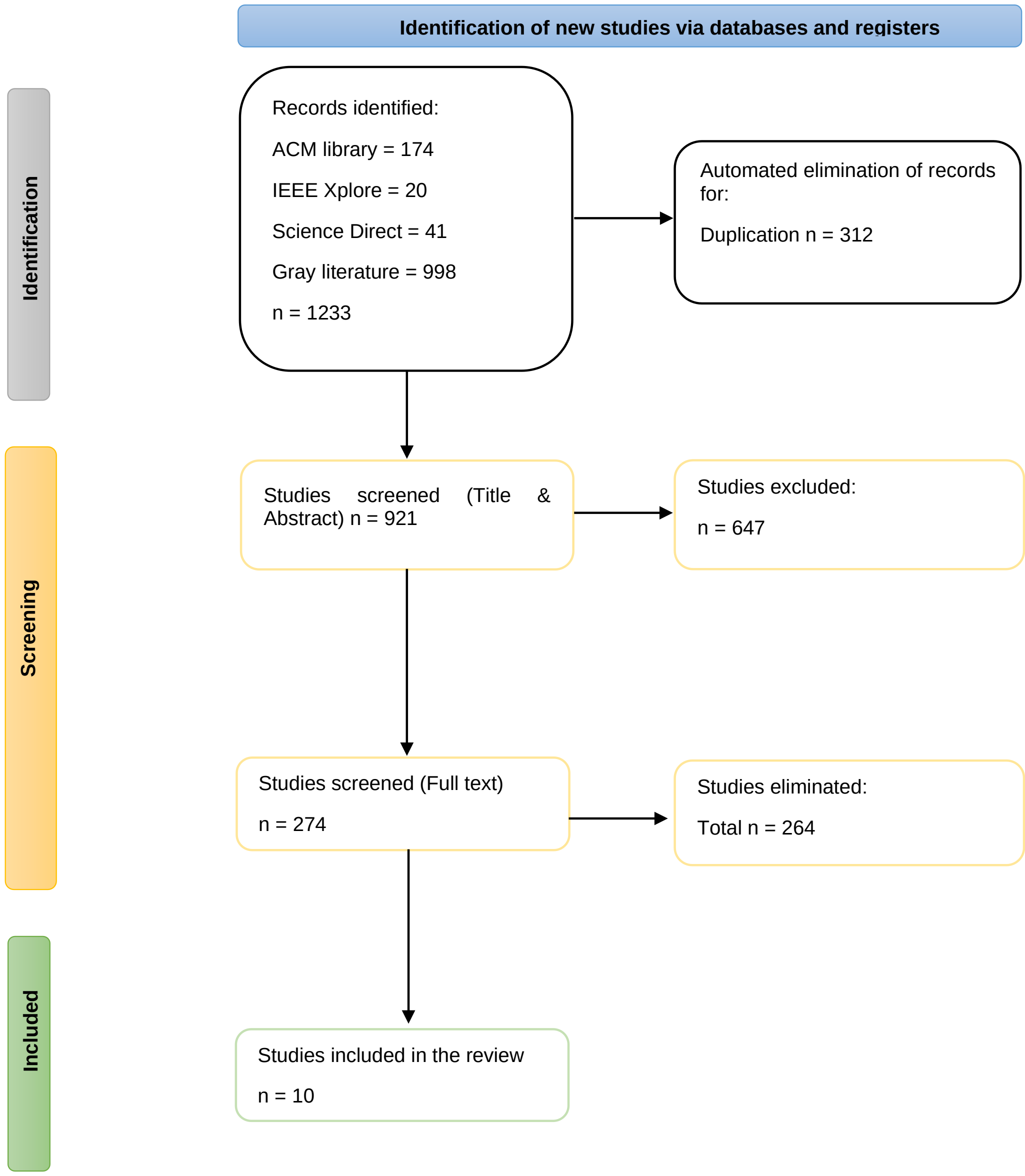

Fig. 1 PRISMA flow diagram of studies included in the meta-analysis

Study Characteristics

The information about the studies included in the systematised review is described in Table 1. The 10 studies used in the quantitative synthesis had samples of patients 385 in total with age between 12 and 22 years and the sample size were varied between 33 and 386. The most widely applied of the game type for physics education is the leader board game. The path coefficient between skill and the level of engagement was 0.375 while that of the path coefficient between skill and immersion was 0. 282. The subject matter of the study was the impact of challenge and skill on perceived learning within the sphere of gamification related to fundamentals of physics education. The results stipulated that challenge, and skill had no direct positive effect on the perceived learning, with the coefficient of 0.009.

Immediacy, in turn, was probed for its moderating effect on the link between skill and learning perceived. The findings showed that while engagement played a role between skill and perceived learning, immersion did not; with the coefficient being 0.209.

Regarding the hypothesized relationships between engagement, immersion, and perceived learning, presented in hypotheses 1-3, it can be stated that engagement was found to have a direct positive effect on perceived learning, equal to 0. 474. This indicates that the various degrees of participation in the learning context that was designed with elements of the game proceeded with the general quantity of perceived learning benefits. However, the perceived learning was not significantly affected by the level of immersion, with the coefficient values being 0.009. This implies that participants' perceived level of learning in the context of the gamified learning environment is not significantly influenced by the level of immersion.

These findings, as reported by Hamari in 2015, contribute to understanding the complex relationships between challenge, skill, engagement, immersion, and perceived learning in the context of gamification in fundamental physics. They highlight the importance of engagement as a mediator in the relationship between skill and perceived learning, while suggesting that immersion may not play a significant role in influencing perceived learning outcomes in this context.

Table 1
The data extracted from the 10 included studies

Author	***Game Elements***	***Gamified Activity***	***Setting***	***Reported Outcome***	***Results***
Rose, 2016	Points, streaks, leader boards, and achievements	List style quizzes with a multiple choice	These groups of 33 students in a first-year undergraduate Physics for Life Sciences course, wrote four multiple-choice quizzes over the term in two separated tests.; Gamified quiz group (Experiment (n) = 175) vs. List style quiz group (Control (n) = 161).	Qualitative and quantitative data on students' behaviors and achievement in the gamified quizzes compared with other students in the same classes who did not have such quizzes but other non-gamified	**Students' performance:** The number of quiz attempts was significantly higher in the gamified group compared to the list-style group, by factors of 2.8 (p = 0.124), 1.8 (p = 0.045), 3.4 (p = 0.024), and 6.3 (p = 0.015) for the four quizzes.

		assignments.	**Students' attitude:** More students in the gamified group continued attempting the quiz even after passing, with increases of 6.6 times (p = 0.027), 1.7 times (p = 0.144), 13 times (p = 0.001), and 10 times (p = 0.004) respectively, compared to the list-style group. **Students' engagement:** Students in the list-style group needed fewer attempts on average to pass a quiz than those in the gamified group. This difference was statistically significant for the third and fourth quizzes (p = 0.739, 0.618,

					0.000, 0.011, respectively).
Zainuddin, 2019	**Socrative:** "SpaceRace" game. **Quizizz:** Memes, avatars, themes, music, and leader boards. **iSpring Learn LMS:** Badges, Points, and leader boards.	Question-and-answer (Q&A) sessions, a paper-based quiz, and feedback	The three groups of participants received both conventional and gamified instruction. Group 1 (31), Group 2 (33), and Group 3 (30).	Academic performance for each paper-based quiz and academic performance for each gamified e-quiz.	**(Paper-based quiz) Paper-based quiz I: G1,** 74.68 (5.62). **G2,** 74.24 (6.63). **G3,** 74.00 (5.32). **Paper-based quiz II: G1,** 84.84 (4.18). **G2,** 88.03 (5.14). **G3,** 82.83 (5.83). **Paper-based quiz III: G1,** 85.97 (4.73). **G2,** 90.00 (6.25). **G3,** 85.83 (5.27). **(Gamified e-quiz) Gamified e-quiz I: Socrative,** 75.16 (5.70). **Quizizz,** 75.91 (6.78). **iSpring LMS,** 74.67 (5.71). **Gamified e-quiz II: Socrative,**

					85.00 (6.19). **Quizizz,** 86.67 (4.62). **iSpring LMS,** 83 (5.02). **Gamified e-quiz III: Socrative,** 85.97 (5.07). **Quizizz,** 90.30 (5.99). **iSpring LMS,** 84.17 (5.27).
Coca & Slisko, 2017	An unused "SpaceRace" game	Questions posed by the professor on Socrative.	Thirty-six prospective teachers studying for a degree in Primary Teaching. (1) The professor introduces some questions or situations in Socrative. Students answer individually. (2) Later, the professor downloads the answers, picks contentious questions, and has them answered in groups. (3) Then, the students answer the test individually again.	Experience with the Socrative and conceptual learning of the students	**Increased involvement:** 70% agree (18% neutral) 12% disagree. **Paying more attention:** 67% agree (24% neutral) 9% disagree. **Better understanding:** 54% agree (36% neutral) 9% disagree. More students preferred that the professor continues to use Socrative in teaching always (0%), more than now (20%), at the same frequency as now (53%), sometimes but less than

					now (24%), or never (3%).
Hamari, 2015	N/A	A questionnaire survey was used to measure the students' experience with the games they interacted with.	Setting 1 (S1): Quantum Spectre was played by 134 high school students fro 11 different classrooms from different places in the United States as part of physics unit on optics. Setting 2 (S2): A game called Spumone was played by forty undergraduate mechanical engineering students in the framework of the engineering dynamics course.	With regard to flow, which is the combination of increased challenge and skill level, the results showed that flow influenced the prediction of engagement and immersion in terms of perceived learning.	**Hypotheses regarding skill effects:** It was equally possible to establish a high path coefficient of skill to engagement equal to 0. 375 and skill to immersion coefficient of 0. 282. Nonetheless, challenge and skill did not affect Perceived learning as a dependent variable to a great extent (0. 009). The result shows that the extent to which participants believed that they learning was moderated by the level

					of engagement (0.209) and not by immersion. **Hypotheses among engagement, immersion, and perceived learning:** Engagement also affected perceived learning to be 0. 474 while as in the case of immersion it did not prove to be an effective measure with the figure recorded being 0. 009.
Hakulinen, 2015	Badges and grades.	The implementation of accomplishment badges in the TRAKLA2 online platform, where students engage in interactive exercises that are automatic	A total of 281 students were randomly split into two groups: one with achievement badges (treatment group) and one without (control group). The treatment group received achievement badges, but grading remained	Time management, carefulness, and learning.	Earning badges did not influence the final grade, although the exercise points themselves did. **Time Management**: Late submissions were 7.6% in the treatment

	ally evaluated, is used in a Data Structures and Algorithms course throughout the semester.	identical for both groups.		group compared to 10.1% in the control group. **Carefulness**: Students receiving badges spent more time per submission on average (treatment group mean = 8.59 minutes, control group mean = 7.26 minutes), with the difference being statistically significant. **Learning (number of exercise sessions throughout the course)**: The treatment group averaged 12.6 sessions, whereas the control group averaged 10.6 sessions, with the

					difference being statistically significant.
Legaki, 2020	Points, levels, challenges, and a leader board	Reading a research paper named thenceforth and challenge-based gamification, named thenceforth.	365 students from two different academic majors: To all Electrical and Computer Engineering respondents (n=279) and Business Administration respondents (n=86). Group Control: : i) no treatment or none, ii) treatment of reading the research paper hence referred to as task Read (see 3.3.3) and iii) the treatment of the use of challenge-based gamification or task Play (see 3.3.4) as well as iv) tasks Read&Play, which combines	Learning is defined in terms of performance and English proficiency.	**Performance:** (**Control**, n=28) 32.3 (11.4). (**Read**, n=27) 44.4 (18.4). (**Play**, n=47) 43.2 (20.6). (**Read&Play**, n=44) 56.7 (20.0). **English proficiency:** (**Control**, n=28) 3.36 (1.37). (**Read**, n=27) 3.59 (1.39). (**Play**, n=47) 3.77 (1.37). (**Read&Play**, n=44) 4.23 (0.96).

			both tasks: Read and Play.		
Chang, 2018	Scores and leader board	Teaching using the DGBL learning tools in the environment.	103 Taiwan college students: 50 in the experimental group used digital game-based learning (DGBL); 53 in the control group used computer-based learning (CBL).	Prior knowledge test and achievement test, Cognitive load questionnaire, Flow questionnaire	**Achievement test:** (DGBL) 80.16 (1.94). (CBL) 74.38 (1.88). **Flow:** (DGBL) 48.42 (1.02). (CBL) 44.50 (0.99). **Cognitive load:** (DGBL) 2.79 (0.60). (CBL) 5.09 (0.58).
Balci, 2022	Badges and leader boards	Quizzes and assignments	In experiment 1, N=102, badges and leader boards were used in only one component of the course grading system namely quizzes. All course grading system was gamified in experiment 2 (N=88) that is quizzes and assignment.**Experiment 1:** Complete by 81 participants (only	Academic performance and motivation.	**Experiment 1 quiz performance:** (Badges with leadership) 9.52 (0.54). (Control) 9.51 (0.45). **Experiment 1 number of attempts:** (Badges with leadership) 3.94 (1.1). (Control) 4.47 (1.7). **Experiment 1 motivation:**

	badges=18, only leader boards=20, both badges and leader boards=22, Control=21).**Experiment 2:** Completed by 88 participants comprised the final subject sample; badges only (n = 20), leader boards only (n = 22), both badges and leader boards (n = 23), control (n = 23).	The mean motivation score was 3.68 (SD=1.04) for the badges-only group and 3.78 (SD=0.89) for badges with leader boards group. The mean motivation score was 3.52 (SD=0.80) for the leader boards-only group and 3.45 (SD=0.76) for badges with the leader boards group. **Experiment 2:** The number of views for the badges was compared for a badges-only group (M=44.5, SD=18.82) and badges with leader boards group (M=40.96, SD=11.18). The mean number of views for five posted

					leader boards were as follows: leader boards-only group M=10.41, SD=7.15, and badges with leader boards group M=7.7, SD=8.54.
Bicen & Kocakoyun, 2018	Points, levels, trophies, badges, achievements, virtual goods, leader boards, and virtual presents	Weekly questions,	Enrolled students were 65 undergraduate students of the Department of Preschool Teaching.	Perceptions of the use of the Kahoot Platform. Performance. Motivation.	**Perception:** Inclusion of a gamification method increased the interest of students in the classroom (M=4.52, SD=.58). **Performance:** Students studied more to become successful through the gamification method (M=4.33, SD=.71). **Motivation:** Using gamification was observed to increase motivation (M=4.36, SD=.62) and communicati

	on to become more successful in the classroom (M=4.44, SD=.58). The reward system was thought to be motivating (M=4.35, SD=.59).

Results Analysis

Performance

As for the effect of the gamification techniques, eight studies addressed it in relation to the students' performance. The analysis outcomes of the total test further show the random effects size and odd ratios to be 25. 32 [1.75, 48.89] at 95% CI. As this meta-analysis demonstrates there are improvements in the student's performance in reference to the event if the gamification elements are incorporated in the learning space (P = 0. 04). The post and pre-surgical patient characteristics of the studies to which this was applied were highly diverse (I2 = 99. 96%). The analysis of this study is presented in the forest plot in Figure 2 below, and funnel plot for publication bias between the studies is in Figure 3.

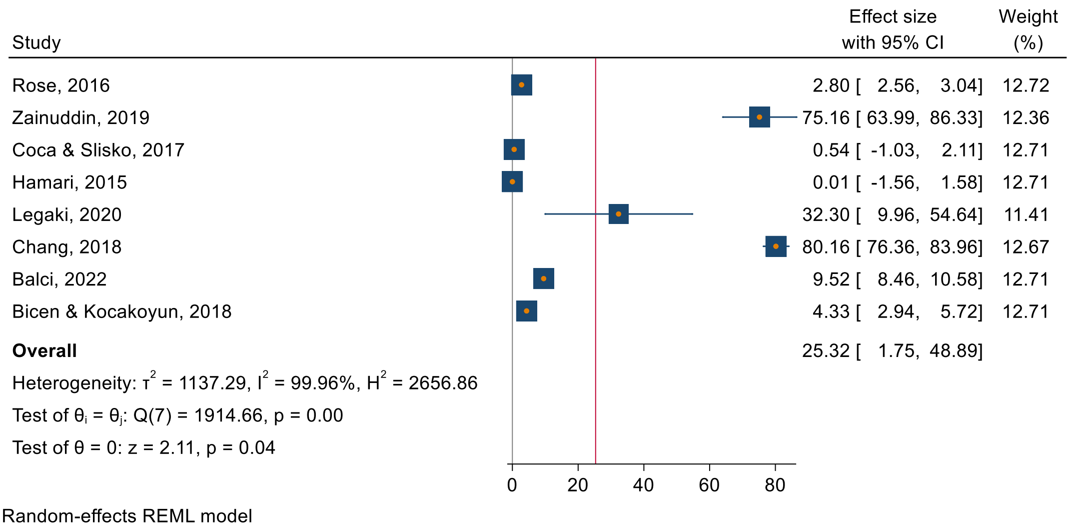

Fig. 2 Forest plot summarizing the analysis of the effects of gamification elements on students' performance.

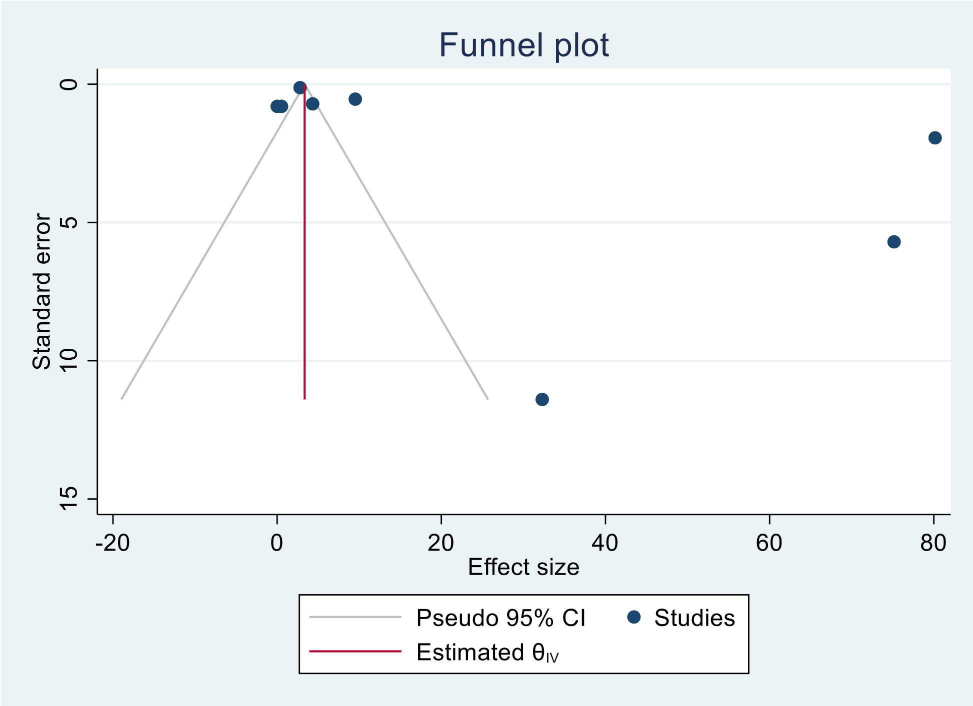

Fig. 3 Funnel plot representing publication bias of the included and analyzed studies.

Attitude

Seven of the included studies reported on the student's change in attitude toward learning after introducing gamification elements. The overall test results reveal a random effects size and odds ratio of 2.78 [0.91, 4.65] at 95% CI. In the analysis, we see that gamification elements significantly affect the attitude of learners (P = 0.00). Notably, the p-value returned by the analysis could be indicative of a random error within the dataset. Similarly, the studies used to make this analysis were highly heterogenous (I^2 = 94.86%). Figure 4 below is a forest plot summarizing this analysis, while Figure 5 is a funnel plot reporting the publication bias between the studies.

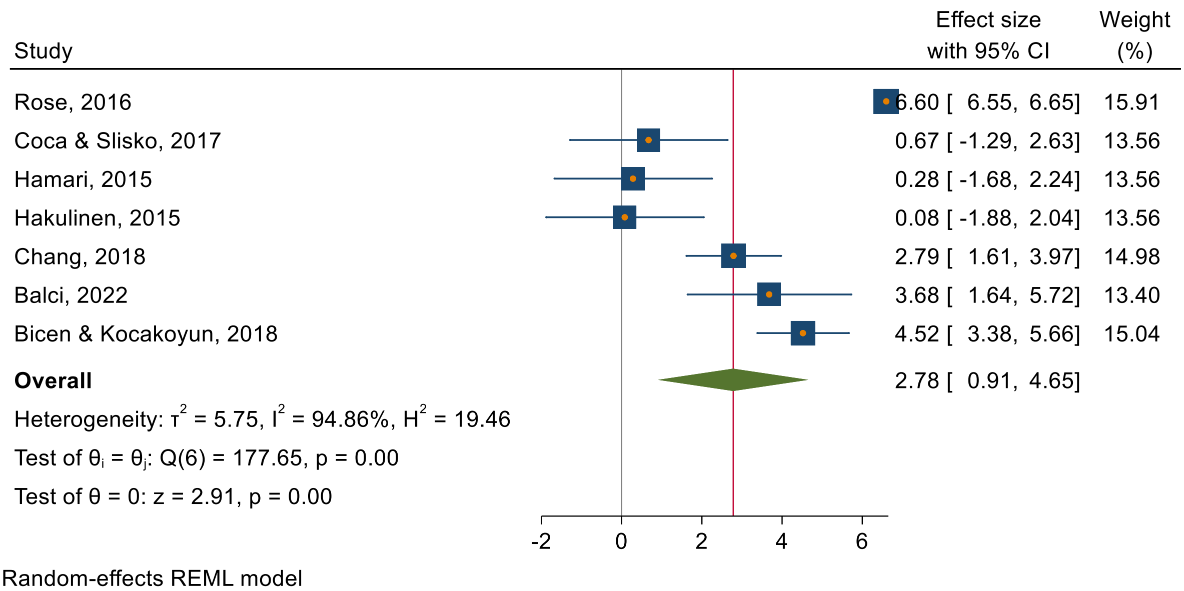

Fig. 4 Forest plot summarizing the analysis of the effects of gamification on students' attitudes.

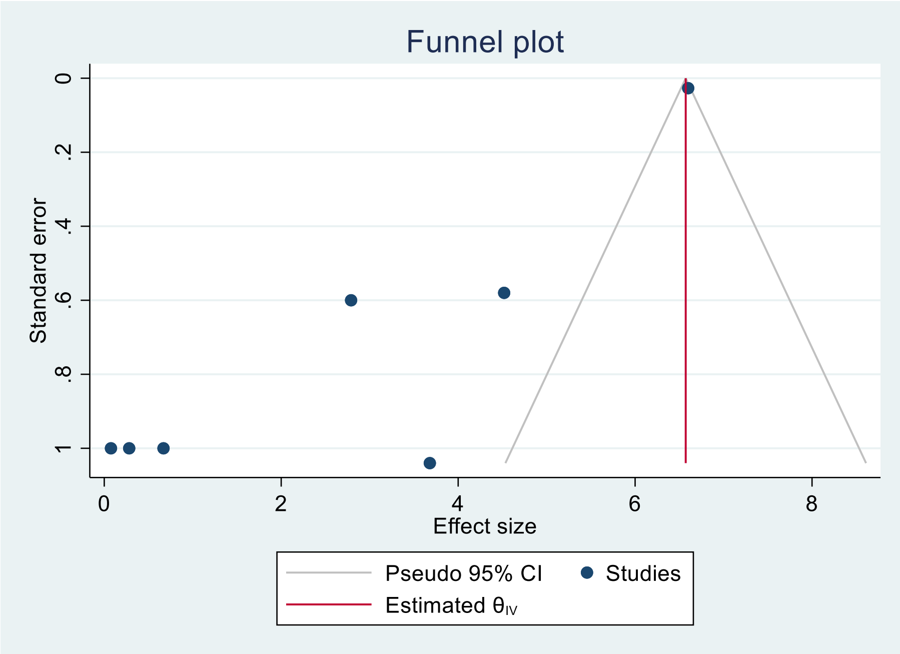

Fig. 5 Funnel plot representing publication bias of the included and analyzed studies.

Engagement

Five studies were analyzed to investigate the change in the student's engagement with the lessons. An overall random effects size and odds ratio of 17.55 [-3.64, 38.74] at 95% CI was discovered. However, this analysis showed no significant change in the student's engagement with the learning material even after introducing gaming elements into the learning environment (P = 0.10). In addition, studies used to make this analysis were found to be highly heterogeneous (I^2 = 99.81%). Figure 6 below is a forest plot summarizing this analysis, while Figure 7 is a funnel plot reporting the publication bias between the studies.

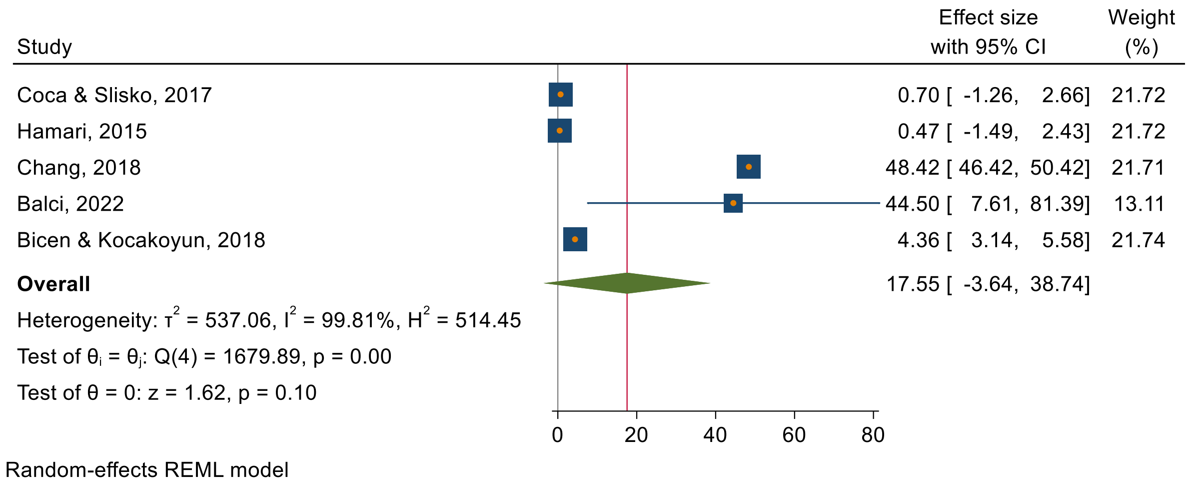

Fig. 6 Forest plot summarizing the analysis of the effects of gamification elements on students' engagement.

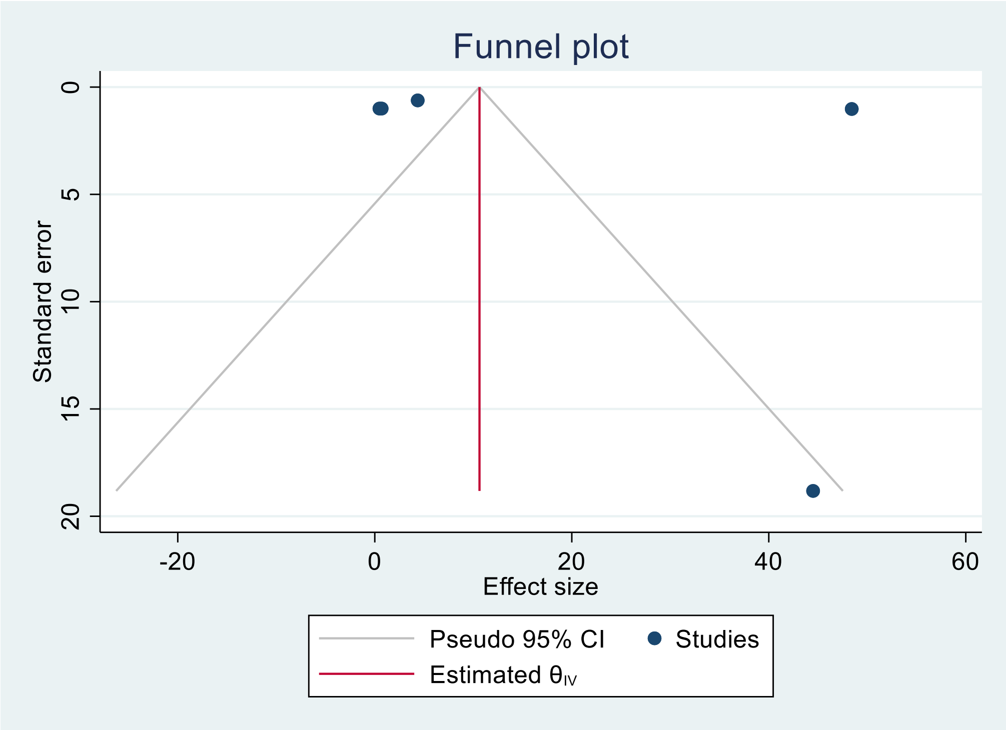

Fig. 7 Funnel plot representing publication bias of the included and analyzed studies.

Discussion
Gamification of education environments is founded on the objective of enhancing students' learning outcomes. The rationale behind these concepts is rooted in the theory of Self-Determination Theory (SDT) and the concept of flow, as previously discussed by Brühlmann et al. (2013). According to this meta-analysis, gamifying learning environments significantly improves learning outcomes, particularly in terms of performance (odds ratio 25.32 [1.75, 48.89] at 95% CI, P = 0.04) and learners' attitudes (odds ratio 2.78 [0.91, 4.65] at 95% CI, P = 0.00). Although the improvement in engagement was not statistically significant (17.55 [-3.64, 38.74] at 95% CI, P = 0.10), there was still an observable increase in learner engagement with the material when gamification elements were introduced.

Currently, the analysis of all the included studies allowed acknowledging that students of different educational levels were demonstrated to show improvements in terms of the given content and subject knowledge. The application of gamification elements helped students view the presented material in a new context, enabling them to engage with the content more creatively. According to Bicen & Kocakoyun (2018), the inclusion of motivational elements in the gamification methods increases students' engagement in class and enhances their chances of success. Yan and Ku's research was focused on impacts of Kahoot application within contexts of learning. On how learning environment can create competition among students Kahoot portrays how learners are willing to compete when in a learning environment that is instituted as a game. Writing about the result of the survey conducted by Bicen & Kocakoyun (2018) revealed that, with the help of gamification elements, the students could keep track of different elements of performance and also rate their performance against other students. This awareness of performance in turn was seen to be a major source of motivational drive which resulted in new heightened aspirations and hence improved performance in physics.

However, positive outcomes of the gamified learning environment have not always been successfully tested in different experiments. For example, Balci et al. (2022) compared impacts of leaderboards and badges to performance and motivational changes while the differences were insignificant. While this particular work denies the theoretical foundation, other research concurs with the favourable impact of gamification on the learning outcomes.

The current meta-analysis gives a statistical answer and reasonably proves the effectiveness of learning environments based on the principles of gamification in increasing student performance. Particularly, in the case of teaching physics, included studies such as Balci et al (2022), indicate that failing to provide an informed analysis it does not necessarily entail positive outcomes even if it introduces gamification elements to students. Namely, going forward, education facilities will have to realize that the existing use of gamification in teaching implies the identification of which game components and gamified actions work best when it comes to developing a deeper understanding of fundamental physics.

While the study provides valuable insights and highlights the future direction of gamification in teaching, it is important to note that the present study exclusively employs single-arm experiments, which may introduce bias and reduce the reliability of the study. Therefore, future studies should focus on conducting more randomized controlled trials (RCTs) to achieve stronger evidence. It will not only provide grounds for the continuation of meta-synthesis but also provide more solid evidence of positive impact of educational gamification. The present study supports the efficacy of gamification in facet of physics tuition but at the same time points out the importance for the implementors to carefully choose and integrate the game elements and activities that will result in beneficial effects on the students’ learning achievement.

Conclusion

This meta-analysis sought to establish the utility of gamification in the context of teaching physics, specifically aiming to determine whether gamified approaches can address and resolve misunderstandings in fundamental physics concepts. By integrating game elements and gamified learning activities into physics education, the meta-analysis explored the extent to which these strategies could enhance students' performance, attention, and engagement.

A thorough review of the extensive analysis suggested that embracing fun elements in the learning environment constellations boosted the learners’ performance and focus. Based on these results, it can be concluded that there is high potential for using gamification to enhance students’ actual perceptions of the key concepts in the physical world, thus contributing to the rectification of mental misconceptions as expressed and entertained by students prior to engaging with the educational intervention.

Specifically, the investigation focused on the effects that points, badges, leaderboards, and game-like tasks had to enhance the learning process’s interest level. Apart from making the learning process more enjoyable these elements also helped in creating a competitive environment among the students: in order to achieve higher scores and better results students tried their best during the learning process.

Furthermore, increased attention that appeared differentiated in students withing the gamified learning environment points to the fact that such approaches are capable of capturing and maintaining students' interest in physics, a subject that could be considered difficult and conceptual by many. Combining physics-learning activities with elements of gaming ensures that the latter makes learning easier to understand and relate to.

To sum up, the meta-analysis highlights that gamification can significantly contribute to the enhancement of learning processes in subjects that require concepts' clarifications, such as physics. Educationally speaking, adopting some of the aspects from game design can increase students' classroom performance as well as increase their learning interest, and better understanding of the material.

Moreover, the study underpins the fact that an appropriate level of implementation of the gamification elements is crucial to boost educational outcomes. It infers that an effectively designed curriculum whose components could be incorporated into games could help students to get timely feedback on their learning processes so that they could correct their mistakes. Cycling through the material and self-reflection is effective in enhancing the students' knowledge and identifying the misconceptions.

Therefore, based on the data obtained in this meta-analysis, it can be concluded that online gamification can be regarded as an effective method for increasing people's understanding of basic concepts in physics. The results of increased performance and attentiveness in games prove that these techniques can pin-point and resolve misconceptions in physics. On the premise that educational institutions are constantly searching for new teaching approaches to increase their effectiveness, the integration of keys aspects of games becomes one of the most effective practices pursued in this sphere at the present stage.

Acknowledgements
This work is fully sponsored by IIUM-UMP-UiTM Sustainable Research Collaboration Grant 2020 (600-RMC/SRC/5/3 (054/2020)).

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