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A meta-analysis: Gamification in education

Yalin Wang

A META-ANALYSIS: GAMIFICATION IN EDUCATION

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YALIN WANG

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Approved by:

Fiona Fui-Hoon Nah, Advisor
Ting Shen, Co-Advisor
Keng Siau

ABSTRACT

Gamification has been used in a variety of contexts including education. In order to understand the effects of gamification in education, a meta-analysis was conducted. A bottom-up approach was used to analyze the effects of game design elements on learning outcomes found in the literature search. The result suggests that gamification can enhance student learning outcomes. Elements such as points, leaderboards, competitions, progress bars, feedback, and collaboration have medium to large effect sizes. Gamification also has larger effects on young children in elementary education than learners at other education levels. The study offers suggestions and guidelines for educators on the use of design elements in gamification.

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NOMENCLATURE

Symbol	Description
g	hedges'g, standardized mean difference
d	Cohen's d
M	Mean
t	t-value in t-tests
F	F-value in ANOVA tests
r	Correlation
SD	Standard deviation
SE	Standard error
n	Sample size

1. INTRODUCTION

Given the increasing popularity of the use of gaming in education and that player engagement can be induced by gaming, gamification and serious games have emerged across various sectors (e.g., business and education) and disciplines (e.g., computer science and mathematics) to engage and motivate users in target activities (Mitchell et al., 2020; Ortega-Arranz et al., 2019; Toda et al., 2019). There has been an increasing number of empirical studies conducted on gamification in education. Gamification presents promising utility in improving students' learning, e.g., in increasing motivation, engagement, and learning achievement. For example, Hursen and Bas (2019) found that motivation in learning science increases with gamification. A study by Huang and Hew (2018) also showed that both engagement and learning achievement in information management increased using gamification in out-of-class activities (Huang & Hew, 2018).

This thesis adopts a commonly cited definition proposed by Deterding et al. (2011), where gamification refers to the use of game elements in non-game contexts. Another similar concept is serious games, which refer to games designed for a primary purpose other than pure entertainment (Alvarez & Djaouti., 2011). In educational settings, gamification blends game design elements (e.g., points, leaderboards, and rewards) with traditional learning and teaching activities, while serious games serve an educational purpose (Plass et al., 2015). Although serious games and gamification share a common toolkit of game elements, research in these overlapping areas has been developed separately (Landers, 2015). In this research, we include studies from gamification and serious gaming that are applied in education to analyze game design elements.

Due to the characteristics (e.g., goals, rules, and competition) of gamified activities, gamification has aroused the interest of educators and academic researchers in education. The lack of motivation and engagement of students has posed a prevailing challenge in education, including in higher education and K-12 education (Legault et al., 2006; Meens et al., 2018). Gamification shows potential as a method to engage and motivate students in deep learning processes and experiences (Kyewski & Krämer, 2018; Looyestyn et al., 2017), and in improving academic achievement (Andolsek, 2016; Dodd & Bowen, 2011).

The amount of empirical research that has examined the effect of gamification or game-based learning on education is increasing in recent years. However, the impacts of gamification on student learning and success have not been well understood by educators and researchers because of inconsistent or conflicting findings in the literature (Ofosu-Ampong, 2020). Various studies have shown mixed results because of the application of different game design elements or the use of different combinations of them. Different application contexts also lead to divergent results, e.g., they may vary by instructional type (e.g., online versus face-to-face learning), educational level (e.g., K-12 versus higher education), course subject (e.g., mathematics, languages, and physical education), and research duration (e.g., days, months, and years). In addition, studies with small sample sizes cannot provide convincing evidence on the impact of gamification and game-based learning (Chuang & Kuo, 2016). In other words, gamification and game-based learning can be broken down by design elements to more fully understand their individual and combined effects. Therefore, the meta-analysis, which is a statistical analysis that combines the results of multiple scientific studies, is helpful in systematically assessing previous research studies to overcome issues with sample sizes and to generate a more complete understanding of the effects of gamification in education (Cooper et al., 2019).

The purpose of this study is three-fold. First, it analyzes the effects of gamification on student learning by integrating empirical studies on gamification and serious games. Second, it provides a more complete understanding of the effects of gamification on education by considering moderating factors (e.g., educational level and course subject). Third, it offers suggestions and guidelines for educators on the use of gamification design elements in education.

In this research, we will use the meta-analysis approach to examine the effects of using various game design elements on learning outcomes. For game-based learning, the game design elements (e.g., points and storytelling) applied in education would be extracted for analysis. We focus on three types of learning outcomes: motivation, engagement, and learning achievement. Meanwhile, the effect of various moderators found in the literature search (e.g., instruction type and duration) would also be analyzed. Our overarching research questions are:

- What is the overall impact of gamification design elements on learning outcomes?
- What are the effects of gamification design elements on students' motivation, engagement, and learning achievement?

- What are the moderating effects of course subject, educational level, instruction type (instructor-led or not), application context (e.g., classroom management, and learning assessment tool), and duration (e.g., less than a month) on students' motivation, engagement, and learning achievement?

2. LITERATURE REVIEW

Since gamification has the potential to increase engagement, it has received increased attention in recent years. Research on gamification has been conducted in a wide range of areas, e.g., in the domains of exercise, education, health (Sardi et al., 2017), crowdsourcing (Morschheuser et al., 2019), government services (Contreras-Espinosa & Blanco-M, 2020), environmental behavior (Wang & Yao, 2020), as well as marketing (Dhahak & Huseynov, 2020), to name a few. In general, the overall results are leaning toward positive findings of the effectiveness of gamification (Hamari et al., 2014; Koivisto & Hamari, 2019).

In the context of education, the impact of gamification on motivation, engagement, and learning achievement has been examined by previous studies and many of them show positive results (Zainuddin et al., 2020a; Ofosu-Ampong, 2020). However, researchers have also found the results of independent studies to be inconsistent and suggested further investigations of specific game design elements under various contexts (Dichev & Dicheva, 2017; Dicheva & Dichev, 2015; So & Seo, 2018; Ofosu-Ampong, 2020; Zainuddin et al., 2020a). Furthermore, some research lacks a theoretical explanation of the link between gamification and learning outcomes (Zainuddin et al., 2020a). A theoretical framework can help explain the relationships between gamification and its effects, identify potential problems in practice, as well as assess related theories by testing theoretical propositions (Kivunja, 2018). In addition, a systematic experimental approach is required to guide the practice of gamification (Dichev & Dicheva, 2017). Considering that different game design elements serve different incentives, learners possess different characteristics, and gamified learning activities are conducted in a variety of subject areas, the guidance of a systematic framework enables the application of gamification to achieve its desired goal more efficiently and effectively.

2.1. GAME DESIGN ELEMENTS

Game design elements serve as game mechanics and game dynamics to promote desired learner behaviors. Game mechanics translate inputs to outputs, while game dynamics regulate the interactions between players and game mechanics (Ofosu-Ampong, 2020). Multiple categories of design elements for gamification have been developed in previous studies. We summarize 15 gamification design elements that are adopted by at least five studies in the literature search. These elements will be examined using the meta-analysis approach to better understand their effects on education. A description of each of these 15 game design elements is displayed in Table 2.1.

2.2. APPLICATION CONTEXTS OF GAMIFICATION IN EDUCATION

We reviewed empirical studies on gamification that have been applied in different educational application contexts. Ten representative studies were chosen and are summarized in Table 2.2 to illustrate these educational contexts.

In the field of education, gamification has been used to increase the engagement and motivation of students as well as improve their performance/achievement. From our review of the literature, we found that gamification in education is mainly carried out in four forms: flipped classroom, classroom management, online homework platform, and learning assessment tool (Lai & Hwang, 2016; Huang & Hew, 2018; Hursen & Bas, 2019; Zainuddin et al., 2020b). Flipped classroom is an instructional strategy and a type of blended learning focused on student engagement and active learning by switching in-class instructional time and out-of-class practicing time (Lai & Hwang, 2016). In flipped classrooms, gamification is often used as a way to encourage student participation in out-of-class activities. Huang and Hew (2018) incorporated gamification into flipped classroom learning. In their study, discussion and problem-solving activities were held in the classroom, and gamification was used to motivate students to participate in out-of-class activities (e.g., self-learning content and quizzes). In our study, we will merge the learning assessment tool with the online homework/exercise platform.

Table 2.1 Gamification design elements.

Design element	Description
Points	Score to illustrate the progress or achievement
Badges/trophies/medals	Recognition for achievement
Ranking/leaderboard	Score or achievement ranking of participants
Level	Milestone to indicate the current achievement or ability
Avatars	Animated characters to represent different persons
Progress bar/personal-record tracking	Graphics to indicate the progress toward a goal
Responsive feedback	Immediate response on behaviors and performance
Storytelling/narrative	Narrative context or theme
Collaboration/group work	Working with others
Competition	Opportunities for comparisons to identify the winners
Rules	Principles and regulations for procedure and action
Mission/goal	Clear goal(s) of gamification activity
Reward/award	Incentive or recognition that can take different forms
Challenges	Predefined quests and increasingly more difficult objectives
Timed activity	Complete tasks in a limited time

Table 2.2 Empirical studies on gamification in education.

Reference	Gamification design elements	Learning outcome(s)	Key findings	Application method	Course subjects
Huang & Hew (2018)	Points, levels, goal, badges, rules, collaboration	Engagement, learning achievement	Increased engagement, increased learning achievement	Flipped classroom	Information management
Hursen & Bas (2019)	Points, badges, leaderboard	Motivation	Increased motivation, positive opinions	Classroom management	Science
Kulhanek et al. (2019)	Points, badges, quests, awards	Motivation	Increased motivation	Homework platform	Engineering
Metwally et al. (2019)	Levels, points, badges, achievements, gifting, countdown timer, progress bar	Satisfaction, behavioral intention, intrinsic motivation	Increased enjoyment, increased motivation	Homework platform	Language learning
Zainuddin et al. (2020b)	Responsive feedback	Learning achievement	No significant effect on learning achievement	Learning assessment	Science
Aljraiwi (2019)	Points, badges, leaderboard	Achievement	Increased learning achievement	Classroom management	Language learning
Quintas et al. (2020)	Points, leaderboard, badge, avatar, level, personalization	Motivation, learning achievement	Increased motivation, increased learning achievement	Classroom management	Physical education
Butler & Bodnar (2017)	Points, quests, badges, awards	Motivation	Neutral impact on motivation	Homework platform	Engineering
Watson-Huggins & Trotman (2019)	Points, level, leaderboard, content unblocking, prize	Motivation	No significant effect on motivation	Classroom management	Mathematics
Jagušt et al. (2018)	Level, narrative, competition	Learning achievement	Increased in the amount of learning content but no significant increase in learning accuracy	Classroom management	Mathematics

Another application of gamification is in classroom management to help improve student engagement and the interaction between students and teachers. ClassDojo is an example of a digital classroom management tool, which involves multiple functions for classroom management such as course content and guideline management, classroom grouping, and immediate communication with students and parents (Bahceci, 2019). Hursen and Bas (2019) used ClassDojo to help teach science in a classroom that aimed to establish effective communication among teachers, parents, and students. On ClassDojo, students' behaviors were scored and recorded for sharing with their parents, and the desired student behaviors were encouraged by offering badges. A leaderboard was also applied to create competition among students.

Furthermore, gamified homework and gamified assessment are also regarded as potential ways to motivate and engage student learning. Gamified homework refers to applying game design elements (e.g., points, leaderboard, and badges) to learning assignments. Similarly, gamified assessment tools apply game design elements to testing. These two ways are typically used in online platforms, which allow learners to complete assignments, take tests, and receive feedback from instructors. A few studies have been conducted on building gamified homework platforms and assessing their effects (Kulhanek et al., 2019; Metwally et al., 2019). Kulhanek and his colleagues gamified curricular homework content in engineering education. The preliminary result suggests that gamification has a positive effect on building students' sense of success. Another study conducted by Metwally et al. (2019) also found the use of a gamified homework platform to be a feasible way to improve students' satisfaction, behavioral intention, and intrinsic motivation. In terms of gamified assessment, Zainuddin et al. (2020b) examined the effect of using e-quizzes as a gamified assessment tool in contrast to paper-based quizzes and found no significant difference in scores between the two groups.

In general, existing studies in the use of gamification in the flipped classroom, classroom management, online homework platform, and learning assessment present positive gamification effectiveness on learner motivation, while the effect on learning achievement is less significant. The discrepancy in the effect of gamification in these different educational application contexts suggests that further explorations are warranted to identify if application contexts moderate the effect on learning outcomes.

2.3. EMPIRICAL RESEARCH ON GAMIFICATION IN EDUCATION

Empirical gamification research in education has been widely applied across subjects in various education levels, course subjects, and application contexts. Furthermore, different combinations of game design elements have been applied, and various learning outcomes were examined in individual studies. Many researchers believe these various research contexts could be the reason for the inconsistent findings. Kalogiannakis et al. (2021) observed that science education presented less significant results on primary school learners than secondary and higher education learners because science education is more restricted in primary education and the concepts are more challenging to students as compared to other subjects. Similarly, Smiderle et al. (2020) concluded that gamified learning environments can affect students differently based on their characteristics.

The effect of gamification presents various results ranging from significantly positive to insignificant effects. Aljraiwi (2019) introduced game design elements such as points, badges, leaderboards in web-based English language learning. The result suggests that gamification significantly improves learning achievement. Similarly, Quintas et al. (2020) described the implementation of exergames in physical education. Exergames are digital motor games that aim to stimulate the player's motor skills. Increased intrinsic motivation and improved learning achievement were observed. However, Butler and Bodnar (2017) found no significant impact of gamified homework on student academic motivation in engineering education. Two other studies by Watson-Huggins and Trotman (2019) and Jagušt et al. (2018) also concluded that gamification did not increase the learning achievement of students in mathematics. Watson-Huggins and Trotman's experiment showed that their gamified intervention did not statistically improve mathematics scores (Watson-Huggins & Trotman, 2019). Jagušt and his colleagues found that by applying gamification design elements of level, narrative, and competition in mathematics learning, students achieved higher performance; however, the number of correct attempts was not affected compared to non-gamified students.

The various application contexts and inconsistent results impede drawing valid conclusions about the efficacy of gamification in education (Dicheva & Dichev, 2015). As such, this meta-analysis can contribute to better effect estimations by combining the results of individual studies using statistical methods.

2.4. META-ANALYSIS OF GAMIFICATION IN EDUCATION

The potential of gamification in education and the inconsistent empirical research results have led to the use of synthesis research, such as meta-analysis. Meta-analysis allows the results of individual studies to be combined using statistical methods to obtain better effect size estimations. Seven meta-analysis studies that focused on similar research objectives were reviewed and summarized in Table 2.3.

All of the overall effect sizes are positive in these seven studies, ranging from 0.25 to 1.01. Individual meta-analysis studies contribute to the literature on gamification in education by using different inclusion criteria. Byun and Jong (2018) focused on K-12 digital game-based math learning, while Fadhli et al. (2020) explored the effectiveness of gamification on children. Yildirim and Sen (2019) only included studies that examine the effect of gamification on student academic achievement, while six other meta-analyses assessed multiple dimensions of learning outcomes. Bai et al. (2020) conducted both a meta-analysis of quantitative studies and a synthesis of qualitative studies. They calculated the independent effect size of each study as well as the variation in effect sizes due to course characteristics (e.g., subject area), student characteristics (e.g., educational level), as well as the type and number of game elements used. Although Bai et al. (2020) considered the effect of game design elements, they only examined the effect of combinations of elements instead of individual elements. On the other hand, Huang et al. (2020) explored the effect of game design elements on learning achievement, whereas motivation and engagement were not included in their research scope. Bai et al. (2020) found an insignificant gamification effect of educational levels, while Huang et al. (2020) showed an alarming difference between implementations in undergraduate and K-12 studies. The inconsistent moderating effect of education level requires more research evidence to support the conclusions. Among these seven studies, only one of them has broken down the effect of individual game elements (Huang et al., 2020), and none of them use theories to explain the relationships between gamification and learning outcomes, leaving a research gap to be filled.

Table 2.3 Synthesis studies on gamification in education.

Reference	Key findings
Byun & Joung (2018)	Small positive effect (Cohen's d=0.37) on K-12 math learning based on a digital game
Fadhli et al. (2020)	Large positive effect (Hedges' g=1.01) on general learning of 6–10-year-old children.
Merchant et al. (2014)	Medium positive effect (Hedges' g=0.51) of game-based instruction on students' learning outcomes in K-12 and higher education. Student performance was enhanced when they conducted the game play individually than in groups.
Sailer & Homner (2020)	The effect of gamification on learning achievement (Hedges' g=0.49) was more stable than motivation (g=0.36) and engagement (g=0.25). Combining competition with collaboration was particularly effective for fostering engagement.
Yildirim & Sen (2019)	Medium positive effect (Hedges' g = 0.557) of game-based instruction on students' learning achievement in K-12 and higher education.
Bai et al. (2020)	Significant medium positive effect (Hedges' g = 0.504) of gamification on learning achievement.
Huang et al. (2020)	Significant small to medium positive effect (Hedges' g = 0.464) of gamification on learning outcomes.

3. THEORETICAL FOUNDATION

In the present study, we examine the effects of 15 gamification design elements on intrinsic motivation, engagement, and learning achievement based on self-determination theory (Ryan & Deci, 2000), flow theory (Csikszentmihalyi, 1990), and goal-setting theory (Locke & Latham, 1994).

3.1. SELF-DETERMINATION THEORY

Self-determination theory (SDT) focuses on providing an understanding of people's inherent growth tendencies and innate psychological needs for self-motivation and personality integration. People take actions with very different types of motivations, which comprise intrinsic motivation and extrinsic motivation. Intrinsic motivation refers to engaging in activities for inherent satisfaction. When people are intrinsically motivated, they act for the fun and enjoyment from the activity itself. On the other hand, in contrast to intrinsic motivation, extrinsic motivation relates to conducting behaviors to attain separable consequences such as receiving rewards or avoiding punishment (Ryan & Deci, 2000). Furthermore, compared to extrinsic motivation, people who are motivated by intrinsic motivation tend to have more enhanced performance, persistence, and creativity (Ryan & Deci, 2000).

In SDT, Ryan and Deci (2000) proposed that satisfaction that arises from three innate psychological needs -- competence, autonomy, and relatedness -- enhances intrinsic motivation. Competence refers to skills and knowledge (Ryan & Deci, 2000). Autonomy refers to the ability to act on one's thoughts and opinions (Ryan & Deci, 2000), and relatedness refers to connectedness with others and the surroundings (Ryan & Deci, 2000). Factors that support or enhance these innate needs can contribute to intrinsic motivation and optimal functioning, while factors that thwart these basic needs can reduce intrinsic motivation and performance. In other words, when external events (e.g., freedom to choose) enhance one's sense of competence and sense of autonomy, one's basic needs are better satisfied, and thus, intrinsic motivation increases. Similarly, increasing one's sense of relatedness (e.g., having opportunities to interact or communicate) can also increase one's intrinsic motivation.

3.2. FLOW THEORY

Flow theory can be used to explain how gamified activities engage learners (Csikszentmihalyi, 1990). In flow theory, flow refers to a mental state in which a person is completely engaged in an activity with full involvement and enjoyment. This mental state features the following 8 factors: (1) a challenging activity that requires skills, (2) merging of action and awareness, (3) clear goals and feedback, (4) concentration on the task at hand, (5) sense of control, (6) loss of self-consciousness, (7) transformation of time, and (8) autotelic experience.

People tend to feel bored when their skill level exceeds the level of challenge of an activity and they feel frustrated or anxious when the level of challenge posed by the activity is beyond their ability. Hence, an activity requires a suitable difficulty level to stimulate a person's interest and involvement, and to achieve a state of flow.

When in a state of flow, people perform an activity spontaneously without the awareness of themselves as being separate from the activity, i.e., by perceiving the merging of action and awareness. This state is often attained in activities that require strenuous physical exertion or high mental discipline.

Additionally, clear goals and feedback are significant factors that engage people in certain activities. People are required to develop a clear sense of purpose and gain feedback relevant to goals to maintain a continuous state of engagement.

Concentration on the task is another frequently mentioned aspect of the flow state. When people attain the state of flow, the target activity would occupy their thoughts and they forget all other aspects of their life during those moments.

A sense of control refers to the feeling of being in control of one's actions and the environment. In other words, a person is not worried about being controlled when entering the flow state. For example, a ballet lover will not worry about potential accidents (e.g. injured, criticism) while dancing; a chess player will not be concerned about who is the winner during the chess game.

Loss of self-consciousness refers to losing the sense of one's self during an activity. Typically, it is represented by a feeling of union with the environment.

The transformation of time that is experienced in the flow state refers to a distortion of temporal experience. While an individual is immersed in an activity, his or her subjective experience of time is altered. Specifically, people in the flow state are not aware of the passing of time and often sense that time stands still.

Autotelic experience refers to a sense of self-rewarding experience and enjoyment from the experience itself. In other words, the activity that consumes people becomes intrinsically rewarding. For instance, a violinist plays the violin because he or she enjoys playing and not to gain or enhance reputation or receiving a material reward.

Based on the flow theory, gamified design elements show the potential to engage learners by providing experience in line with the factors mentioned above.

3.3. GOAL-SETTING THEORY

Locke and Latham (1990) proposed the goal-setting theory to explain the relationship between goals and performance (Locke & Latham, 1990). A goal can be understood as the objective of action that a person tries to achieve. According to the theory, working toward a goal is a major source of motivation, which in turn improves performance.

The goal-setting theory purports that task performance is affected by the following mechanisms (Locke & Latham, 2002). Goals provide directing effort and attention toward activities. By setting a goal, an individual can evaluate how much effort and time are required to put into an activity. Additionally, goals serve a stimulating function. High-demanding goals tend to lead to greater effort and better performance than low-demanding goals. According to goal-setting theory, some people perform better than others because they have different or higher-demanding goals (Locke & Latham, 1994). For example, individuals who set specific yet difficult goals perform better than those who set general and easy goals. Therefore, setting effective goals is critical to achieving desired performance.

According to Locke and Latham (1990), five goal-setting principles can help improve the chances of realizing a goal: clarity, challenge, commitment, feedback, and task complexity (Locke & Latham, 1990). Clarity refers to the specificity of a goal. A clear and measurable goal is more achievable than one that is poorly defined. For example, effective goals have a specific timeline for completion. Challenge refers to a decent level of difficulty of a goal, which serves to motivate individuals to strive toward the goal. While goals should be challenging to encourage individuals to transcend themselves, goals should also be achievable and realistic to increase commitment. Otherwise, individuals may lose interest and confidence and thus quit the activity. Feedback refers to receiving information on the progress. Feedback provides individuals the opportunity to clarify expectations of others or themselves and adjust the difficulty of their goals. Task complexity refers to a collection of properties inherited by a task. These properties (e.g., priority, due date, duration, and urgency) define the difficulty of a task and its significance to a performer. To set an effective goal, task complexity should fall within resource limitations (e.g., time and equipment). In conclusion, the aforementioned principles should be taken into account to set an effective goal to increase the chances of realizing the goal.

4. HYPOTHESES AND RESEARCH MODEL

In the present study, the independent variables are 15 game design elements and the dependent variables are three learning outcomes, which are motivation, engagement, and learning achievement. The moderating variables include instruction type, course subject, education level, duration, and application context. The justifications for the hypothesized effects of game design elements are classified into five principles based on learners' psychological needs in the literature (Nah et al., 2019; Majuri et al., 2018; Aparicio et al., 2012): performance checking, goal orientation, reinforcement, sociality, and fun. Performance checking provides opportunities for learners to learn about the progress and quality of their learning. Goal orientation refers to setting goals and directions for learners to work hard. In the context of gamification, reinforcement refers to strengthening action in learning with positive feedback such as praise or physical rewards. Sociality refers to elements that enable learners to collaborate on tasks, interact with others, and gain a better understanding of others' performance. Fun refers to elements that help in creating enjoyment, interest, and joy in learning. Table 4.1 presents the grouping or principles used for hypothesis justifications and the theories used for the justifications. A research model graph is present in Figure 4.1 to summarize all the hypotheses and provide an overview. The hypotheses can help provide the link to the underlying theory and specific question, provide a basis and evidence to prove the validity of the research, and guide the research method and data analysis.

Table 4.1 Grouping for hypothesis justifications for game design elements.

Principle	Elements	Dependent	Theory
Performance checking	Levels, badges, progress bar/personal-record tracking, responsive feedback	Motivation	SDT
		Engagement	Flow
		Learning achievement	Goal-setting
Goal orientation	Points, ranking/leaderboard, challenges, goal/task/mission, rules, competition, timed activity	Motivation	SDT
		Engagement	Flow
		Learning achievement	Goal-setting
Reinforcement	Reward/award	Motivation	SDT
		Engagement	Flow
		Learning achievement	Goal-setting
Sociality	Collaboration/group	Motivation	SDT
		Engagement	Flow
		Learning achievement	SDT
Fun	Narrative/storytelling, avatar	Motivation	SDT
		Engagement	Flow
		Learning achievement	SDT

4.1. HYPOTHESES

As shown in Table 4.1, five main principles serve as the basis for 15 hypotheses (25 sub-hypotheses) that were generated and are described in the same order as listed in the table.

4.1.1. Performance Checking. Levels, badges, progress bar/personal-record tracking, and responsive feedback enable learners to check their task completion progress and whether their performance meets the target.

4.1.1.1. Motivation. Levels and badges are usually designed as separate tasks. The progress bar is used to provide information about the task completion progress, while responsive feedback tells the learner what worked and what did not work. Once a task is completed, a learner can get access to the next level of learning content, or get a badge representing an achievement, and the progress bar can advance representing the current progress of completing a task. These gamified elements can convey the information of achievement, which can give learners a sense of competence. The sense of competence is indicated as one of the basic psychological needs in self-determination theory. The satisfaction of a sense of competence can increase the intrinsic motivation of learners. On the other hand, receiving responsive feedback during learning enables students to know if the steps they are taking are in the right direction. Responsive feedback allows the players to act on their thoughts to see the effects of changing their behaviors in the activity and offers learners a sense of autonomy. The satisfaction of a sense of autonomy, as indicated in the self-determination theory, can thus increase learners' intrinsic motivation. Hence, the following hypotheses are proposed:

- H1a: Levels can increase the learner's motivation.
- H2a: Badges can increase the learner's motivation.
- H3a: Progress bar/personal-record tracking can increase the learner's motivation.
- H4a: Responsive feedback can increase the learner's motivation.

4.1.1.2. Engagement. According to the flow theory, a clear sense of the goal(s) and responsive feedback relevant to the goal(s) can contribute to engagement. Clear goals and feedback are significant factors that maintain players in the flow state. Levels and badges usually represent or signify achievement. Regarding the use of levels and badges in learning, learning tasks are divided into separate goals, and learners can receive badges when goals are completed. The use of levels and badges helps provide goals in the learning task. Progress bar/personal-record tracking helps provide feedback about the integral direction of learning, while responsive feedback tends to provide information about more specific behaviors. Levels and badges help offer clear goals to achieve the state of flow or a high level of engagement, while progress bar/personal-record tracking helps learners maintain the flow or engagement state by providing feedback related to their learning. Hence, the following hypotheses are proposed:

- H1b: Levels can increase the learner's engagement.
- H2b: Badges can increase the learner's engagement.
- H3b: Progress bar/personal-record tracking can increase the learner's engagement.
- H4b: Responsive feedback can increase the learner's engagement.

4.1.1.3. Learning achievement. According to the goal-setting theory, setting effective goals is critical to achieving desired performance. Individuals who set specific and suitable (level of difficulty) goals performed better than those who set general or inappropriate goals. Levels and badges help learners set goals at their own pace, and progress bar/personal-record tracking provides the goal completion progress and thus helps learners evaluate how much effort and time is required to put into an activity. Responsive feedback provides learners with instant and personalized messages on their specific learning behaviors. These types of information can help learners set effective goals, and thus achieve desired performance in learning. Hence, the following hypotheses are proposed:

- H1c: Levels can increase the learner's achievement.
- H2c: Badges can increase the learner's achievement.

- H3c: Progress bar/personal-record tracking can increase the learner's achievement.
- H4c: Responsive feedback can increase the learner's achievement.

4.1.2. Goal Orientation. Points, ranking/leaderboard, challenges, mission/goal/task/assignment, rules, competition, and timed activity provide learners clear goals in learning.

4.1.2.1. Motivation. The completion of goals in learning can help learners gain a sense of competence. Points serve as a specific goal for learners. Applied with ranking/leaderboards, learners are encouraged to set the goal that they want to achieve. Challenges and missions often refer to a series of goals that require learners to perform a prescribed set of actions, following a guided path. The use of competition motivates learners to perform better than their competitors. Timed activity is setting time constraints for learners to complete tasks. In this case, it serves as a form of challenge for learners. When learners gain the desired points, rise in positions on the leaderboards, complete the tasks within challenges and missions, achieve goals in set time constraints, or win competitions following the set rules, the intrinsic motivation of learners can be stimulated by satisfying their sense of competence. Hence, the following hypotheses are proposed:

- H5a: Points can increase the learner's motivation.
- H6a: Ranking/leaderboard can increase the learner's motivation.
- H7a: Challenges can increase the learner's motivation.
- H8a: Mission/goal/task/assignment can increase the learner's motivation.
- H9a: Rules can increase the learner's motivation.

- H10a: Competition can increase the learner’s motivation.
- H11a: Timed activity can increase the learner’s motivation.

4.1.2.2. Engagement. According to the flow theory, learners tend to feel bored when their skills exceed the level of challenge of the learning activity and feel frustrated or anxious when the level of challenge of the activity is beyond their ability. Hence, an activity requires a suitable difficulty level to stimulate a person to compete and achieve the state of flow. Setting a suitable difficulty level in learning with a target score and a series of challenges, missions, game rules or time constraints are useful and common methods to engage learners in the state of flow. When learners feel that they are up to speed to compete, they tend to be stimulated to work hard for receiving points or completing challenges/missions within game rules or time constraints. Similarly, a leaderboard can also provide an achievable goal for learners as they compete with other learners. Competitions require learners to exceed their opponents in learning, providing a clear goal for learners and thus help learners maintain a state of flow. As such, points and leaderboards are promising in setting appropriate challenge levels and achievable goals in learning, while suitable difficulty levels and achievable goals can help individuals engage in the state of flow. Hence, the following hypotheses are proposed:

- H5b: Points can increase the learner’s engagement.
- H6b: Ranking/leaderboard can increase the learner’s engagement.
- H7b: Challenges can increase the learner’s engagement.
- H8b: Missions can increase the learner’s engagement.
- H9b: Rules can increase the learner’s engagement.

- H10b: Competition can increase the learner's engagement.
- H11b: Timed activity can increase the learner's engagement.

4.1.2.3. Learning achievement. Serving as goals, points, ranking/leaderboards, challenges, timed activity, rules, mission/goal/task/assignment and competition provide learners directing effort and attention toward learning activities. With a goal in mind, an individual can evaluate how much effort and time are required to put into an activity. These game design elements make goals achievable and realistic and thus improve the commitment of the goals. For instance, learners can be asked to earn a certain number of points, attain a certain position in a ranking/leaderboard, complete a series of challenges or win in competitions. Rules can also be given to guide the learning activity. In these cases, goals, points, ranking/leaderboards, challenges, quests, missions, rules, and competition help set effective goals to achieve desired performance. However, timed activity can directly constrain the time invested in learning and thus probably constrain the learning achievement. Chuderski (2016) found time pressure can prevent relational learning. Similarly, Gonzalez (2004) observed participants under high time constraints performed worse than participants did under low time constraints on dynamic decision making. As such, we hypothesize that timed activity decreases the learner's achievement. Hence, the following hypotheses are proposed:

- H5c: Points can increase the learner's achievement.
- H6c: Ranking/leaderboard can increase learner's achievement.
- H7c: Challenges can increase learner's achievement.
- H8c: Missions can increase learner's achievement.
- H9c: Rules can increase learner's achievement.

- H10c: Competition can increase learner's achievement.
- H11c: Timed activity can decrease learner's achievement.

4.1.3 Reinforcement. Rewards/awards of different forms (e.g., recognition, privileges, and monetary incentives) encourage users to keep up with their performance.

4.1.3.1. Motivation. When learners are rewarded for good behavior, they tend to repeat the behaviors to receive the reward that they are interested in. In this case, learners are extrinsically motivated to learn to be rewarded rather than enjoy the fun in the learning activity itself. Extrinsic motivation is a type of motivation as well. Hence, the following hypothesis is proposed:

- H12a: Rewards/awards can increase the learner's motivation

4.1.3.2. Engagement. Rewards/awards can serve as a goal and a form of feedback, which are significant factors that engage learners in a flow state in certain learning activities. Learners can gain feedback relevant to goals to maintain a continuous state of engagement. Hence, the following hypothesis is proposed:

- H12b: Rewards/awards can increase the learner's engagement.

4.1.3.3. Learning achievement. Rewards/awards encourage preferred behaviors. Therefore, rewards/awards are proposed to increase extrinsic motivation. Extrinsic motivation can serve as specific goals for learners and help learners become driven and competitive to achieve preferred learning achievement. Hence, the following hypothesis is proposed:

- H12c: Rewards/awards can increase the learner's achievement.

4.1.4 Sociality. Collaboration and group work, which refers to individuals working together for a common goal, faciliate learners to communicate with others**.**

4.1.4.1. Motivation. In self-determination theory, relatedness refers to individuals' connectedness with others and their surroundings. Collaboration creates conducive learning environments for learners to communicate their thoughts and opinions with others. As such, when communication is applied to learning, the sense of relatedness can be satisfied and thus the intrinsic motivation can increase. Hence, the following hypothesis is proposed:

- H13a: Collaboration can increase the learner's motivation.

4.1.4.2. Engagement. Social needs are innate to humans. When learners are communicating with each other and collaborating on a task, they tend to maintain a high level of engagement or flow (Nah & Eschenbrenner, 2015). When a high-quality and meaningful learning group work is taking place, the target learning activity can pre-occupy the participants' thoughts and maintain their interest and engagement. Hence, the following hypothesis is proposed:

- H13b: Collaboration can increase the learner's engagement.

4.1.4.3. Learning achievement. Collaboration and group work can enhance interaction and knowledge sharing among group members. The opportunities for communication with others can improve learner's sense of relatedness and thus increase intrinsic motivation. In SDT, people who are motivated by intrinsic motivation tend to have more enhanced performance, persistence, and creativity. Hence, the following hypothesis is proposed:

- H13c: Collaboration can increase the learner's achievement.

4.1.5. Fun. Narrative/storytelling and avatar can add fun to the learning activity. These elements are usually used in combination.

4.1.5.1. Motivation. Narrative/storyline can create a virtual theme-based environment for learning, making the distance between learners and the learning content closer. Interesting plots of a story can make learners curious and interested in the activity and enjoy the learning activity itself. For instance, Su and Cheng (2015) applied a storyline in biology learning using a mobile application, which increases students' interests and facilitates learners' learning process.

Avatars can represent the learners themselves or resembling a teacher, guide, storyteller, or even any character related to the theme. Compared to traditional teaching methods of using text and numbers, the application of avatars increases the vividness and fun in the learning activity. In this case, learners can gain a sense of relatedness and be more curious and interested in the activity, and thus improve their intrinsic motivations. Hence, the following hypotheses are proposed:

- H14a: Narrative/storytelling can increase the learner's motivation.
- H15a: The use of avatars can increase the learner's motivation.

4.1.5.2. Engagement. Narrative/storyline can create a virtual theme-based environment for learning, which helps improve the learner's union with the virtual learning environment. In addition, a fun virtual storyline can catch the learner's attention in the environment and leaners can gain a sense of loss of self-consciousness. The learning material can occupy their thoughts while they are immersed in the story. The loss of self-consciousness and the focused concentration on the learning task can create and enhance the learners' state of flow.

Avatars can represent the learners themselves or resembling a teacher, guide, storyteller, or even any character related to the theme. Contrasted to traditional learning content with more abstract content, avatars add more fun to the learning activity. As such, learners are able to gain enjoyment from the learning experience. In this case, the autotelic experience of learners can help them attain the flow or engaging experience. Hence, the following hypotheses are proposed:

- H14b: Narrative/storytelling can increase the learner's engagement.
- H15b: The use of avatars can increase the learner's engagement.

4.1.5.3. Learning achievement. Narrative/storyline and avatar can contribute to offer fun and enjoyment to learning. Applied with narrative/storyline and avatar, learners can feel the joy of learning instead of external benefits. Therefore, they can help to offer intrinsic motivation to learners. According to SDT, learners who are motivated by intrinsic motivation tend to have more enhanced performance, persistence, and creativity and thus can have better learning achievement. Hence, the following hypotheses are proposed:

- H14c: Narrative/storytelling can increase the learner's achievement.
- H15c: The use of avatars can increase the learner's achievement.

4.2. RESEARCH MODEL

The research model is shown in Figure 4.1. The effects of 15 gamification design elements are hypothesized on three learning outcomes. The independent variables are 15 game design elements. The dependent variables are 3 learning outcomes. The research model also includes 5 moderating variables: instruction type, course subject, education level, duration, and application context.

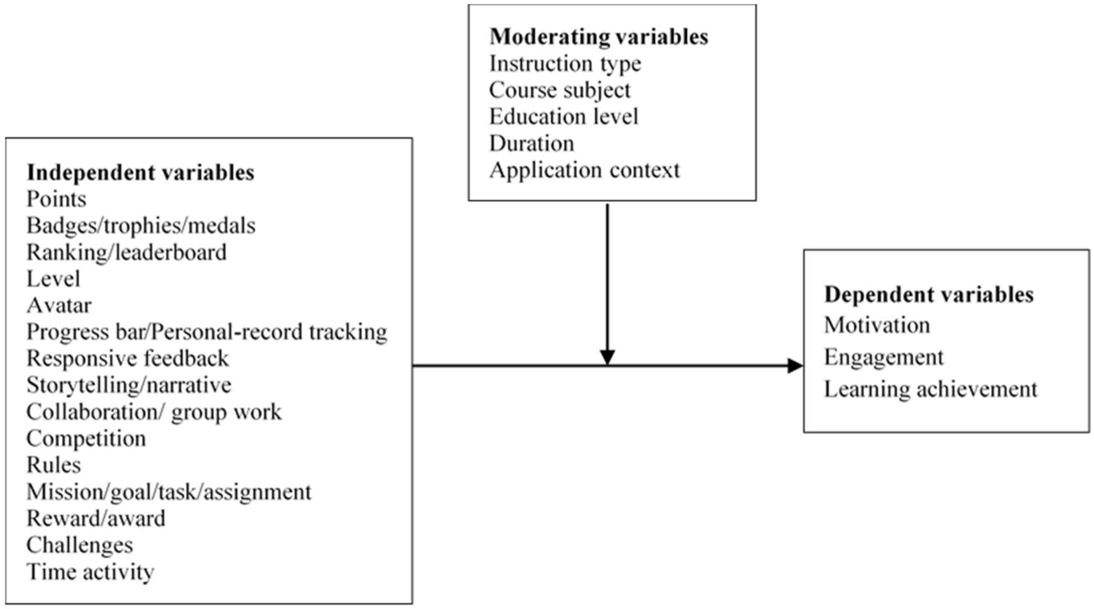

Figure 4.1 Research model.

5. METHODOLOGY

A meta-analysis was conducted. Considering that the number of empirical studies on gamification in education has been increasing and independent empirical studies in this field show different results, a meta-analysis is warranted. The meta-analysis allows combining the results of individual studies using statistical methods to obtain a more precise overview in this field. The relationships among variables in the research model can be assessed by their effect sizes. An effect size quantifies the difference between two groups that can help examine the effect of gamification in our case (Coe, 2002). The entire meta-analysis process mainly consists of 6 serial sub-processes: (1) literature search, (2) screening searched literature according to inclusion and exclusion criteria, (3) coding and organizing collected papers, and (4) applying meta-analysis on the collected data using R.

5.1. LITERATURE SEARCH

To identify independent studies that examined gamification in education, we conduct a literature search in major databases that include ACM Digital Library, Education Full Text, ERIC, Scopus, IEEE, PsycInfo, and Google Scholar. Since studies in these databases except Google Scholar allow an advanced search, we conducted the literature search using the search term SU (gam*) AND SU ("education" or "learning" or "motivation" or "engagement"). The search term can be split into the following conditions. Only studies that meet all the following conditions are presented on the search results pages.

- The study is tagged with subjects including “gamify”, “gamification”, “gamified”, “game”, or “gaming”.
- The study is tagged with subjects including “learning”, “education”, “motivation”, or “engagement”.

Among these databases, we conducted a comprehensive search on the ACM Digital Library, Education Full Text, and ERIC. All the search results in these three databases were reviewed. Scopus, IEEE, PsycInfo, and Google Scholar are supplementary sources. In the current stage, only published articles in journals and conference proceedings are included in the meta-analysis. In total, we found that Education Full Text, ERIC, and PsycInfo have 8 duplicated qualified studies. Besides, Education Full Text, ERIC, and PsycInfo mainly consist of journal articles in gamification in education, while ACM Digital Library, Scopus, and IEEE feature conference proceedings in this field.

5.2. INCLUSION AND EXCLUSION CRITERIA

Based on the results derived from the literature search, we conducted a manual screening using the 8 criteria. Studies to be included in the present meta-analysis must satisfy all the following criteria in the research: (1) have at least one gamification intervention as a predictor; we included studies that explored the effect of either gamification or games on student learning, and extracted and coded the game design elements that are adopted as independent variables. Studies that only focus on the development of framework and approach (Almeida et al., 2018), the requirement of gamified learning application (Gomes, 2019) or opinions of stakeholders on gamified learning are excluded. While only a few studies examine the effect of individual elements (Andrade et al., 2020; Morris et al., 2019), most studies examine the combination of game elements in their dependent variables (Purgina et al., 2020). (2) adopted the quasi-experimental or experimental approach as the research design; studies that only adopt case studies, interviews, or observations as research methods are excluded. (3) used a between-subject design with experimental (gamified group) and control groups (non-gamified group) or a within-subject design with pre-test and post-test data; (4) applied quantitative statistical methods for data analysis; (5) explored learning behaviors, grading outcomes, or perceptions as dependent variables, such as engagement, motivation, or learning achievement; studies that examined the effect of gamification on participants' attitudes on usability are not included. (6) learners or students as research subjects; learners or students are participants in gamified learning activities. Studies that are conducted on employers or specific application users are not included. (7) statistics available (e.g., sample size, standard deviation, mean, standard error); studies that fail to provide the statistics required to calculate an effect size are excluded. We calculated an effect size by one of six combinations of statistics. The detailed statistics and formulas are provided in section 5.4.1. (8) be written in English; (9) be published in journals or conference proceedings. Apart from satisfying the above criteria, we checked the included studies list to avoid duplication before identifying a new study to be included. This step is completed by checking the author, year, title, and sample size of the studies. Details of the screening process are presented in Figure. 5.1.

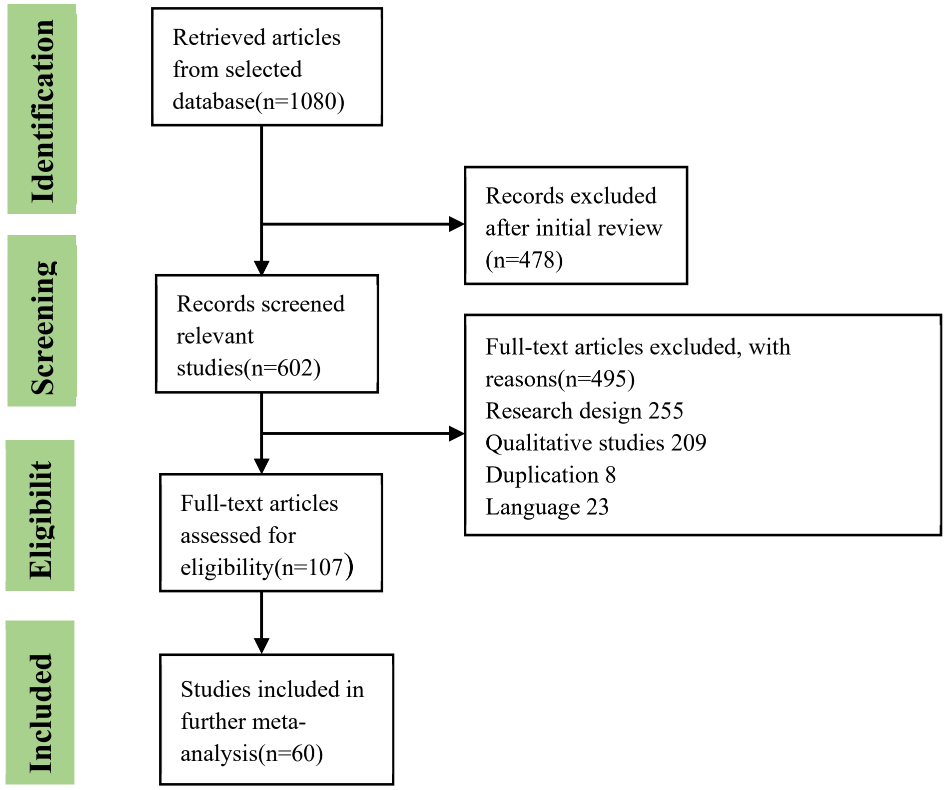

Figure 5.1 Screening process.

5.3. CODING PROCEDURE

We included 60 studies (72 samples) from the literature search. Some studies include distinct groups of participants, which means these studies provide multiple samples (Ahmad et al., 2021; Jong et al., 2018). In the random effect model, each sample is treated as an individual study. Noted that each study mentioned in the following text also corresponds to a sample. We identify the independent, moderating, and dependent variables in the 60 studies that are included in the meta-analysis, code the qualitative data into categorical variables, and extract the quantitative statistics for data analysis.

5.3.1. Independent Variables. The gamification design elements serve as independent variables in the research model. We identified and extracted the game design elements used in the empirical studies. For example, Quintas et al. (2020) adopted Just Dance Now exergame as a gamified intervention on students in physical education learning. In this case, we extracted the game design elements that were applied in the exergame including points, points, leaderboard, badge, avatar, level, and personalization/customization. Since most studies examine the overall effect of a combination of game design elements, we are not able to collect statistics of individual game design elements in most cases. Therefore, to calculate the break-down effect of individual game design elements, we calculated the effect size of each game design element by combining the effect sizes of all the studies that used the same elements.

5.3.2. Dependent Variables. Student learning outcomes are the dependent variables in the study. However, student learning outcomes possess multiple dimensions. In Landers's (2015) theory of gamified learning, motivation, engagement, and cognitive learning consist of important roles in learning outcomes. Motivation and engagement mediate cognitive learning (Landers, 2015). Cognitive learning is treated as the learning achievement in the present study. As such, in the present study, we mainly focus on the three dimensions of learning outcomes: motivation, engagement, and learning achievement. Motivation is often measured by a subjective survey. To capture learners' motivation, self-reported measurements on how much they enjoyed the learning activity and how much they were interested in learning the course content were used. Therefore, we identified the dependent variable as the motivation of which the studies explored the interest, enjoyment, or fun in gamified learning. Engagement, which refers to how much the learners focused on learning and how involved they were in learning, was measured as the frequency or time of participation in gamified learning or the number of completed tasks. Learning achievement was often presented in forms, such as memory or reasoning skill, and was mostly measured by the score that is graded by teachers or systems in empirical gamification studies.

5.3.3. Moderating Variables. We identified the moderating variables by manually reviewing papers. Six moderating variables were coded in the present study: education level, course subject, instruction type (Instructor-led or not), type of gamification (game-based or not), duration of application, application context. Among them, education level was coded as primary, middle, and higher education; course subject was coded using two levels, STEM or non-STEM subject and specific subject. The distinction of instructor-led or not depends on whether instructors participated in the learning process, as well as whether they led and organized the whole learning process. Studies in which instructors were only in charge of helping learners familiarize themselves with the gamified application or rules in the early stages, supervising the process, or answering questions about the gamified application were categorized as non-instructor-led. Duration of application was coded as 1 day or less, 1 week or less, 1 month or less, half a year or less, 1 year or less, and more than 1 year. The application context was coded as flipped classroom, class management/lecture content introduction or gamified exercises/homework.

5.3.4. Statistics. We choose hedges' g as the effect size. To calculate the effect size, we only collected studies that provide at least one of the combinations: (1) group size, mean, and standard deviation; (2) group size, mean, and standard error; (3) group size, f-value; (4) group size, t-value; (5) sample size, Cohen's d; (6) group size, correlation r.

5.4. META-ANALYSIS

Based on the coding process, we identified the set of variables to be included in the meta-analysis. A general rule-of-thumb is that we included all variables that have at least five data points or sample size for the meta-analysis (Jackson & Turner, 2017). Hence, we only applied meta-analysis on elements that have at least 5 data points in each pair of an independent variable and a dependent variable.

The process of meta-analysis is guided by Harrer et al.'s (2019) guide book. We use the formulas proposed by Borenstein et al. (2009) to calculate the effect sizes. Hedges' g was chosen to measure the effect size, which is the difference between groups with different conditions. The effect size was calculated using the standard deviation. When standard deviation for calculating Hedges' g is not available, the Hedges' g can be converted from the following statistics: standard error, t-value, F-value, Cohens'd, or correlation r (Thalheimer & Cook).

A meta-analysis was applied based on the data derived from the coding procedure. The entire meta-analysis can be divided into 8 steps: (1) calculate the effect size of each group; (2) combine the effect sizes on each dependent variable in each study; (3) combine the effect sizes of each study; (4) calculate an overall effect size; (5) combine the effect sizes of studies that adopt the same game design element as well as the same dependent variable; (6) calculate the effect size of each game design elements on learning outcomes; (7) calculating moderating effects; (8) generate a funnel plot.

5.4.1. Effect Size of Each Group. In the coding spreadsheet, each row represents a group of data. An effect size can be calculated in each group of data. In the effect size calculator, group t is assumed to be the experimental group, and group c is assumed to be the control group. The formulas for calculating Hedges' g from standard deviation, standard error, t-value, F-value, Cohen's d, and correlation r are provided as follows (Thalheimer & Cook):

(1) Calculate hedges' g from standard deviation(sd), mean(m) and group size(n).

$$SD^*_{pooled} = \sqrt{\frac{(n_t - 1)sd_t}{n_t n_c}}$$

$$Hedges'g = \frac{M_t - M_c}{SD^*_{pooled}}$$

(2) Calculate hedges' g from standard error(se), mean(m) and group size(n).

$$sd_t = se_t\sqrt{n_t}$$

$$SD^*_{pooled} = \sqrt{\frac{(n_t - 1)sd_t}{n_t n_c}}$$

$$Hedges'g = \frac{M_t - M_c}{SD^*_{pooled}}$$

(3) Calculate hedges' g from t-value(t) and group size(n) (d=Cohen's d).

$$d = t\sqrt{\left(\frac{n_t + n_c}{n_t n_c}\right)\left(\frac{n_t + n_c}{n_t + n_c - 2}\right)}$$

$$Hedges'g \cong d \times (1 - \frac{3}{4(n_t + n_c) - 9})$$

(4) Calculate hedges' g from F-value(F) and group size(n) (d=Cohen's d).

$$d = \sqrt{F\left(\frac{n_t + n_c}{n_t n_c}\right)\left(\frac{n_t + n_c}{n_t + n_c - 2}\right)}$$

$$Hedges'g \cong d \times (1 - \frac{3}{4(n_t + n_c) - 9})$$

(5) Calculate hedges' g from Cohen's d and sample size ($n_t + n_c$).

$$Hedges'g \cong d \times (1 - \frac{3}{4(n_t + n_c) - 9})$$

(6) Calculate hedges' g from correlation(r) and group size(n) (N=$n_t + n_c$).

$$r = \frac{d}{\sqrt{d^2 + \frac{(N^2 - 2 \times N)}{n_t n_c}}}$$

$$Hedges'g \cong d \times (1 - \frac{3}{4(n_t + n_c) - 9})$$

5.4.2. Effect Sizes of Each Study. A study can have multiple effect sizes on a single dependent variable, or have multiple dependent variables. For example, Chen et al. (2020) tested the effect of gamification on creative tendency by measuring the risking score, curiosity score, and imagination score (Chen et al., 2020). All three scores can be viewed as dimensions of learning achievement. In other words, we have three effect sizes on learning achievement from an individual sample. In another example, Hew et al. (2015) explored the effect of gamification on both engagement and learning achievement and thus have more than one effect size. In these cases, to figure out the effect size of each study, we conducted a multivariate random-effects model to combine multiple effect sizes.

5.4.3. Overall Effect Size. Based on the result in section 5.4.2, we applied a standard random-effects model to calculate the overall effect size and I^2 for the heterogeneity test.

5.4.4. Effect Sizes of Design Elements on Dependent Variables. Based on the result of section 5.4.1, we filtered the results that matched each game design element and a dependent variable. After that, we appliee a multivariate random-effects model on the filtered result to calculate the effect size of each element on each dependent variable. For example, we filtered all the studies that applied a leaderboard on testing learners' learning achievement and apply a multivariate random-effects model in order to calculate the effect size of the leaderboard on learners' learning achievement.

5.4.5. Moderating Effect. Based on the result of section 5.4.2, we applied a multivariate random-effects model to test the moderating effects of education level, course subject, instruction type, duration, and application form.

5.4.6. Publication Bias. We can conveniently generate a funnel plot from the standard random-effects model in section 5.4.3 in the R meta-analysis packages to detect publication bias, which is the degree to which "the research that appears in the published literature is systematically unrepresentative of the population of completed studies" (Rothstein et al., 2005).

6. RESULTS

6.1. OVERALL IMPACT OF GAME DESIGN ELEMENTS ON LEARNING OUTCOMES

Figure. 6.1 shows the forest plot for 60 studies (72 samples) and their corresponding hedges' g, standard error, 95% confidence interval, and weight. The gray squares indicate the estimates of the effect size in each individual sample, whereas the horizontal line that crosses each square represents the 95% confidence interval. TE and seTE are the individual effect sizes and their standard error that are used for conducting the random-effects model. The weight column informs the proportion of a sample to the total sample. The area of each square is proportional to the study's weight in the meta-analysis. From the forest plot, we can derive a direct overview of the results of the analysis. The individual effect sizes range from g = -1.37 to g = 4.05. The overall mean effect size in the random-effects model is g = 0.43 ($p<0.0001$), which is a small to medium effect size (Cohen, 2013). The overall mean effect size is statistically significant with a t-value of 5.30, $p < 0.0001$. The 95% confidence interval is 0.27 to 0.59. The I^2 is 97%, which suggests considerable heterogeneity and informs us of very high variability in the sample (Fletcher, 2007). Apart from the true effect size, the variability in the sample can be caused by factors such as research design, publication bias, and characteristics of participants, to name a few. The high heterogeneity indicates the requirement of moderating factor analysis to explain the variance. The moderating factor analysis results will be discussed in section 6.3.

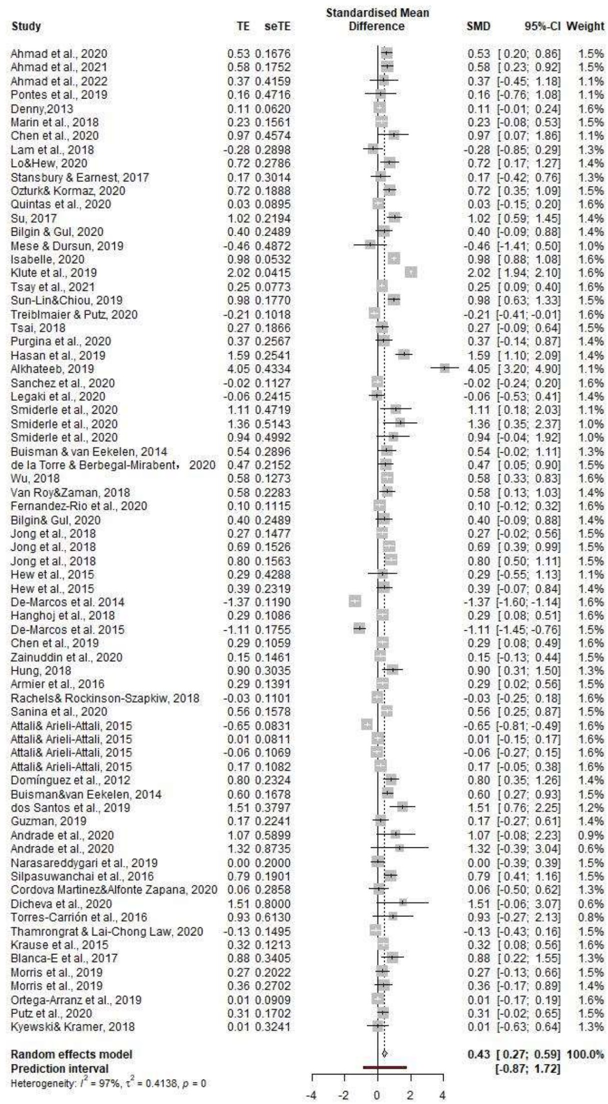

Figure 6.1 Forest plot of effect size of each study.

6.2. BREAK-DOWN EFFECTS OF GAME DESIGN ELEMENTS ON LEARNING OUTCOMES

The model result of the effect of game design elements on overall learning outcomes is provided in Table 6.1. Among 15 game design elements, points, badges, and leaderboards are most frequently used in gamified learning, which is consistent with the conclusions of existed studies (Majuri et al., 2018; Zainuddin, 2020a).

Overall, all game design elements we found but challenges have positive effect sizes. Among them, personal-record tracking/progress bar, responsive feedback, mission/goal/task/assignment, competition, and collaboration/group present significant medium to large effect sizes. Badge/trophy/medals, point, ranking/leaderboard, rules, timed activity, and avatar present small to medium effect sizes, while the effect sizes of level, challenge, reward/award, narrative/storyline, and customization/personalization are not statistically significant.

For the effects of game design elements on motivation (Table 6.2), most of the game design elements are not statistically significant. Only H5a is supported by the result (g=0.249, p=0.0129). It is worth noting that Ranking/leaderboard and Reward/award present a negative effect size on motivation. Although almost all the break-down effects of game design elements are not supported by the statistics, the sum-up effect on motivation is statistically significant (g=0.2301, p=0.009).

Among studies included in the sample of this meta-analysis, only three game design elements were tested for their impact on learning engagement by more than 5 studies (Table 6.3). For the effects of game design elements on engagement, the sum-up effect on engagement is statistically significant (g=0.4941, p=0.0089), and the effect size ranges from 0.034 to 0.4824. Similar to the effect size on motivation, only the effect size of points is statistically supported by the result (g=0.70, p=0.01).

With regard to learning achievement, all the game design elements show positive effects on learning achievement (Table 6.4). Compared to motivation and engagement, the sum-up effect of gamification is most significant on learning achievement (g= 0.5176, p<0.0001). Among them, the effect sizes of 11 game design elements including level, badge/trophy/medals, personal-record tracking/progress bar, responsive feedback, point, ranking/leaderboard, mission/goal/task/assignment, rules, timed activity, collaboration/group, and avatar are statistically significant. Elements that have large p-values tend to have small sample sizes or small effect sizes.

Table 6.1 Effects of game design elements on overall learning.

	Elements	Hedges' g	P-value	k
1	Level	0.2769	0.0918	20
2	Badge/trophy/Medals	0.2868	0.0098	33
3	Personal-record tracking/progress bar	0.94	0.0008	16
4	Responsive feedback	0.5613	0.0105	15
5	Point	0.4845	0.0001	50
6	Ranking/leaderboard	0.4541	0.0004	38
7	Challenge	-0.0071	0.9732	10
8	Mission/goal/task/assignment	0.57	0.0113	17
9	Rules	0.158	0.0137	5
10	Competition	0.5705	0.0204	10
11	Timed activity	0.2102	0.0416	9
12	Reward/award	0.0791	0.6757	14
13	Collaboration/group	0.7365	0.0021	15
14	Narrative/storyline	0.3008	0.2216	8
15	Avatar	0.3758	0.0001	11

Table 6.2 Summary of effect size of game design elements on motivation.

	Elements	Hedges' g on Motivation	P-value	k	Hypotheses	Result
1	Level	0.1938	0.1739	7	H1a	Rejected
2	Badge/trophy/Medals	0.078	0.3737	8	H2a	Rejected
3	Responsive feedback	0.1644	0.3498	6	H4a	Rejected
4	Point	0.249	0.0129	14	H5a	Supported
5	Ranking/leaderboard	-0.0596	0.3435	6	H6a	Rejected
6	Mission/goal/task/assignment	0.0867	0.4409	5	H8a	Rejected
7	Competition	0.1785	0.3183	5	H10a	Rejected
	Total	**0.2301**	**0.009**	**18**		

Table 6.3 Summary of effect size of game design elements on engagement.

	Elements	Hedges' g on Motivation	P-value	k	Hypotheses	Result
1	Badge/trophy/Medals	0.1437	0.4824	9	H2b	Rejected
2	Point	0.6967	0.0034	13	H5b	Supported
3	Ranking/leaderboard	0.2701	0.1963	14	H6b	Rejected
	Total	**0.4941**	**0.0089**	**19**		

Table 6.4 Summary of effect size of game design elements on learning achievement.

	Elements	Hedges' g on Motivation	P-value	k	Hypotheses	Result
1	Level	0.6016	0.0171	18	H1c	Supported
2	Badge/trophy/Medals	0.4462	0.0057	24	H2c	Supported
3	Personal-record tracking/progress bar	0.9911	0.0033	12	H3c	Supported
4	Responsive feedback	0.7571	0.0124	13	H4c	Supported
5	Point	0.5758	0.0006	41	H5c	Supported
6	Ranking/leaderboard	0.605	0.0038	32	H6c	Supported
7	Challenge	0.0929	0.734	9	H7c	Rejected
8	Mission/goal/task/assignment	0.8513	0.0147	11	H8c	Supported
9	Rules	1.0787	0.0359	5	H9c	Supported
10	Competition	0.6462	0.0737	8	H10c	Supported
11	Timed activity	0.2574	0.0492	7	H11c	Rejected
12	Reward/award	0.3382	0.3791	9	H12c	Supported
13	Collaboration/group	0.8807	0.0037	13	H13c	Supported
14	Narrative/storyline	0.0967	0.8128	6	H14c	Rejected
15	Avatar	0.5683	0.0001	10	H15c	Supported
	Total	**0.5176**	**0.0001**	**58**		

6.3. EFFECTS OF MODERATING VARIABLES

According to the data in Table 6.5, although studies on all education levels present positive effects of gamification, none of them is statistically significant. In addition, 45 out of 72 studies were conducted in higher education; however, the effect size on higher education has the smallest value. Since the F-test among education level subgroups is significant, a post-hoc test was conducted. The result of the post-hoc test shows that there is a significant difference between elementary level and secondary level (p=0.02), as well as between elementary level and higher education level (p=0.007). However, the mean effect of the elementary level (hedges' g=1.2359) is not significantly higher than the mean effect of the general education level, as the regression coefficient is not significant: t = 0.9486, p = 0.3121.

Both mathematics and non-STEM course (e.g., general knowledge, language learning) show positive moderating effects. However, 3 out of 4 course subjects are not significantly supported. No studies conducted on engineering are collected since gamified learning contents tend to be application-based or basic knowledge, which means course contents in empirical studies need to fit technology, science, and non-STEM better. Course content on technology is positively moderating the effect of gamification, and this result is statistically significant. Given the results, we conclude that there is no moderating effect of types of course subjects, as the results of the omnibus test point towards an insignificant moderating effect: p = 0.7536.

In the aspect of instruction type, non-instructor-led learning activity significantly enhances the gamification effect, while the moderating effect of instruction-led learning activity is not significant. On the other hand, the moderating effect of all types of durations and application contexts is not significant.

Table 6.5 Effects of moderating variables.

Moderator	Hedges' g	k	p-value	F-test (p-value)	I^2
Education level					
Elementary	1.2359	8	0.3121	0.0247	99.0%
Secondary	0.4571	18	0.8718		76.6%
Higher education	0.3132	45	0.9993		93.4%

Table 6.5 Effects of moderating variables. (Cont.)

Course subject					
Science	0.2173	6	0.6982	0.7536	70.4%
Technology	0.391	24	0.5654		92.1%
Engineering	-	-	-		-
Mathematics	0.5639	11	0.5373		95%
Non-STEM	0.5063	31	0.6062		92.9%
Instruction type					
Instructor-led	0.4019	32	0.5815	0.5815	98.2%
Non-Instructor-led	0.508	40	0.0003		93.7%
Duration					
1 week or less	0.3215	14	0.4036	0.740	92.0%
1 month or less	0.3146	9	0.4027		77.8%
Half a year or less	0.48	35	0.7213		98%
1 year or less	0.37	4	0.6325		16.4%
Not given	0.3768	10	0.5001		67%
Application context					
Flipped classroom	0.31	5	0.358	0.5770	87.7%
Classroom management	0.42	41	0.5		98.2%
Gamified exercises	0.6	38	0.2051		93.5%

6.4. PUBLICATION BIAS

The funnel plot generated from the meta-analysis suggests there is generally a symmetrical distribution around the hedges' g effect sizes with a few outliers. In the graph, each dot represents a single study. The horizontal axis is the hedges' g, and the vertical axis is the standard error. As shown in Figure 6.2, this funnel plot suggests a slight publication bias in the meta-analysis (Sterne & Egger, 2001). At the bottom-left of the triangle in the graph, dots in the lower standard error are insufficient. The funnel plot indicates that the studies that have higher hedges' g and lower standard error tend to be published.

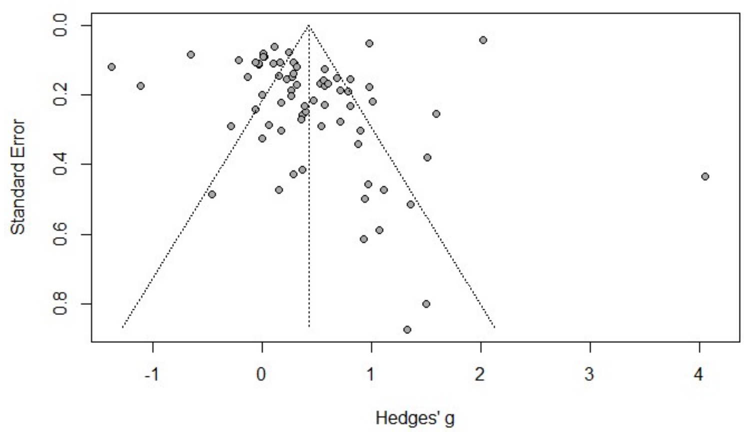

Figure 6.2 Funnel plot.

6.5. DISCUSSION OF FINDINGS

In general, the results of the present study show an overall positive effect (g=0.43) of gamification in education, which is consistent with existing studies (Huang et al., 2020, Bai et al., 2020). From the aspect of individual studies, most studies report a positive effect size of gamification in learning.

Among the 15 game design elements, points, leaderboards, and badges are most applied in education, while other innovative elements such as quests, roleplay, and virtual reality are rarely adopted. This could be attributed to the ease of use of points, leaderboards, and badges. These elements usually can be directly applied to the traditional teaching modes such as grading and ranking students. In contrast, quests, rules, and virtual reality require an elaborated gamified framework that demands the investment of time, specialists, and equipment. In addition, the five game design elements of competition, group, personal-record tracking/progress bar, responsive feedback, and mission/goal/task/assignment exhibit medium to large statistically significant effect size. This indicates that learners tend to have better learning outcomes when their learning activities are applied with elements that enable them to socialize, check their performance, and set goals. These results also contribute to verify the correctness of goal-setting theory in explaining the relationships between goals and performance (Locke & Latham, 1994). Similarly, as for self-determination theory, the effect of the sense of relatedness on intrinsic motivation which consequently affects performance is supported (Ryan & Deci, 2000).

The results of gamification on motivation generally show small to medium-sized effects. Despite this, Coe (2002) acknowledges that an effect size of even as little as 0.1 should not be neglected in the education field, since making a small and inexpensive change to raise academic achievement could be a very significant improvement. Although the effect sizes on motivation are not statistically significant, the potential power of gamification on motivation should not be underestimated since the sample size of examining the motivation is not large enough to draw a firm conclusion. Besides, game design elements including personal-record tracking/progress bar, point, collaboration/group, and challenge have more significant effects than other elements. These four elements all focus on enhancing the learner's psychological needs. While personal-record tracking/progress bar, point, and challenges provide a sense of competence by visualizing the effort that learners have made, collaboration provides opportunities for communication that could improve a sense of relatedness. This also contributes to confirming the validity of self-determination theory in explaining the relationships between psychological needs and intrinsic motivation. Furthermore, the leaderboard presents a negative effect size on motivation in the result, which is consistent with existing studies. It is consistent with the existing opinion that ranking systems could decrease student's motivation and confidence by bringing a high degree of pressure (Chan et al., 2018).

The result of effect sizes on engagement is limited. We can only derive the effect size of 3 elements since few studies have assessed engagement. From the result, points, badges, and ranking/leaderboards are all goal-oriented elements. This result supports that setting specific and clear goals can help enhance the coercion of action and awareness enables students to achieve a state of flow or engagement (Csikszentmihalyi, 1990).

Compared to motivation and engagement, learning achievement is much more explored in empirical studies. 58 out of 72 studies have examined learning achievement versus 18 and 19 have examined motivation and engagement. One reason may be the ease of measuring learning achievement. Learning achievement is commonly measured by test scores that have been developed and used in the education system. Game design elements that benefit learners in setting goals and checking performance present a medium to large-sized effect on learning achievement, which contributes to verifying the propositions in goal-setting theory (Locke & Latham, 1994). These elements include level, point, rules, competition, leaderboard/ranking, mission/goal/task/assignment, responsive feedback, personal-record tracking/progress bar. In addition, the use of avatars presents a significant large-sized effect on learning achievement, while the use of rewards/awards does not. Avatars add fun to learning and make learners interested in the learning activity itself, whereas rewards/awards attract learners to learning with external incentives rather than intrinsic motivation. This result indicates learners tend to have more enhanced performance when motivated by intrinsic motivation compared to extrinsic motivation (Ryan & Deci, 2000).

A moderator analysis is conducted due to considerable heterogeneity in the result of the random-effects model (I^2=97%). The moderator analysis is computed to determine which factors were most likely to contribute to the observed variance. However, given the results, there is no moderating effect among the chosen factors. Although the result regarding the moderating effect of education level on learning outcomes is not statistically significant, it presents the positive effect of gamification in elementary learners is significantly different from other education levels. This implies gamification may be more effective on young learners. The differences in gamification applied with different types of instruction are not obvious, which suggests gamification can be equally effective with or without instructors. However, it is noted that gamification is significantly effective (hedges' g = 0.508, p=0.0003) on non-instructor-led learning, which indicates gamification can have an effect that is equal to that of the guidance of instructors. Further, the moderator analysis results suggest no significant differences are causing by course subject, duration of gamified intervention, and application context.

7. CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

7.1. CONCLUSIONS

Given that the research results of gamification in education are mixed and inconsistent, we conducted a meta-analysis to pool published empirical studies to obtain a more comprehensive understanding of this question. This study contributes to the literature in four aspects. First, we conclude that gamification has a positive significant influence on improving student learning outcomes in general ($g=0.43$, $p<0.0001$). Further, we provide a nuanced framework by breaking down the effects of game design elements. This framework shows how individual game design elements affect different aspects of student learning outcomes. From the framework, we find that gamification is most effective in enhancing learning achievement. Elements that benefit goal setting, personal performance checking, and sociality are more effective in improving student learning outcomes. These elements include point, ranking/leaderboard, competition, Personal-record tracking/progress bar, responsive feedback, and collaboration/group. Third, we try to figure out the moderating effect of five factors (education level, course subject, instruction type, duration, and application context) on student learning outcomes and find young children in primary education are able to utilize gamification to a greater extent in improving learning outcomes than learners in other education levels. We also find that gamification could generate an equally positive effect as the guidance of the instructor on student learning outcomes. The fourth contribution of the present research is theory testing. We developed a list of hypotheses based on three theories and examined if the research result validates the theoretical propositions. According to the results, three sub-hypotheses support the propositions in self-determination theory. One sub-hypothesis (H5a) validates that a sense of competence can enhance an individual's intrinsic motivation. Two sub-hypotheses (H13c, H15c) demonstrate that intrinsic motivation can improve the quality of performance. As for flow theory, one sub-hypothesis (H5b) supports that clear goal, feedback, as well as the appropriate challenge can help individuals maintain a state of flow or engagement. Goal-setting theory is supported by 10 sub-hypotheses (H1c, H2c, H3c, H4c, H5c, H6c, H8c, H9c, H10c, H12c). Given the results, it is concluded that setting effective goals can improve an individual's performance.

7.2. LIMITATIONS

There are three limitations to this research. First, we only include studies in the specified databases after the manual screening. Studies that do not meet the inclusion criteria or are not published were excluded from the meta-analysis. Therefore, the screening process and publication bias may threaten the validity of the research. Additionally, most empirical studies examine the effect of a combination of game design elements rather than individual elements, and the break-down effects on the element derived in this study could be biased. Third, the heterogeneity of the sample in meta-analysis is considerable, and the variance is not able to be explained in the moderator analysis, which leaves an unsolved problem for future research. Moderators such as student personalities or characteristics, group size for collaboration, and gender ratio are not considered in this study because few empirical studies report such information.

Hence, we call for future empirical research of gamification in education to include the analysis of these factors.

7.3. IMPLICATIONS

This study contributes to building a comprehensive knowledge base of research evidence and guidelines that can be used by stakeholders of education to take full advantage of the mechanics of design elements in gamification to maximize the effectiveness of education. More specifically, student learning outcomes are influenced by multiple factors (e.g., the difficulty of learning content and teaching method). Under such complex situations, the findings in the present study could offer suggestions on the use of design elements in practice. Further, this study makes a new attempt to explore gamification in education by breaking down the effects by its design elements, which is innovative in this research field. Moreover, we test the theoretical propositions based on the derived quantitative results. This study contributes to the advancement of academic research by verifying propositions developed using theories. Finally, we hope this study has shed light on the potential of gamification in pursuing our shared goals of improving educational outcomes for all learners.

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Studies that marked with * are included in meta-analysis

VITA

Yalin Wang entered the Guangdong University of Finance in China in September 2012. In June 2016, she received her bachelor's degree in Information Management and Information Systems. In order to learn more in-depth knowledge in the field of data science, she started her master's studies at Missouri University of Science and Technology in August 2019. In May 2021, she received her Master of Science in Information Science and Technology.