International Journal of Game-Based Learning
Volume 14 • Issue 1

The Impact of Educational Games on Learning Outcomes:
Evidence From a Meta-Analysis

Jiaopin Ren, Zhongyuan Institute of Science and Technology, China
https://orcid.org/0000-0001-8709-9928

Wei Xu, City University of Macau, China*
https://orcid.org/0000-0002-7224-1116

Ziqing Liu, City University of Macau, China

ABSTRACT

The objective of this study is to examine and compare the impact of serious games and gamification on learning achievement and motivation. The results of the meta-analysis indicate that gamification has a more positive influence on learning achievement and motivation compared to serious games. The analysis reveals that gamification demonstrates a stronger impact on extrinsic motivation than on intrinsic motivation. Serious games have a more positive effect on intrinsic motivation in comparison to extrinsic motivation. The overall outcome suggests that gamification has relatively stronger effects than serious games. While the impact on extrinsic motivation is more significant with both approaches, serious games excel in fostering intrinsic motivation. However, further research is recommended to investigate the specific mechanisms that drive these effects and to identify optimal strategies for implementing serious games and gamification in diverse educational settings.

KEYWORDS

extrinsic motivation, gamification, intrinsic motivation, learning achievement, serious games

1. INTRODUCTION

Numerous studies have been committed to serious games and gamification (e.g. Raju et al., 2021; Krath & von Korflesch (2021); Tan et al., 2021; Högberg et al., 2019). According to Katrin Becker's study (2015), a serious game can be defined as a digital game that is designed for a purpose beyond entertainment. It is intended to educate or train individuals while also providing an engaging and interactive gaming experience. Serious games are often used as a tool for learning, communication, or decision-making in various fields such as education, healthcare, business, and defense. On the other hand, gamification refers to the use of game design elements and principles in non-game contexts, with the aim of increasing engagement, motivation, and participation. It involves incorporating game-like

DOI: 10.4018/IJGBL.336478
*Corresponding Author

features such as rewards, challenges, levels, and leaderboards into activities that are not inherently game-like. Gamification can be seen as a means to enhance user experience and drive behavioral change by applying game mechanics and psychology to real-world situations. To sum up, while serious games are designed as digital games with a specific educational or training purpose, gamification involves applying game elements to non-game contexts to enhance user engagement and motivation.

According to Kim and Lee (2015), a game is characterized by an engaging series of choices that allow players to achieve specific and compelling goals. As technological advancements have facilitated the integration of games or game elements in educational settings, educators have embraced various game-related approaches to enhance student interest, enjoyment, and instructional effectiveness (Kim, Song, Lockee, & Burton, 2018). The growing popularity of game-related approaches has prompted researchers to investigate their hypothesized motivational impact in instructional contexts (Kim et al., 2018; Sailer & Homner, 2020). Games could be considered a beneficial tool to enhance learning experiences and teaching strategies (Gee, 2013).

Different approaches to game implementation result in distinct game-related practices. Two common approaches include serious games and gamification (Loh, Sheng, Ifenthaler, 2015; Becker, 2015). Serious games are digital games designed not solely for entertainment purposes, but to be used for educational, training, or healthcare purposes (Loh et al., 2015). On the other hand, gamification refers to the use of game mechanics in non-gaming contexts to engage learners, enhance learning, and solve problems (Kapp, 2012; Kim et al., 2018; Yu, 2015).

Gamification activities and processes can be employed by educators to create game-related learning environments and address learning challenges (Kim et al., 2018; van Grove, 2011; Werbach & Hunter, 2012). However, unlike serious games, the primary emphasis of gamification is on incorporating game elements into pedagogical practices (Kim et al., 2018). It is important to note that gamification is not a distinct form of digital game in itself (Loh et al., 2015). Therefore, educators should consider utilizing gamification alongside digital games (Domínguez et al., 2013).

Hence, it is essential to differentiate between the serious game and gamification approaches, as they have distinct definitions and potential impacts on pedagogical practices. By recognizing their unique characteristics, we can effectively evaluate and compare the efficiency of these game-related approaches.

To measure the efficiency of game implementation, various dimensions can be considered. A commonly used criterion is learning achievement, which evaluates the extent to which learners have progressed in their academic performance (Kim et al., 2018). Additionally, the motivational power of games plays a significant role in assessing the efficacy of game-related approaches (Sailer & Homner, 2020). Motivation can be further classified into intrinsic and extrinsic motivations (Ryan & Deci, 2000a; 2000b). Therefore, we can adopt learning achievement and motivation as criteria for evaluating and comparing the efficiency of these game-related approaches in pedagogical practices.

Given the significance of this study, its primary objective is to validate the effectiveness of game implementation in pedagogical practices through meta-analyses. By utilizing statistical findings, we can provide compelling evidence to support game implementation as an innovative approach, rather than a trivial one, in pedagogical practices (Kim et al., 2018; Sailer & Homner, 2020).

Moreover, this study aims to differentiate between serious games and gamification, both theoretically and in terms of their practical effects on learning achievement and motivation. It is essential to avoid confusion between these game-related concepts. By comparing the effects of these approaches, we can investigate the specific contexts in which each approach is most effective. Consequently, educators can maximize the efficiency of game-related approaches in pedagogical practices.

Given the significance of this study, our primary objective is to validate the effectiveness of game implementation in pedagogical practices through meta-analyses. By analyzing statistical findings, we can provide persuasive evidence to support the use of games as an innovative approach in pedagogical practices (Kim et al., 2018; Sailer & Homner, 2020), demonstrating that it is not a trivial approach.

Additionally, we aim to differentiate between serious games and gamification in terms of their theoretical analyses and practical effects on learning achievement and motivation. It is important to clearly distinguish between these two game-related concepts. By comparing the effects of these approaches, we can investigate the specific contexts in which each approach can be highly efficient. This will allow educators to maximize the effectiveness of game-related approaches in pedagogical practices.

Moreover, based on the distinctions between serious games and gamification, future research can focus on refining pedagogical models related to game implementation. Since serious games and gamification represent different applications of games, meta-analyses can highlight the essential qualities of each approach for researchers to consider when designing and refining models.

In line with our research objectives, we have investigated and compared the effects of serious games and gamification on learning achievement and motivation. This has led us to formulate the following two research questions:

RQ1: Do the approaches of serious games and gamification have different impacts on learning achievement?
RQ2: Do the approaches of serious games and gamification have different impacts on motivation?

Given that motivation encompasses both intrinsic and extrinsic motivation, it is important to examine the overall impact of game-related approaches on these motivation subtypes. Furthermore, it is crucial to compare the effects of different game-related approaches on both intrinsic and extrinsic motivation. As a result, we have formulated a third research question related to motivation subtypes:

RQ3: Do game-related approaches have distinct effects on intrinsic motivation and extrinsic motivation?

To ensure a solid foundation for conducting meta-analyses, it is essential to examine previous studies that provide academic support.

2. LITERATURE REVIEW

In this section, we will explore and analyze the existing research to distinguish between serious games and gamification. We will focus on theoretical concepts and practical contexts as established by past studies.

2.1 Differentiating Gamification From Serious Games: A Focus on Gamefulness

The study found significant and positive relationships between flow experience and intrinsic motivation, specifically intrinsic motivation to know and intrinsic motivation to experience simulation, as well as the three types of extrinsic motivation. However, there was a negative correlation between flow experience and intrinsic motivation towards accomplishments and amotivation. Additionally, there was a significant difference between the mean scores of pre-tests and post-tests, indicating the effectiveness of the serious game in promoting medical students' motivation, flow, and learning achievements (Zairi et al., 2022).

Recent advancements in serious games and gamification have revealed significant findings. Integrating schema into games enhances knowledge acquisition, retention, cognitive load, and motivation (Ye et al., 2022). Game-based features in intelligent learning environments boost engagement, motivation, attention, enjoyment, and learning achievements (Sun et al., 2023). Lowering game difficulty increases positive emotions, learning motivation, and has consistent effects across different goal orientations, with no significant impact on performance (Cao et al., 2022). Gamified learning improves students' motivation, even amid challenges like the pandemic (Chen et al., 2023). Non-digital gamification enhances course satisfaction, while mixed gamification enhances cognitive engagement (Qiao et al., 2023). Additionally, integrating Escape Rooms into mathematics teaching improves achievement, motivation, autonomy, and addresses negative attitudes towards the subject (Saleh Alabdulaziz, 2023).

The term "gamification" was coined in late 2010 through the efforts of industry players (Deterding, Khaled, Nacke, & Dixon, 2011). Since its introduction, game and user experience designers have proposed various related terms, such as "gamefulness" and "game design," aiming to differentiate and clarify these concepts (Matallaoui, Hanner, & Zarnekow, 2017).

A crucial factor in distinguishing these terms is the differentiation between playing and gaming in terms of the types of activities involved (Caillois, 1961). "Playing" refers to spontaneous, unrestricted, and expressive actions without following set rules. On the other hand, "gaming" refers to activities that are rule-based and goal-oriented (Caillois, 1961). According to Caillois (1961), games should involve voluntary and enjoyable activities with explicit rule systems and measurable outcomes, creating goods of external value (Salen & Zimmermann, 2004).Consistent with the distinction between playing and gaming, McGonigal (2011) has introduced playfulness and gamefulness. Accordingly, McGonigal (2011) has proposed four fundamental features of games: goals, rules, feedback system, and free will. Goals can provide platers with the purposes for playing; Rules present the limitations and boundaries of achieving the goals; feedback systems enable players to reach the goals when they respect the game rules; learners' free will can guarantee active participation in the activities and concentration on the rules (McGonigal, 2011). Even if games involve other features, such as storytelling, interactivity, or rewarding systems, these features develop and enrich the fundamental features (Matallaoui et al., 2017).

Additionally, Deterding et al. (2011) have defined gamification as the use of game design elements in non-game contexts and accordingly proposed two dimensions, whole versus parts and gaming versus playing, to differentiate gamification from other related concepts. Whole versus parts demonstrates the extent to which a product is using gaming elements (Deterding et al., 2011; Matallaoui et al., 2017). In contrast, gaming versus playing reflects whether the product involves rule-bounded and outcome-related elements or just consists of the playing aspect (Deterding et al., 2011; Matallaoui et al., 2017).

Gamification partly requires gaming elements with other aspects of the product untouched, whereas serious games require complete game designs with an education or learning background (Deterding et al., 2011; Matallaoui et al., 2017). Gamification also requires rule-based goal-oriented designs that encourage players to progress by completing tasks or surpassing others (Deterding et al., 2011; Matallaoui et al., 2017).

However, although the researchers have discussed the distinction between playing and gaming, experimental procedures conducted by Salen & Zimmermann (2004), Barr Barr, Nobel, and Biddle (2007), and Groh (2011) have demonstrated that people can integrate these concepts and that the distinction might remain theoretical to some extent.

Gamification involves integrating gaming elements into a product while keeping other aspects unchanged, whereas serious games require complete game designs with an educational or learning background (Deterding et al., 2011; Matallaoui et al., 2017). Gamification relies on rule-based, goal-oriented designs that motivate players to progress by completing tasks or surpassing others (Deterding et al., 2011; Matallaoui et al., 2017).

However, research conducted by Salen & Zimmermann (2004), Barr Barr, Nobel, and Biddle (2007), and Groh (2011) has shown that individuals can integrate the concepts of playing and gaming, suggesting that the distinction between the two may be more theoretical than practical.

Oliveira and Petersen (2014) argue that serious games emphasize the use of Information and Communications Technology (ICT) to create engaging experiences that promote awareness, understanding, and mastery of specific concepts or skills. In contrast, gamification focuses on leveraging ICT to facilitate or constrain specific behaviors based on immersive experiences (Oliveira & Petersen, 2014). While both serious games and gamification can engage players, serious games typically provide implicit engagement in a more comprehensive manner, while gamification offers engagement in specific behaviors within a more integrated framework (Oliveira & Petersen, 2014), which aligns with the findings of Deterding et al. (2011).

In terms of practices, serious games typically require comprehensive game designs that span throughout the activities, while gamification can be implemented without the need for actual games, by incorporating elements into everyday contexts to motivate and engage players (Oliveira & Petersen, 2014). Serious games involve the use of specific rules and actions in a cohesive manner, encouraging players to compete with others. They can also be played in teams to promote collaborative awareness and foster community spirit. On the other hand, gamification draws from game designs but does not necessarily require the form of traditional games. It allows players to immerse themselves in gamified designs and enhance their performance through self-challenges (Oliveira & Petersen, 2014). Additionally, serious games often involve winners and losers after competitions, while gamification emphasizes slightly competitive game elements that encourage players to make progress regardless of others' performance (Oliveira & Petersen, 2014). Although it has been shown by Salen & Zimmermann (2004), Barr et al. (2007), and Groh (2011) that these concepts can be integrated and that the distinction may be somewhat theoretical, the differences between gamification and serious games still warrant discussion, as these approaches to utilizing games require slightly different orientations and features in pedagogical practices.

2.2 Comparing Gamification and Serious Games in Gamified Contexts

In their study, Aldemir, Ataş, and Celik (2019) have introduced the Gamified Environment and Learning Design (GELD) model, which outlines the elements and flexibility of gamified contexts in game-related approaches. The model consists of five key components: gamified environment, gamified course, design, game elements, and people. It is important to note that these elements may overlap, indicating the dynamic relationship between the gamified learning experience and the broader context (Aldemir, Ataş, & Celik, 2019).

The gamified environment holds a dominant and inclusive role in the GELD model as it sets the overall direction for the practices. A successful gamified environment relies on finding a balance between fun and seriousness and implementing motivating strategies (Aldemir et al., 2019).

When creating efficient gamified environments, instructors must strike a balance between fun and seriousness, ensuring consistency between playful elements and the educational purpose (Kapp, 2012). The primary objective of gamifying educational environments is to make serious activities enjoyable (Deterding et al., 2011; Zichermann & Cunningham, 2011; Werbach & Hunter, 2012). It is worth noting that the level of seriousness incorporated in gamified procedures determines the type of game-related pedagogical practices. Serious games emphasize the integration of seriousness within playful experiences, while gamification tends to have a lower level of seriousness.

Therefore, serious games place greater emphasis on incorporating seriousness for educational purposes within gamified environments, while gamification focuses more on entertainment. Instructors should distinguish between these game-related approaches and adapt gamified procedures according to their pedagogical goals.

Motivation encompasses both extrinsic and intrinsic factors (Nevid, 2012; Ryan & Deci, 2000a; 2000b). Extrinsic motivation stems from external sources and involves rewards such as trophies, money, social recognition, or praise. In contrast, intrinsic motivation arises from individuals' internal factors, such as personal satisfaction or fulfillment (Nevid, 2012; Ryan & Deci, 2000a; 2000b).

When considering conducive conditions for motivation, psychologically safe environments play a crucial role. These environments allow participants to freely express their opinions and make progress without fear of failure (Aldemir et al., 2019; Kapp, 2012). During gamification procedures, participants experience a sense of satisfaction and positive motivation once they achieve their goals of knowledge or skill mastery (Deterding et al., 2011). Instructors should also provide progressive step-by-step procedures, ensuring mastery and facilitating participants' adaptation to gamified experiences. This approach contributes to long-lasting motivation (Aldemir et al., 2019; Zichermann & Cunningham, 2011).

Hence, the need for motivating designs underscores the importance of motivation in implementing game-related approaches. In addition to assessing the effectiveness of pedagogies through learning outcomes, instructors should also focus on fostering learners' motivation in gamified experiences (Kim et al., 2018). Moreover, considering the differences between serious games and gamification, it is pertinent to discuss the potential impact of these approaches on intrinsic and extrinsic motivation. This aligns with the objectives of our study.

3. METHODOLOGY

This section details the research methods used to conduct the meta-analyses. The methods include identification, screening, eligibility, and inclusion criteria. Additionally, we examined the meta-analysis parameters based on the experimental scales employed in the included studies.

3.1 Literature Search for Identification

To ensure research sensitivity and scope, we adopted the research criteria used in the studies by Seaborn and Fel (2015) and Sailer and Homner (2020) for our literature search. We did not impose restrictions on the publication year. The search scope encompassed databases such as ERIC, IEEE Xplore, PubMed, SpringerLink, and Web of Science.

We utilized the following keywords in our search: gamification or serious game*, learning, and experiment*. Initially, our search yielded 7109 results. We further refined the results by using the keywords learning achievement and motivation. Upon removing duplicate records and refining the initial results, we identified 172 potentially eligible records.

3.2 Screening and Eligibility Criteria

In order to select eligible studies, we applied the following inclusion criteria:

1) Publication Language: Studies had to be published in English.
2) Research Topic: Studies needed to clearly describe the effectiveness of gamification or serious games on learning achievement or motivation, or present comparisons between these game-related approaches.
3) Research Design: Studies were required to use quantitative statistical methods to examine the effects of game-related approaches on learning achievement or motivation.
4) Experimental Conditions: Studies had to include a comparison between an experimental group and a control group, with at least one game-related condition compared to at least one condition based on another instructional approach.
5) Availability of Statistical Data: Studies needed to report sufficient statistical findings, such as participant numbers, means, and standard deviations, to enable the application of meta-analytic techniques.

During the selection process, we reviewed the abstracts for screening and the full-text contents for eligibility. Any studies that did not meet the following exclusion criteria were included:

1) Not published in English.
2) Did not involve experimental or statistical procedures, but were instead reviews.

3) Did not clearly describe the experimental topics or the target items assessed in the experimental procedures.
4) Did not present sufficient information to allow for the application of meta-analytical techniques.

3.3 Selection of Final Sample

We screened the initial literature records and identified a total of 57 studies that met the inclusion criteria (see Table 1). These studies focused on examining the effects on motivation. In Table 1, we have provided a summary of the specific motivation-related concepts that were investigated in each study. If a study described motivation in a general sense, we categorized it as "uncategorized motivation." However, if a study described specific motivation-related concepts, we classified them into corresponding motivation subtypes according to the criteria outlined in section 4.3.1.

3.4 Statistical Analysis

To perform meta-analyses, we integrated multiple sets of data due to the similarity of research dimensions in various studies. We utilized the "Combine Means and SDs Into One Group" program developed by The Chinese University of Hong Kong, which can be found at https://www.obg.cuhk.edu.hk/ResearchSupport/StatTools/CombineMeansSDs_Pgm.php, to combine the collected data.

For conducting the meta-analyses, we employed STATA 15. As the heterogeneity among experimental conditions and participant samples influences the analysis models (Borenstein, Hedges, Higgins, & Rothstein, 2009), we carefully considered the range of heterogeneity within the data.

To address the diverse scales used in the studies' data reporting, we applied Cohen's d, a standardized mean difference (SMD) statistical parameter, to assess the difference between means of the experimental and control groups based on the pooled standard deviation (Borenstein et al., 2009).

4. RESULTS

4.1 Do Serious Game and Gamification Approaches Impact Learning Achievement Differently?

Table 1 provides an overview of relevant studies on the effects of game-related approaches on learning achievement. Using the STATA 15 platform, we conducted data analysis and obtained the following results.

4.1.1 Examining Overall Effects on Learning Achievement

Table 2 shows the heterogeneity test results of the dataset, indicating significant heterogeneity (I^2 = 81.0%, Cochran's Q = 242.13, $p < 0.05$). Therefore, we used a random-effects model to investigate the effects of game-related pedagogical models on learning achievement.

The overall effects on learning achievement, and the random-effects model revealed a significant positive impact (d = 0.480, z = 7.730, $p < 0.05$, 95% CI [0.358, 0.601]) of game-related approaches on learning achievement.

4.1.2 Comparing Serious Game and Gamification Approaches on Learning Achievement

In the subgroup analysis, the serious game subgroup showed a significant effect (d = 0.381, z = 5.214, $p < 0.05$, 95% CI [0.238, 0.524]), while the gamification subgroup had a more significant effect (d = 0.634, z = 5.911, $p < 0.05$, 95% CI [0.424, 0.844]). The results indicate that gamification has a stronger impact on learning achievement compared to serious games.

Both subgroups had high heterogeneity within them ($p < 0.05$), but low heterogeneity between them ($p = 0.051 > 0.05$). The heterogeneity in the gamification subgroup (I^2 = 86.0%, $p < 0.05$) was significantly higher than in the serious game subgroup ($I^2 = 74.6\%$, $p < 0.05$). Overall, gamification has a more positive and varying impact on learning achievement compared to serious games.

4.1.3 Factors Influencing Heterogeneity and Publication Bias

We conducted a meta-analysis regression to analyze variables that may contribute to the heterogeneity. Variables included year, pedagogy (serious game or gamification), sample size, mean and standard deviation of the experimental and control groups.

Results showed that mean values of the experimental and control groups were significant factors ($p < 0.05$) contributing to heterogeneity. Different studies use different scales for target items, leading to variations in mean values and the use of standardized mean difference.

Through sensitivity analysis, we found that the study by Hussein et al. (2019) had the most influence in the serious game approach, while the study by Duggal et al. (2021) had the most influence in the gamification approach.

Publication bias was assessed using Egger's test, which showed no significant publication bias ($p = 0.138 > 0.1$). The funnel plot did not display significant asymmetries, except for one insignificant data point. The trim and fill analysis confirmed that the effects on motivation remained statistically significant.

We analyzed the impact of game-related approaches on motivation (Table 1) using meta-analysis in STATA 15. The dataset showed significant heterogeneity ($I^2 = 95.2\%$, Cochran's $Q = 287.79$, $p < 0.05$), so we used a random-effects model. Our analysis revealed a significant positive effect of game-related approaches on motivation ($d = 0.522$, $z = 6.028$, $p < 0.05$, 95% CI [0.352, 0.691]).

In the subgroup analysis comparing the effects of the serious game approach with those of the gamification approach on motivation, both subgroups showed statistically significant results. The serious game subgroup had a significant effect on motivation ($d = 0.323$, $z = 2.594$, $p = 0.009 < 0.05$, 95% CI [0.079, 0.566]), while the gamification subgroup had a more significant effect ($d = 0.660$, $z = 6.521$, $p < 0.05$, 95% CI [0.462, 0.858]). The heterogeneity was high in both subgroups, with the serious game subgroup showing significantly higher heterogeneity ($I^2 = 90.4\%$, $p < 0.05$) compared to the gamification subgroup ($I^2 = 87.8\%$, $p < 0.05$). Overall, the gamification approach had a more significant and stable impact on motivation compared to the serious game approach.

In order to investigate the potential sources of heterogeneity, we conducted a meta-analysis regression to analyze the variables influencing heterogeneity, using the same variable names as in section 4.1.3.

The regression results (Table 3) revealed that the approach ($p = 0.007 < 0.05$), Em ($p < 0.05$), and Cm ($p < 0.05$) were the main factors contributing to significant heterogeneity. This suggests that the effects of the serious game and gamification approaches on motivation vary significantly. Additionally, different studies used different scales for participants' target item, resulting in varying means or standard deviations. This justifies the use of Standardized Mean Difference (SMD).

We also conducted a sensitivity analysis to identify influential studies. The results showed that the study by O'Garra et al. (2021) significantly decreased the overall effects of serious games on motivation, while the studies by Chang et al. (2018) and Pimentel et al. (2021) significantly increased the overall effects. This indicates relatively unstable effects of serious games on motivation. On the other hand, the study by Haruna et al. (2018) had the most influential effect, increasing the overall effects of the gamification approach on motivation.

Regarding publication bias, the Egger's test results (Table 4) indicated that there is no obvious publication bias ($p = 0.233 > 0.1$). The funnel plot showed no apparent asymmetries, except for a few dots representing highly significant effects. The trim and fill analysis did not alter the set of data, confirming that the effects on motivation have statistical significance.

4.3 Do Game-Related Approaches Have Differential Effects on Intrinsic and Extrinsic Motivation?

This research question aims to compare the effects of game-related approaches on intrinsic and extrinsic motivation. To address this, we need to classify the motivation-related concepts in the extracted studies as either intrinsic or extrinsic motivation. The following criteria were used for classification.

4.3.1 Classification of Motivation-Related Concepts into Intrinsic and Extrinsic Motivation

Several researchers (Abbasi et al., 2021; Alcalá & Garijo, 2017; C.-Y. Hung et al., 2018; C.-M. Hung et al., 2014; H.-T. Hung, 2021; Hussein et al., 2019; Hwang et al., 2013; Özer et al., 2018; Sánchez et al., 2020; Su, 2017) have investigated the effectiveness of game-related approaches in terms of a general motivation dimension, referred to as uncategorized motivation.

On the other hand, other studies (Abbasi et al., 2021; Bayley & Brown, 2015; Chang et al., 2018; C.-H. Chen & Yeh, 2019; Gamito et al., 2014; Giannakos et al., 2015; Haruna et al., 2018; H.-T. Hung et al., 2018; Lee et al., 2020; Leiker et al., 2016; Li et al., 2017; Lin et al., 2021; Magen-Nagar et al., 2019; Molina-Torres et al., 2021; O'Garra et al., 2021; Pan et al., 2019; Pimentel et al., 2021; Sánchez et al., 2020) include concepts related to motivation that necessitate further determination of their subtypes.

According to the Self-Determination Theory (SDT) (Ryan & Deci, 2000a; 2000b), intrinsic motivation is characterized by inherent satisfaction and spontaneous behaviors, while extrinsic motivation emphasizes instrumental value and the potential outcomes of events. Additionally, intrinsic motivation is associated with competence and autonomy at an inherent level, whereas extrinsic motivation involves competence, autonomy, and relatedness, often through the presence of rewards within a supportive community (Kim et al., 2018; Ryan & Deci, 2000a; 2000b). Intrinsic motivation is driven by a sense of spontaneous satisfaction, while extrinsic motivation focuses on external outcomes. Based on these distinctions, we have classified the motivation-related concepts found in the extracted studies (refer to Table 1).

4.3.2 Analysis of the Overall Effects of Game-Related Approaches on Intrinsic and Extrinsic Motivation

The dataset analysis revealed significant heterogeneity ($I^2 = 89.0\%$, Cochran's $Q = 336.08$, $p < 0.05$, see Table 2) among the studies. Therefore, we conducted a random-effects model to examine the effects of game-related pedagogical models on motivation.

Overall, the random-effects model showed a significant positive effect of game-related approaches on motivation ($d = 0.485$, $z = 6.343$, $p < 0.05$, 95% CI [0.335, 0.635]).

Subgroup analysis for intrinsic motivation indicated a significant effect ($d = 0.403$, $z = 3.514$, $p < 0.05$, 95% CI [0.178, 0.628]), while for extrinsic motivation, there was a significant effect ($d = 0.441$, $z = 3.206$, $p = 0.001 < 0.05$, 95% CI [0.172, 0.711]). These results suggest that game-related approaches have a more notable impact on extrinsic motivation compared to intrinsic motivation.

Regarding subgroup heterogeneity, all subgroups exhibited high heterogeneity ($p < 0.05$), but the heterogeneity between groups was relatively low ($p = 0.367 > 0.05$). Notably, the heterogeneity in the extrinsic motivation subgroup ($I^2 = 91.1\%$, $p < 0.05$) and intrinsic motivation subgroup ($I^2 = 88.8\%$, $p < 0.05$) was higher than that in the uncategorized motivation subgroup ($I^2 = 85.1\%$, $p < 0.05$). This suggests that game-related approaches have slightly varying impacts on extrinsic motivation compared to intrinsic motivation.

4.3.3 Analysis of the Differences in Effects of Game-Related Approaches on Intrinsic and Extrinsic Motivation

In addition to the overall effects analysis, we conducted subgroup analyses to examine the specific game-related approaches and their effects on intrinsic and extrinsic motivation. This allowed us to assess the differences in impacts between the two motivation types within each approach.

For the serious game approach, the results showed a significant effect on extrinsic motivation ($d = 0.352$, $z = 2.118$, $p = 0.034 < 0.05$, 95% CI [0.026, 0.677]), while the effect on intrinsic motivation was not significant ($d = 0.205$, $z = 0.823$, $p = 0.411 > 0.05$, 95% CI [-0.284, 0.695]). These findings indicate that the serious game approach has a greater positive impact on intrinsic motivation compared to extrinsic motivation, and that the effects on extrinsic motivation are notably unstable.

For the gamification approach, the results demonstrated a significant effect on intrinsic motivation ($d = 0.481$, $z = 3.404$, $p < 0.05$, 95% CI [0.204, 0.758]), as well as a significant effect on extrinsic motivation ($d = 0.603$, $z = 4.374$, $p < 0.05$, 95% CI [0.333, 0.873]). These findings suggest that the gamification approach has a greater positive impact on extrinsic motivation compared to intrinsic motivation, and that the positive effects on both motivation types are consistently stable.

4.3.4 Analysis of Heterogeneity Factors and Examination of Publication Bias

To investigate potential sources of heterogeneity, we conducted a meta-analysis regression to analyze the variables that could influence the heterogeneity. We used the same variable names as in 4.1.3 and included the variable "motivation" (with motivation subtypes coded as follows: 1 = uncategorized motivation, 2 = intrinsic motivation, 3 = extrinsic motivation).

The regression results (see Table 3) revealed that approach ($p = 0.012 < 0.05$), Em ($p < 0.05$), and Cm ($p < 0.05$) are the main factors contributing to significant heterogeneity. This indicates that the motivation subtypes themselves are not the sources of heterogeneity, suggesting that the extracted studies on motivation are stable.

To identify influential studies, we conducted a sensitivity analysis. The results showed that the studies by Alcalá & Garijo (2017), Haruna et al. (2018), and O'Garra et al. (2021) were the most influential among the extracted studies.

Regarding publication bias, the Egger's test results (see Table 4) indicated that there was no significant publication bias ($p = 0.353 > 0.1$). The funnel plot did not show any apparent asymmetries. Additionally, the trim and fill analysis did not alter the results, confirming the statistical significance of the effects on motivation.

4.4 Variations in Demographics and Test Methods

Before conducting a comparison of this study, it is important to consider the variations in demographics and test methods. These variations can affect the generalizability and reliability of the findings. Different studies may have diverse participant demographics, including age, gender, educational background, and cultural factors. These variations can influence how individuals engage with serious games or gamification and their response to these interventions. The methodologies employed in studies can vary, including the types of assessments used, the duration of the intervention, and the specific learning outcomes measured. Some studies may use pre- and post-tests to evaluate learning achievement, while others may focus on self-report measures of motivation. The choice of test methods can impact the validity and reliability of the results.

Considering these variations in demographics and test methods is crucial while conducting a meta-analysis to ensure that the findings are robust and applicable to a broader population. It is also important for researchers to carefully evaluate the methodology and limitations of individual studies before drawing conclusions from the meta-analysis.

5. DISCUSSION

This section will discuss the implications of the research findings. The meta-analyses results indicate that the effects of gamification on learning achievement and motivation are more significant compared to serious games. Therefore, we will explore the factors that may contribute to these differences in effects on learning achievement and motivation.

5.1 Factors Contributing to Different Effects of Serious Games and Gamification on Learning Achievement and Motivation

Serious games are designed specifically for educational purposes, incorporating complete game designs (Deterding et al., 2011; Matallaoui et al., 2017). By utilizing serious games, game-based learning can enhance information processing ability (Hayes, 2008), problem-solving capability (Mayer & Wittrock, 2006), learning effectiveness (Lin et al., 2021; Papastergious, 2009), and independent learning capability (Yien, Hung, Hwang, & Lin, 2011). These characteristics make serious games an effective approach for motivating learners to make academic progress.

On the other hand, gamification involves incorporating game elements into the overall design (Deterding et al., 2011; Matallaoui et al., 2017). Like game-based learning with serious games, gamification utilizes game mechanics to provide motivating activities that enhance motivation, learning, and problem-solving skills (Kim et al., 2018). However, gamification is not developed with specific educational purposes in mind; rather, it focuses on creating a set of incentive activities and systematic processes based on game characteristics (Kim et al., 2018).

Games can stimulate learners' interest in tasks through playful experiences, and gamification takes advantage of this by creating more immersive activities than traditional game-based learning (Kim et al., 2018). This increased immersion is associated with learning achievement and motivation (Kim et al., 2018; Li et al., 2012; Su & Cheng, 2015). Consequently, gamification is capable of fostering a high level of engagement among learners.

It is important to note that immersive experiences in gamification heavily rely on learner engagement. However, there are various uncontrollable external and internal factors that can influence the degree to which learners make progress in their learning (Kim et al., 2018; Radoff, 2011). These factors include the design of the gamification system, the pedagogical context, as well as learners' frustration and distraction. As a result, gamification may have less consistent effects on learning achievements compared to serious games, as the immersive experiences in gamification are easily influenced by external distractions or internal reluctance (Kim et al., 2018; Radoff, 2011).

In summary, games that do not have specific educational purposes can offer unlimited playful experiences that can significantly impact learning achievements and motivation. Therefore, gamification may have a stronger influence on learning achievement and motivation compared to serious games. However, it is important to recognize that the effects of gamification may be unstable due to its dependence on learner engagement, which can be influenced by external and internal factors.

5.2 Factors Contributing to Different Effects of Game-Related Approaches on Intrinsic and Extrinsic Motivation

The findings indicate that game-related approaches generally have a more positive impact on extrinsic motivation, with gamification specifically showing stronger effects on extrinsic motivation compared to intrinsic motivation. This may be due to the controllable nature of extrinsic conditions. Extrinsic motivation is influenced by external factors such as rewards, pressure, or punishment, while intrinsic motivation arises from internal reactions such as pleasure, curiosity, or interest (Kim et al., 2018; Ryan & Deci, 2000a; 2000b).

It is worth noting that not all individuals can easily achieve intrinsic motivation in specific learning contexts due to its abstract nature and inherent effects, whereas most individuals can find motivation from external factors that can be controlled (Kim et al., 2018). As a result, educators often focus on these external factors to stimulate learners' interest and employ strategies to enhance their extrinsic motivation (Kim et al., 2018).

Furthermore, the results demonstrate that serious games have a more positive impact on intrinsic motivation compared to extrinsic motivation. Serious games encompass comprehensive experiences that elicit internal stimuli related to goals, rules, and interaction for players (Deterding et al., 2011; Kim et al., 2018).

Notably, the features of intrinsic motivation, such as goals, rules, and interactions, align with the characteristics of serious games. Goals in games represent desired outcomes, such as rewards or positions, that players strive for (Kim et al., 2018), which resonates with the inherent satisfaction that fuels intrinsic motivation (Ryan & Deci, 2000a; 2000b). Rules in games refer to the agreements or promises that govern gameplay (Kim et al., 2018), and they are linked to intrinsic motivation as they require the internalization of regulations (Ryan & Deci, 2000a; 2000b). Interactions in games involve reciprocal actions and timely feedback, contributing to players' spontaneous enjoyment based on the balance between challenges and skills (Csikszentmihalyi, 2008; Kapp, 2012; Kim et al., 2018; Ryan & Deci, 2000a; 2000b; Werbach & Hunter, 2012).

In general, the controllability of external conditions is in line with the partial and flexible designs of gamification, leading to significant effects on extrinsic motivation. Conversely, the internal stimuli from goals, rules, and interactions in serious games exhibit significant effects on intrinsic motivation.

5.3 Implications for Designing Gamified Courses in Pedagogical Practices

Instructors should pay attention to the design of gamified courses based on the principles of gamification. Several influential factors, such as participants' emotional states, course integration, and adaptation, need to be considered (Aldemir et al., 2019).

The emotional states of participants play a crucial role in the design of gamified courses (Aldemir et al., 2019). Game designs should aim to stimulate participants' desired emotional responses (Hunicke, LeBlanc, & Zubek, 2004). At the beginning of gamified courses, cultivating curiosity is essential (Aldemir et al., 2019; Chou, 2015). Curiosity serves as the initial phase of discovery before the onboarding phase in gamified experiences (Chou, 2015). However, if participants do not understand the course content, their curiosity may not be fostered, leading to less satisfying learning experiences (Aldemir et al., 2019). Therefore, instructors should be aware of participants' interests and background information to facilitate effective curiosity (Aldemir et al., 2019). Conversely, negative emotional states of participants can still provide valuable guidance and support for the design of gamified courses to cater to their needs (Aldemir et al., 2019; Kapp, 2012).

In addition, gamified courses can integrate both online and in-class sessions (Aldemir et al., 2019; Keller, 2010). Both formats require flexibility, availability of materials, self-paced learning, social interactions, and direct interaction with instructors (Aldemir et al., 2019). Designing flexible courses that incorporate mental breaks and social rewards can help participants stay engaged and remain motivated to make progress (Werbach & Hunter, 2012). By understanding participants' learning preferences, instructors can use online platforms to deliver new knowledge and utilize class time to address specific problems through personalized guidance (Aldemir et al., 2019). It is important for educators to find a balance between the online and in-class sections to optimize efficiency based on participants' self-regulation (Aldemir et al., 2019).

Furthermore, participants' adaptation is crucial in gamified courses. Self-efficacy plays a significant role in determining participants' assigned roles within the gamified courses (Aldemir et al., 2019; Kapp, 2012). Participants with high self-efficacy tend to have a greater sense of confidence and actively engage in learning tasks (Kapp, 2012). As a result, the level of instructor control can decrease, but not disappear entirely. Therefore, participants need to adapt to a combination of freedom and control based on their self-regulation skills and technological competence (Aldemir et al., 2019; Kapp, 2012).

6. CONCLUSION

6.1 Key Findings

The first research question (RQ1) examines the effects of game-related approaches on learning achievement. The meta-analysis results indicate that game-related approaches, overall, have a positive impact on learning achievement ($d = 0.480$, $z = 7.730$, $p < 0.05$, 95% CI [0.358, 0.601]). Subgroup analysis reveals that the effect of gamification on learning achievement ($d = 0.634$, $z = 5.911$, $p < 0.05$, 95% CI [0.424, 0.844]) is more significant than that of serious games ($d = 0.381$, $z = 5.214$, $p < 0.05$, 95% CI [0.238, 0.524]). The regression analysis identifies Em ($p < 0.05$) and Cm ($p < 0.05$) as factors contributing to high heterogeneity, justifying the use of a random-effects model. Despite the absence of significant publication bias ($p = 0.138 > 0.1$), it can be concluded that gamification and serious games impact learning achievement differently, with gamification showing a more positive impact on learning achievement compared to serious games.

RQ2 examines the effects of game-related approaches on motivation. The meta-analysis findings indicate that game-related approaches, overall, enhance motivation ($d = 0.522$, $z = 6.028$, $p < 0.05$, 95% CI [0.352, 0.691]). Subgroup analysis reveals that the effect of gamification on motivation ($d = 0.660$, $z = 6.521$, $p < 0.05$, 95% CI [0.462, 0.858]) is more significant than that of serious games ($d = 0.323$, $z = 2.594$, $p = 0.009 < 0.05$, 95% CI [0.079, 0.566]). The regression analysis identifies approach ($p = 0.007 < 0.05$), Em ($p < 0.05$), and Cm ($p < 0.05$) as factors contributing to high heterogeneity, which validates the use of a random-effects model. Moreover, no significant publication bias ($p = 0.233 > 0.1$) is observed. These results lead to the conclusion that gamification and serious games have different impacts on motivation, with gamification showing a more positive effect on motivation compared to serious games.

RQ3 aims to compare the effects of game-related approaches on intrinsic motivation versus extrinsic motivation. After categorizing the motivation-related concepts in the included studies, a subgroup analysis was conducted. The findings indicate that game-related approaches, on the whole, have a more positive impact on extrinsic motivation ($d = 0.441$, $z = 3.206$, $p = 0.001 < 0.05$, 95% CI [0.172, 0.711]) compared to intrinsic motivation ($d = 0.403$, $z = 3.514$, $p < 0.05$, 95% CI [0.178, 0.628]). Additionally, the effects of specific game-related approaches on intrinsic and extrinsic motivation were investigated. Serious games were found to have a more positive impact on intrinsic motivation ($d = 0.352$, $z = 2.118$, $p = 0.034 < 0.05$, 95% CI [0.026, 0.677]) than on extrinsic motivation ($d = 0.205$, $z = 0.823$, $p = 0.411 > 0.05$, 95% CI [-0.284, 0.695]). On the other hand, gamification exhibited a more positive effect on extrinsic motivation ($d = 0.603$, $z = 4.374$, $p < 0.05$, 95% CI [0.333, 0.873]) than on intrinsic motivation ($d = 0.481$, $z = 3.404$, $p < 0.05$, 95% CI [0.204, 0.758]). The regression analysis revealed that the factors of approach ($p = 0.012 < 0.05$), Em ($p < 0.05$), and Cm ($p < 0.05$), which stemmed from experimental variations, contributed to the heterogeneity observed. These findings underscore the distinct effects of the two game-related approaches and support the use of a random-effects model. Moreover, no significant publication bias was detected ($p = 0.353 > 0.1$). In conclusion, game-related approaches have varying effects on intrinsic and extrinsic motivation. While overall they have a more positive impact on extrinsic motivation, serious games showed a stronger effect on intrinsic motivation, while gamification significantly enhanced extrinsic motivation.

We have also examined the potential factors that may explain these findings. Games that do not have specific educational objectives may offer more enjoyable and engaging experiences that capture learners' attention to the learning process. The presence of visible and controllable external stimuli, such as rewards, punishments, and leaderboards, may contribute to the significant effects of game-related approaches on extrinsic motivation. These findings suggest that instructors should pay attention to learners' emotional states, the integration of offline and online components, and the adaptation of both learners and instructors in gamified courses.

The main conclusions of this study are that gamification has a stronger positive impact on both learning achievement and motivation compared to serious games. Additionally, game-related approaches, overall, have a greater influence on enhancing extrinsic motivation rather than intrinsic motivation. It should be noted that serious games still have a more positive effect on intrinsic motivation compared to extrinsic motivation.

6.2 Limitations of this Study and Implications for Future Research

One major limitation of this study is the limited coverage of available studies. It is possible that we may have missed valuable findings due to the restricted availability of sources. We would greatly appreciate it if readers could contribute additional related studies to expand and diversify the results of this study.

Furthermore, the relatively high heterogeneity among the included studies is another limitation. Due to the variations in experimental procedures, we utilized random-effects models for the meta-analyses. However, reducing heterogeneity among the studies would minimize research errors and yield more persuasive results regarding the effects of game-related pedagogical models on learning achievement and motivation.

These limitations provide valuable insights for future research. Efforts should be made to broaden the coverage of research to address the heterogeneity issue. Future studies could specifically focus on comparing the effectiveness of serious game pedagogical models with gamification pedagogical models. Additionally, exploring other dimensions associated with the efficacy of game-related approaches would be beneficial.

ACKNOWLEDGMENT

The authors would like to extend gratitude to anonymous reviewers, editors, and the financial support. This study is supported by The research project of educational science planning in Henan Province, China (Grant No. 2023YB0327), and the Social Science Foundation of Hebei Province, China (Grant No. HB23JY019).

REFERENCES

Abbasi, S., Kazi, H., Kazi, A. W., Khowaja, K., & Baloch, A. (2021). Gauge object oriented programming in student's learning performance, normalized learning gains and perceived motivation with serious games. *Information (Basel)*, *12*(3), 101–121. doi:10.3390/info12030101

Alcalá, D. H., & Garijo, A. H. (2017). Teaching games for understanding: A comprehensive approach to promote student's motivation in physical education. *Journal of Human Kinetics*, *59*(1), 17–27. doi:10.1515/hukin-2017-0144 PMID:29134045

Aldemir, T., Ataş, A. H., & Celik, B. (2019). A systematic design model for gamified learning environments: GELD model. In W. H. Tan (Ed.), *Design, Motivation, and Frameworks in Game-Based Learning* (pp. 30–56). IGI Global. doi:10.4018/978-1-5225-6026-5.ch002

Arnab, S., Brown, K., Clarke, S., Dunwell, I., Lim, T., Suttie, N., Louchart, S., Hendrix, M., & de Freitas, S. (2013). The development approach of a pedagogically-driven serious game to support Relationship and Sex Education (RSE) within a classroom setting. *Computers & Education*, *69*(1), 15–30. doi:10.1016/j.compedu.2013.06.013

Baños, R. M., Cebolla, A., Oliver, E., Alcañiz, M., & Botella, C. (2013). Efficacy and acceptability of an Internet platform to improve the learning of nutritional knowledge in children: The ETIOBE mates. *Health Education Research*, *28*(2), 234–248. doi:10.1093/her/cys044 PMID:22498924

Barma, S., Daniel, S., Bacon, N., Gingras, M.-A., & Fortin, M. (2015). Observation and analysis of a classroom teaching and learning practice based on augmented reality and serious games on mobile platforms. *International Journal of Serious Games*, *2*(2), 69–88. doi:10.17083/ijsg.v2i2.66

Barr, P., Nobel, J., & Biddle, R. (2007). Video game values: Play as human-computer interaction. *Interacting with Computers*, *19*(2), 180–195. doi:10.1016/j.intcom.2006.08.008

Bayley, J. E., & Brown, K. E. (2015). Translating group programmes into online formats: Establishing the acceptability of a parents' sex and relationships communication serious game. *BMC Public Health*, *15*(1), 1225–1238. doi:10.1186/s12889-015-2545-0 PMID:26651616

Becker, K. (2015). *Choosing and Using Digital Games in the Classroom – A Practical Guide*. Springer Publishing.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2009). *Introduction to Meta-analysis*. Wiley. doi:10.1002/9780470743386

Caillois, R. (1961). *Man, Play, and Games*. University of Illinois Press.

Cao, Y., Gong, S., Wang, Z., Cheng, Y., & Wang, Y. (2022). More challenging or more achievable? The impacts of difficulty and dominant goal orientation in leaderboards within educational gamification. *Journal of Computer Assisted Learning*, *38*(3), 845–860. doi:10.1111/jcal.12652

Casalsa, M., Gangolellsa, M., Macarullaa, M., Forcadaa, N., Fuertesb, A., & Jonesb, R. V. (2020). Assessing the effectiveness of gamification in reducing domestic energy consumption: Lessons learned from the EnerGAware project. *Energy and Building*, *210*, 109753–109765. doi:10.1016/j.enbuild.2019.109753

Cechellaa, F., Abbada, G., & Wagner, R. (2021). Leveraging learning with gamification: An experimental case study with bank managers. *Computers in Human Behavior Reports*, *3*(2), 1–9. doi:10.1016/j.chbr.2020.100044

Çetinkaya, L. (2019). The effects of problem based mathematics teaching through mobile applications on success. *Education in Science*, *44*(197), 65–84. doi:10.15390/EB.2019.8119

Chang, C.-C., Warden, C. A., Liang, C., & Lin, G.-Y. (2018). Effects of digital game-based learning on achievement, flow and overall cognitive load. *Australasian Journal of Educational Technology*, *34*(4), 155–167. doi:10.14742/ajet.2961

Chen, C.-H., & Yeh, H.-C. (2019). Effects of integrating a questioning strategy with game-based learning on students' language learning performances in flipped classrooms. *Technology, Pedagogy and Education*, *28*(3), 347–361. doi:10.1080/1475939X.2019.1618901

Chen, C.-Y., Huang, H.-J., Lien, C.-J., & Lu, Y.-L. (2020). Effects of multi-genre Digital game-based instruction on students' conceptual understanding, argumentation skills, and learning experiences. *IEEE Access : Practical Innovations, Open Solutions*, *8*, 110643–110655. doi:10.1109/ACCESS.2020.3000659

Chen, M.-F., Chen, Y.-C., Zuo, P.-Y., & Hou, H.-T. (2023). Design and evaluation of a remote synchronous gamified mathematics teaching activity that integrates multi-representational scaffolding and a mind tool for gamified learning. *Education and Information Technologies*, *28*(10), 13207–13233. doi:10.1007/s10639-023-11708-6 PMID:37361748

Chou, Y. (2015). *Actionable Gamification Beyond Points, Badges, and Leaderboards*. Leanpub.

Cichy, I., Kaczmarczyk, M., Wawrzyniak, S., Kruszwicka, A., Przybyla, T., Klichowski, M., & Rokita, A. (2020). Participating in physical classes using Eduball stimulates acquisition of mathematical knowledge and skills by primary school students. *Frontiers in Psychology*, *11*, 2194–2209. doi:10.3389/fpsyg.2020.02194 PMID:33013568

Csikszentmihalyi, M. (2008). *Flow: The Psychology of Optimal Experience*. HarperCollins.

Dankbaar, M. E. W., Alsma, J., Jansen, E. E. H., van Merrienboer, J. J. G., van Saase, J. L. C. M., & Schuit, S. C. E. (2016). An experimental study on the effects of a simulation game on students' clinical cognitive skills and motivation. *Advances in Health Sciences Education : Theory and Practice*, *21*(3), 505–521. doi:10.1007/s10459-015-9641-x PMID:26433730

Dankbaar, M. E. W., Richters, O., Kalkman, C. J., Prins, G., ten Cate, O. T. J., van Merrienboer, J. J. G., & Schuit, S. C. E. (2017). Comparative effectiveness of a serious game and an e-module to support patient safety knowledge and awareness. *BMC Medical Education*, *17*(1), 30–40. doi:10.1186/s12909-016-0836-5 PMID:28148296

De La Garza1, J. R., Kowalewski, K.-F., Friedrich, M., Schmidt, M. W., Bruckner, T., Kenngott, H. G., Fischer, L., Müller-Stich, B.-P., & Nickel, F. (2017). Does rating the operation videos with a checklist score improve the effect of E-learning for bariatric surgical training? Study protocol for a randomized controlled trial. *Trials, 18*, 134-144. .10.1186/s13063-017-1886-7

Deterding, S., Khaled, R., Nacke, L. E., & Dixon, D. (2011). Gamification: Toward a definition. In *CHI 2011 Gamification Workshop Proceedings* (pp. 12-15). New York: ACM Press.

Domínguez, A., Saenz-de-Navarrete, J., de-Marcos, L., Fernández-Sanz, L., Pagés, C., & Martínez-Herráiz, J.-J. (2013). Gamifying learning experiences: Practical implications and outcomes. *Computers & Education*, *63*, 380–392. doi:10.1016/j.compedu.2012.12.020

Duggal, K., Gupta, L. R., & Singh, P. (2021). Gamification and machine learning inspired approach for classroom engagement and learning. *Mathematical Problems in Engineering*, *3*, 1–18. doi:10.1155/2021/9922775

Fellnhofer, K. (2016). All-in-One: Impact study of an online math game for educational purposes. International Journal of Technology. *Enhanced Learning*, *8*(1), 59–76. doi:10.1504/IJTEL.2016.075953

Froome, H. M., Townson, C., Rhodes, S., Franco-Arellano, B., LeSage, A., Savaglio, R., Brown, J. M., Hughes, J., Kapralos, B., & Arcand, J. (2020). The effectiveness of the Foodbot Factory mobile serious game on increasing nutrition knowledge in children. *Nutrients*, *12*(11), 3413–3427. doi:10.3390/nu12113413 PMID:33172094

Fuster-Guilló, A., Pertegal-Felices, M. L., Jimeno-Morenilla, A., Azorín-López, J., Rico-Soliveres, M. L., & Restrepo-Calle, F. (2019). Evaluating impact on motivation and academic performance of a game-based learning experience using Kahoot. *Frontiers in Psychology*, *10*, 1–8. doi:10.3389/fpsyg.2019.02843 PMID:31920872

Gamito, P., Oliveira, J., Lopes, P., Brito, R., Morais, D., Silva, D., Silva, A., Rebelo, S., Bastos, M., & Deus, A. (2014). Executive functioning in alcoholics following an mHealth cognitive stimulation program: Randomized controlled trial. *Journal of Medical Internet Research*, *16*(4), e102–e115. doi:10.2196/jmir.2923 PMID:24742381

Gee, J. P. (2013). Games for Learning. *Educational Horizons*, *91*(4), 16–20. doi:10.1177/0013175X1309100406

Giannakos, M., Garneli, V., & Chorianopoulos, K. (2015). Exploring the importance of "Making" in an educational game design. In K. Chorianopoulos, M. Divitini, J. BaalsrudHauge, L. Jaccheri, & R. Malaka (Eds.), *14th International Conference on Entertainment Computing (ICEC) 2015* (pp. 367–374). Cham: Springer. https://doi.org/ doi:10.1007/978-3-319-24589-8_28

Groh, F. (2011). Gamification: State of the art definition and utilization. In N. Asaj, K. Bastian, M. Poguntke, F. Schaub, B. Wiederschiem, & M. Weber (Eds.), *Proceedings of the 4th Seminar on Research Trends in Media Informatics* (pp. 39-45). Institute of Media Informatics Ulm University.

Gulec, U., & Yilmaz, M. (2016). A serious game for improving the decision making skills and knowledge levels of Turkish football referees according to the laws of the game. *SpringerPlus*, *5*(1), 622–632. doi:10.1186/s40064-016-2227-0 PMID:27330888

Haruna, H., Hu, X., Chu, S. K. W., Mellecker, R. R., Gabriel, G., & Ndekao, P. S. (2017). Improving sexual health education programs for adolescent students through game-based learning and gamification. *International Journal of Environmental Research and Public Health*, *15*(9), 1–26. doi:10.3390/ijerph15092027 PMID:30227642

Haubruck, P., Nickel, F., Ober, J., Walker, T., Bergdolt, C., Friedrich, M., Müller-Stich, B. P., Forchheim, F., Fischer, C., Schmidmaier, G., & Tanner, M. C. (2018). Evaluation of app-based serious gaming as a training method in teaching chest tube insertion to medical students: Randomized controlled trial. *Journal of Medical Internet Research*, *20*(5), e195–e211. doi:10.2196/jmir.9956 PMID:29784634

Hayes, E. (2008). Game content creation and it proficiency: An exploratory study. *Computers & Education*, *51*(1), 97–108. doi:10.1016/j.compedu.2007.04.002

Hodges, G. W., Oliver, J. S., Jang, Y., Cohen, A., Ducrest, D., & Robertson, T. (2021). Pedagogy, partnership, and collaboration: A longitudinal, empirical study of serious educational gameplay in secondary biology classrooms. *Journal of Science Education and Technology*, *30*(1), 331–346. doi:10.1007/s10956-020-09868-y PMID:33424211

Högberg, J., Hamari, J., & Wästlund, E. (2019). Gameful Experience Questionnaire (GAMEFULQUEST): An instrument for measuring the perceived gamefulness of system use. *User Modeling and User-Adapted Interaction*, *29*(3), 619–660. doi:10.1007/s11257-019-09223-w

Hung, C.-M., Huang, I., & Hwang, G.-J. (2014). Effects of digital game-based learning on students' self- efficacy, motivation, anxiety, and achievements in learning mathematics. *Journal of Computers in Education*, *1*(2-3), 151–166. doi:10.1007/s40692-014-0008-8

Hung, C.-Y., Sun, J. C.-Y., & Liu, J.-Y. (2018). 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), 1–19. doi:10.1080/10494820.2018.1481103

Hung, H.-T. (2018). Gamifying the flipped classroom using game-based learning materials. *ELT Journal*, *72*(3), 296–308. doi:10.1093/elt/ccx055

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). *MDA: A formal approach to game design and game research*. Proceedings of the AAAI Workshop on Challenges in Game AI. San Jose, CA.

Hussein, M. H., Ow, S. H., Cheong, L. S., & Thong, M.-K. (2019). A digital game-based learning method to improve students' critical thinking skills in elementary science. *IEEE Access : Practical Innovations, Open Solutions*, *7*, 96309–96318. doi:10.1109/ACCESS.2019.2929089

Hwang, G.-J., Hsu, T.-C., Lai, C.-L., & Hsueh, C.-J. (2017). Interaction of problem-based gaming and learning anxiety in language students' English listening performance and progressive behavioral patterns. *Computers & Education*, *106*, 26–42. doi:10.1016/j.compedu.2016.11.010

Hwang, G.-J., Hung, C.-M., & Chen, N.-S. (2013). Improving learning achievements, motivations and problem-solving skills through a peer assessment-based game development approach. *Educational Technology Research and Development*, *62*(2), 129–145. doi:10.1007/s11423-013-9320-7

Kapp, K. M. (2012). *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. Pfeiffer.

Kato-Lin, Y.-C., Kumar, U. B., Prakash, B. S., Prakash, B., Varadan, V., Agnihotri, S., Subramanyam, N., Krishnatray, P., & Padman, R. (2020). Impact of pediatric mobile game play on healthy eating behavior: Randomized controlled trial. *JMIR mHealth and uHealth*, *8*(11), e15717–e15723. doi:10.2196/15717 PMID:33206054

Keller, J. M. (2010). *Motivational Design for Learning and Performance: The ARCS Model Approach*. Springer. doi:10.1007/978-1-4419-1250-3

Kim, J. T., & Lee, W. H. (2015). Dynamical model for gamification of learning (DMGL). *Multimedia Tools and Applications*, *74*(19), 8483–8493. doi:10.1007/s11042-013-1612-8

Kim, S., Song, K., Lockee, B., & Burton, J. (2018). *Gamification in Learning and Education: Enjoy Learning like Gaming*. Springer International Publishing AG., doi:10.1007/978-3-319-47283-6

Kolić-Vehovec, S., Smojver-Ažić, S., Dorčić, T. M., & Zubković, B. R. (2019). Evaluation of serious game for changing students' behaviour in bullying situation. *Journal of Computer Assisted Learning*, *36*(3), 323–334. doi:10.1111/jcal.12402

Krath, J., & von Korflesch, H. F. (2021). Designing gamification and persuasive systems: a systematic literature review. In *Proceedings of the 5th international GamiFIN conference* (pp. 100-109). CEURWS. http://ceurws.org/Vol-2883/

Lee, S., Shih, M., Liang, J., & Tseng, Y. (2021). Investigating learners' engagement and science learning outcomes in different designs of participatory simulated games. *British Journal of Educational Technology*, *52*(10), 1197–1214. doi:10.1111/bjet.13067

Leiker, A. M., Miller, M., Brewer, L., Nelson, M., Siow, M., & Lohse, K. (2016). The relationship between engagement and neurophysiological measures of attention in motion-controlled video games: A randomized controlled trial. *JMIR Serious Games*, *4*(1), e4–e15. doi:10.2196/games.5460 PMID:27103052

Li, K., Hall, M., Bermell-Garcia, P., Alcock, J., Tiwari, A., & González-Franco, M. (2017). Measuring the learning effectiveness of serious gaming for training of complex manufacturing tasks. *Simulation & Gaming*, *48*(6), 770–790. doi:10.1177/1046878117739929

Lin, H.-C. K., Lin, Y.-H., Wang, T.-H., Su, L.-K., & Huang, Y.-M. (2021). Effects of incorporating augmented reality into a board game for high school students' learning motivation and acceptance in health education. *Sustainability (Basel)*, *13*(6), 3333–3347. doi:10.3390/su13063333

Loh, C. S., Sheng, Y., & Ifenthaler, D. (2015). Serious games analytics: Theoretical framework. In C. S. Loh, Y. Sheng, & D. Ifenthaler (Eds.), *Serious Games Analytics: Methodologies for Performance Measurement, Assessment, and Improvement* (pp. 3–29). Springer. doi:10.1007/978-3-319-05834-4_1

Magen-Nagar, N., Shachar, H., & Argaman, O. (2019). Changing the learning environment: Teachers and students' collaboration in creating digital games. *Journal of Information Technology Education Innovations in Practice*, *18*, 61–85. doi:10.28945/4405

Mansoory, M. S., Khazaei, M. R., Azizi, S. M., & Niromand, E. (2021). Comparison of the effectiveness of lecture instruction and virtual reality-based serious gaming instruction on the medical students' learning outcome about approach to coma. *BMC Medical Education*, *21*(1), 347–354. doi:10.1186/s12909-021-02771-z PMID:34130676

Matallaoui, A., Hanner, N., & Zarnekow, R. (2017). Introduction to gamification: foundation and underlying theories. In S. Stieglitz, C. Lattemann, S. Robra-Bissantz, R. Zarnekow, & T. Brockmann (Eds.), *Gamification: Using Game Elements in Serious Contexts* (pp. 3–18). Springer., doi:10.1007/978-3-319-45557-0_1

McGonigal, J. (2011). *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*. Penguin.

Montes, H., Hijón-Neira, R., Pérez-Marìn, D., & Montes, S. (2021). Using an online serious game to teach basic programming concepts and facilitate gameful experiences for high school students. *IEEE Access : Practical Innovations, Open Solutions*, *9*, 12567–12578. doi:10.1109/ACCESS.2021.3049690

Nevid, J. (2012). *Psychology: Concepts and Applications* (4th ed.). Cengage Learning. doi:10.1037/031848

Ninaus, M., Pereira, G., Stefitz, R., Prada, R., Paiva, A., Neuper, C., & Wood, G. (2015). Game elements improve performance in a working memory training task. *International Journal of Serious Games*, *2*(1), 1–16. doi:10.17083/ijsg.v2i1.60

O'Garra, T., Reckien, D., Pfirman, S., Simon, B. E., Bachman, G. A., Brunacini, J., & Lee, J. J. (2021). Impact of gameplay vs. reading on mental models of social-ecological systems: A fuzzy cognitive mapping approach. *Ecology and Society*, *26*(2), 25–55. doi:10.5751/ES-12425-260225

Oliveira, M., & Petersen, S. (2014). The choice of serious games and gamification: A case study to illustrate key differences. In M. Ma, M. F., Oliveira, & J. Baalsrud Hauge (Eds.), Serious Games Development and Applications 2014 (Vol. 8778, pp. 213-223). Cham: Springer. doi:10.1007/978-3-319-11623-5_18

Ou, K.-L., Liu, Y.-H., & Tarng, W. (2021). Development of a virtual ecological environment for learning the Taipei Tree Frog. *Sustainability (Basel)*, *13*(11), 5911–5931. doi:10.3390/su13115911

Özer, H. H., Kanbul, S., & Ozdamli, F. (2018). Effects of the gamification supported flipped classroom model on the attitudes and opinions regarding game-coding education. [iJET]. *International Journal of Emerging Technologies in Learning*, *13*(1), 109–123. doi:10.3991/ijet.v13i01.7634

Pan, Y.-H., Huang, C.-H., Lee, I.-S., & Hsu, W.-T. (2019). Comparison of learning effects of merging TPSR respectively with sport education and traditional teaching model in high school physical education classes. *Sustainability (Basel)*, *11*(7), 2057–2032. doi:10.3390/su11072057

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*(1), 1–12. doi:10.1016/j.compedu.2008.06.004

Peijnenborgh, J. C., Hurks, P. P., Aldenkamp, A. P., van der Spek, E. D., Rauterberg, G., Vles, J. S., & Hendriksen, J. G. (2016). A study on the validity of a computer-based game to assess cognitive processes, reward mechanisms, and time perception in children aged 4-8 years. *JMIR Serious Games*, *4*(2), e15–e31. doi:10.2196/games.5997 PMID:27658428

Phungoen, P., Promto, S., Chanthawatthanarak, S., Maneepong, S., Apiratwarakul, K., Kotruchin, P., & Mitsungnern, T. (2020). Precourse preparation using a serious smartphone game on advanced life support knowledge and skills: Randomized controlled trial. *Journal of Medical Internet Research*, *22*(3), e16987–e16998. doi:10.2196/16987 PMID:32149711

Pimentel, J., Cockcroft, A., & Andersson, N. (2021). Impact of game jam learning about cultural safety in Colombian medical education: A randomised controlled trial. *BMC Medical Education*, *21*(1), 132–144. doi:10.1186/s12909-021-02545-7 PMID:33632194

Qiao, S., Yeung, S. S., Zainuddin, Z., Ng, D. T. K., & Chu, S. K. W. (2023). Examining the effects of mixed and non-digital gamification on students' learning performance, cognitive engagement and course satisfaction. *British Journal of Educational Technology*, *54*(1), 394–413. doi:10.1111/bjet.13249

Radoff, J. (2011). Game on: Energize your business with social media games. *International Journal of Advertising*, *30*(5), 916–917. doi:10.2501/IJA-30-5-916-917

Raju, R., Bhat, S., Bhat, S., D'Souza, R., & Singh, A. B. (2021). Effective usage of gamification techniques to boost student engagement. *Journal of Engineering Education Transformations*, *34*(0), 713–717. doi:10.16920/jeet/2021/v34i0/157171

Ryan, R. M., & Deci, E. L. (2000a). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist*, *55*(1), 68–78. doi:10.1037/0003-066X.55.1.68 PMID:11392867

Ryan, R. M., & Deci, E. L. (2000b). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. doi:10.1006/ceps.1999.1020 PMID:10620381

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, *32*(1), 77–112. doi:10.1007/s10648-019-09498-w

Saleh Alabdulaziz, M. (2023). Escape rooms technology as a way of teaching mathematics to secondary school students. *Education and Information Technologies*, *28*(10), 13459–13484. doi:10.1007/s10639-023-11729-1 PMID:37361796

Salen, K., & Zimmermann, E. (2004). *Rules of Play: Game Design Fundamentals*. MIT Press.

Sánchez, S. P., Belmonte, J. L., Cabrera, A. F., & Núñez, J. A. L. (2020). Gamification as a methodological complement to flipped learning—An incident factor in learning improvement. *Multimodal Technologies and Interaction*, *4*(2), 12–25. doi:10.3390/mti4020012

Scales, C. D. J. Jr, Moin, T., Fink, A., Berry, S. H., Afsar-Manesh, N., Mangione, C. M., & Kerfoot, B. P. (2016). A randomized, controlled trial of team-based competition to increase learner participation in quality-improvement education. *International Journal for Quality in Health Care : Journal of the International Society for Quality in Health Care*, *28*(2), 227–232. doi:10.1093/intqhc/mzw008 PMID:26857941

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of Human-Computer Studies*, *74*, 14–31. doi:10.1016/j.ijhcs.2014.09.006

Sionti, M., Schack, T., & Aloimonos, Y. (2018). An embodied tutoring system for literal vs. metaphorical concepts. *Frontiers in Psychology*, *9*, 1–11. doi:10.3389/fpsyg.2018.02254 PMID:30546328

Su, C., & Cheng, C. (2015). A mobile gamification learning system for improving the learning motivation and achievements. *Journal of Computer Assisted Learning*, *31*(3), 268–286. doi:10.1111/jcal.12088

Su, C.-H. (2017). The effects of students' learning anxiety and motivation on the learning achievement in the activity theory based gamified learning environment. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(5), 1229–1258. doi:10.12973/eurasia.2017.00669a

Sun, L., Kangas, M., & Ruokamo, H. (2023). Game-based features in intelligent game-based learning environments: A systematic literature review. *Interactive Learning Environments*, 1–17. doi:10.1080/10494820.2023.2179638

Tan, C. I., Wong, C. Y., Abdullah, A., & Lee, J. E. K. (2021). Investigating the Effects of Social Gameplay Elements in Gamifying Online Classes. In Eu*ropean Conference on Games Based Learning ECGBL 2021* (pp. 80). Academic Conferences International Limited.

van Grove, J. (2011). *Gamification: How competition is reinventing business, marketing & everyday life*. Mashable. http://mashable.com/2011/07/28/gamification/#jwRDwxY4Okqq

Vázquez-Cano, E., Mengual-Andrés, S., & López-Meneses, E. (2021). Chatbot to improve learning punctuation in Spanish and to enhance open and flexible learning environments. *International Journal of Educational Technology in Higher Education*, *18*(1), 33–53. doi:10.1186/s41239-021-00269-8

Werbach, K., & Hunter, D. (2012). *For the Win: How Game Thinking Can Revolutionize your Business*. Wharton Digital Press.

Winter, M., Pryss, R., Probst, T., & Reichert, M. (2020). Learning to read by learning to write: Evaluation of a serious game to foster business process model comprehension. *JMIR Serious Games*, *8*(1), e15374–e15387. doi:10.2196/15374 PMID:31917374

Ye, L., Zhou, X., Yang, S., & Hang, Y. (2022). Serious game design and learning effect verification supporting traditional pattern learning. *Interactive Learning Environments*, 1–15. doi:10.1080/10494820.2022.2042032

Yeo, C. L., Ho, S. K. Y., Tagamolila, V. C., Arunachalam, S., Bharadwaj, S. S., Poon, W. B., Tan, M. G., Edison, P. E., Yip, W. Y., Haium, A. A. A., Jayagobi, P. A., Vora, S. J., Khurana, S. K., Allen, J. C., & Lustestica, E. I. (2020). Use of web-based game in neonatal resuscitation - is it effective? *BMC Medical Education*, *20*(1), 170–181. doi:10.1186/s12909-020-02078-5 PMID:32456704

Yien, J. M., Hung, C. M., Hwang, G. J., & Lin, Y. C. (2011). A game-based learning approach to improving students' learning achievements in a nutrition course. *The Turkish Online Journal of Educational Technology*, *10*(2), 1–10.

Yu, Z. (2015). Indicators of satisfaction in clickers-aided EFL class. *Frontiers in Psychology*, *6*, 587. doi:10.3389/fpsyg.2015.00587 PMID:25999898

Zairi, I., Ben Dhiab, M., Mzoughi, K., & Ben Mrad, I. (2022). The Effect of Serious Games on Medical Students' Motivation, Flow and Learning. *Simulation & Gaming*, *53*(6), 581–601. doi:10.1177/10468781221123919

Zichermann, G., & Cunningham, C. (2011). Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. Sebastopol, CA: O' Reilly Media.

APPENDIX

Table 1. The extracted studies for meta-analyses and the involved research dimensions

Authors and publication years		Research dimensions involved in the studies	
Serious games	Abbasi et al., 2021	**Learning achievement**	
		Uncategorized motivation	
		Attention	Extrinsic motivation
		Relevance	Intrinsic motivation
		Confidence	Extrinsic motivation
		Satisfaction	Intrinsic motivation
	Baños et al., 2013	Learning achievement	
	Barma et al., 2015	Learning achievement	
	Bayley & Brown, 2015	Intention	Intrinsic motivation
		Subjective norms	Intrinsic motivation
		Perceived behavioral control	Intrinsic motivation
		Attitude	Extrinsic motivation
	Casalsa, et al., 2020.	Learning achievement	
	Chang et al., 2018	Learning achievement	
		Flow	Intrinsic motivation
	C.-Y. Chen et al., 2020.	Learning achievement	
	Dankbaar et al., 2016	Learning achievement	
	Dankbaar et al., 2017	Learning achievement	
	De La Garza1 et al., 2017	Learning achievement	
	Fellnhofer, 2016	Learning achievement	
	Froome et al., 2020	Learning achievement	
	Fuster-Guilló et al., 2019	Learning achievement	
	Gamito et al., 2014	Cognitive abilities	Intrinsic motivation
		Mental flexibility	Intrinsic motivation
		Task execution time	Extrinsic motivation
	Giannakos et al., 2015	Intention	Intrinsic motivation
		Immersion	Intrinsic motivation
	Gulec & Yilmaz, 2016	Learning achievement	
	Haubruck et al., 2018	Learning achievement	
	Hussein et al., 2019	Learning achievement	
		Uncategorized motivation	
		Self-efficacy	Intrinsic motivation
	Kato-Lin et al., 2020	Learning achievement	
	Kolić-Vehovec et al., 2019	Learning achievement	
	Leiker et al., 2016	Learning achievement	
		Engagement	Intrinsic motivation
	Li et al., 2017	Learning achievement	
		Confidence	Intrinsic motivation
		Engagement	Intrinsic motivation

continued on following page

Table 1. Continued

Authors and publication years		Research dimensions involved in the studies	
Serious games	Mansoory et al., 2021	Learning achievement	
	Molina-Torres et al., 2021	Learning achievement	
		Attendance	Extrinsic motivation
	Montes et al., 2021	Learning achievement	
	Ninaus et al., 2015	Learning achievement	
	O'Garra et al., 2021	Cognitive connections of learning goals and contents	Extrinsic motivation
	Peijnenborgh et al., 2016	Learning achievement	
	Phungoen et al., 2020	Learning achievement	
	Pimentel et al., 2021	Self-efficacy	Intrinsic motivation
	Sionti et al., 2018.	Learning achievement	
	Winter et al., 2020.	Learning achievement	
	Yeo et al., 2020	Learning achievement	
Gamification	Alcalá & Garijo, 2017	Learning achievement	
		Uncategorized motivation	
	Arnab et al., 2013	Learning achievement	
	Cechella et al., 2021	Learning achievement	
	Çetinkaya, 2019	Learning achievement	
	C.-Y. Chen et al., 2020	Learning achievement	
	C.-H. Chen & Yeh, 2019	Learning achievement	
		Cognitive load: mental effort	Intrinsic motivation
		Cognitive load: mental load	Intrinsic motivation
	Cichy et al., 2020	Learning achievement	
	Duggal et al., 2021	Learning achievement	
	Haruna et al., 2018	Attention	Intrinsic motivation
		Relevance	Extrinsic motivation
		Confidence	Intrinsic motivation
		Satisfaction	Extrinsic motivation
		Attention	Intrinsic motivation
		Relevance	Extrinsic motivation
		Confidence	Intrinsic motivation
		Satisfaction	Extrinsic motivation
	Hodges et al., 2021	Learning achievement	
	C.-M. Hung et al., 2014	Learning achievement	
		Uncategorized motivation	
	C.-Y. Hung et al., 2018	Uncategorized motivation	
	H.-T. Hung, 2018	Attention	Intrinsic motivation
		Relevance	Extrinsic motivation

continued on following page

Table 1. Continued

Authors and publication years		Research dimensions involved in the studies	
Gamification	H.-T. Hung, 2018	Confidence	Intrinsic motivation
		Satisfaction	Extrinsic motivation
	Hwang et al., 2013	Learning achievement	
		Uncategorized motivation	
	Lee et al., 2020	Learning achievement	
		Behavioral engagement	Extrinsic motivation
		Cognitive engagement	Intrinsic motivation
		Emotional engagement	Intrinsic motivation
		Social engagement	Extrinsic motivation
	Lin et al., 2021	Intrinsic motivation	
		Attention	Extrinsic motivation
		Relevance	Extrinsic motivation
		Confidence	Intrinsic motivation
		Satisfaction	Intrinsic motivation
	Magen-Nagar et al., 2019	Intrinsic motivation	
		Class collaboration	Extrinsic motivation
		Class collaboration (Pre-school)	Extrinsic motivation
	Ou, Liu, & Tarng, 2021	Learning achievement	
	Özer et al., 2018	Uncategorized motivation	
	Pan et al., 2019	Learning achievement	
		Self-direction	Extrinsic motivation
		Respect	Extrinsic motivation
		Effort	Extrinsic motivation
		Group cohesion	Extrinsic motivation
		Helping others	Extrinsic motivation
		Cooperation	Extrinsic motivation
	Sánchez et al., 2020	Learning achievement	
		Uncategorized motivation	
		Intrinsic motivation	
		Interaction with classmates	Extrinsic motivation
		Interaction with teacher	Extrinsic motivation
		Cooperation	Extrinsic motivation
		Interaction with contents	Extrinsic motivation
	Scales et al., 2016	Learning achievement	
	Su, 2017	Learning achievement	
		Uncategorized motivation	
	Vqzquez-Cano et al., 2021	Learning achievement	

Table 2. Heterogeneity measures of the data

Dataset	I^2 (%)	df	Cochran's Q	p
Data for Research Question 1	81.0	46	242.13	0.000
Data for Research Question 2	91.3	25	287.79	0.000
Data for Research Question 3	89.0	37	336.08	0.000

Table 3. Meta-regression examining the potential factors contributing to heterogeneity

_ES		Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Data for Research Question 1	year	.0258805	.0186565	1.39	0.173	-.0118875	.0636485
	approach	.0187564	.1057504	0.18	0.860	-.195324	.2328369
	en	.000302	.0027656	0.11	0.914	-.0052966	.0059006
	em	.1033202	.0163992	6.30	0.000	.0701217	.1365187
	esd	.0156681	.0314799	0.50	0.622	-.0480597	.0793959
	cn	.0014037	.0023888	0.59	0.560	-.0034322	.0062396
	cm	-.1009717	.0165773	-6.09	0.000	-.1345306	-.0674128
	csd	-.0465929	.0347386	-1.34	0.188	-.1169175	.0237316
	_cons	-52.06822	37.66684	-1.38	0.175	-128.3207	24.18431
Data for Research Question 2	year	-.0167766	.0297563	-0.56	0.580	-.0795569	.0460036
	approach	.3782752	.1222048	3.10	0.007	.1204455	.6361048
	en	-.0004149	.0016658	-0.25	0.806	-.0039294	.0030995
	em	.4209059	.0866958	4.85	0.000	.2379937	.6038181
	esd	-.1081834	.0965485	-1.12	0.278	-.3118829	.0955162
	cn	.000921	.0020467	0.45	0.658	-.0033971	.0052392
	cm	-.3963369	.0901156	-4.40	0.000	-.5864643	-.2062096
	csd	.0775799	.0943327	0.82	0.422	-.1214448	.2766046
	_cons	33.3982	59.99967	0.56	0.585	-93.19004	159.9864
Data for Research Question 3	year	-.0089105	.0273439	-0.33	0.747	-.064835	.047014
	approach	.2924156	.109159	2.68	0.012	.0691603	.5156709
	en	-.0009815	.0022695	-0.43	0.669	-.005623	.0036601
	em	.4509651	.0878225	5.13	0.000	.2713479	.6305822
	esd	.0061303	.055055	0.11	0.912	-.1064699	.1187305
	cn	.0016286	.0026854	0.61	0.549	-.0038637	.007121
	cm	-.433258	.0922443	-4.70	0.000	-.6219188	-.2445972
	csd	-.0549299	.049872	-1.10	0.280	-.1569297	.0470699
	_cons	17.74675	55.17017	0.32	0.750	-95.08892	130.5824

Table 4. Egger's tests examining publication bias in the data

Std_Eff		Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Data for Research Question 1	slope	.1734355	.1805288	0.96	0.342	-.1901682	.5370392
	bias	1.52911	1.013612	1.51	0.138	-.5124098	3.570631
Data for Research Question 2	slope	.2046378	.2004307	1.02	0.317	-.2090308	.6183064
	bias	1.984133	1.620502	1.22	0.233	-1.360419	5.328686
Data for Research Question 3	slope	.2686389	.1910258	1.41	0.168	-.1187794	.6560573
	bias	1.200678	1.274825	0.94	0.353	-1.384786	3.786143

Jiaopin Ren, First Author, https://orcid.org/0000-0001-8709-9928, instructor in Department of English, School of Foreign Studies, Zhongyuan Institute of Science and Technology. Her research interest includes educational technologies, online teaching and learning, and language acquisition. Affiliation: Department of English, School of Foreign Studies, Zhongyuan Institute of Science and Technology.

Wei Xu, Corresponding Author, is an Associate Professor of Applied Linguistics at the Faculty of Humanities and Social Sciences, City University of Macau, and the programs coordinator for Bachelor of Arts in English and Bachelor of Arts in Applied Linguistics. His research interests include second language acquisition, foreign language education, educational technology, and multicultural studieshttps://orcid.org/0000-0002-7224-1116.

Ziqing Liu, Third Author, is a student of Master of Education program at the School of Education, City University of Macau. Her research interests are educational technology, educational psychology, and language education. https://orcid.org/0009-0007-8575-1012.