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Gamification as a Learning Tool for Pro-Environmental Behavior: A Systematic Review

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ABSTRACT

Although games provide a certain degree of entertainment, gamification is subtly affecting the behavior of users. Teaching the public to practice pro-environmental behavior (PEB) through gamification has gained an increasing amount of attention and concern in academic circles. As a relatively new research field, a systematic literature review (SLR) on gamification as a learning tool for PEB was conducted using articles with the publication date of 2007 to the present. By reviewing 56 articles from the Web of Science, Scopus and Google Scholar databases, the following findings were made: (1) gamification elements mainly represented by reward, feedback, competition, points, goal, leaderboards, challenge, meaning are the PEB learning tools that authors displayed most concern with; (2) improving energy efficiency and reducing carbon emission were the most commonly learned PEBs via gamification; and (3) the self-determination theory, the goal framing theory, the theory of planned behavior and the Octalysis framework were the most commonly applied theories in the research field of gamification and PEB.

Contribution/Originality: This study is one of the very few literature reviews on gamification, helping researchers understand the research status of gamification as a learning tool. The paper's primary contribution is to discover the gamification elements that have received the most attention and the most commonly used basic theories in previous studies, making gamification a viable solution to promote pro-environmental behavior.

1. Introduction

Through games, a "fun" virtual world is created for users, in which user emotions are deeply affected (Huber & Hilty, 2015). At the same time, the users can be motivated to take concrete actions without dogmatism (Brynjarsdottir, 2012). In the past few years, as technology and game-based applications have developed, gamification has been applied to educate, promote, and persuade users in many fields, including health (Berger, 2019), finance (Huber & Hilty, 2015), education (Santos et al., 2016), tourism (Negruşa et al., 2015) and management (Castelletti et al., 2018). In particular, the potential of "applied gaming" is of considerable significance (Fleming et al., 2017).

Gamification is defined as "use of game design elements in non-game contexts" (Deterding et al., 2011), and is grouped in a variety of ways with a specific intention to use game mechanisms or elements in other environments. Potentially containing gamification elements including reward, challenge, mission, feedback, competition, cooperation, and others, gamification engagement does not necessarily require a complete gaming experience (Morganti et al., 2017). Gamification does not specify the requirements and conditions of "non-game contexts" (Huber & Hilty, 2015). Thus, the usage scenarios of gamification applications are considerably extensive (Huber & Hilty, 2015). For a gamified application, the gamification elements are integral to success (Wee & Choong, 2019). Gamification provides a new direction for enhancing and promoting users to participate in desired behavior, and the potential thereof has been extended to environment protection (Simões et al., 2013). Such gamification concept was applied by Ro et al. (2017) in environmental psychology research on promoting pro-environmental behaviors (PEB).

With the continuous upgrading of educational technology, digital games can be effectively integrated into the classroom. Digital game-based learning has been proven to improve learners' confidence in technical skills (Charlier & De Fraine, 2012). Games that incorporate professional knowledge are useful learning tools and can promote users' social skills. They can promote active participation and interaction and balance learning goals (Cardinot & Fairfield, 2019). Grey et al. (2017) also obtained similar results, proving that the learning function of games can be used as an effective learning tool for social experiences. Therefore, when discussing the issue of games and gamification, the negative effects of addiction and offensiveness should not be exaggerated, but their positive effects as educational tools should be emphasized (Bösche & Kattner, 2011).

PEB is also referred to as "environmental behavior" (Aguiar-Castillo et al., 2019) or "sustainable behavior" (Ebermann & Brauer, 2016), and concerns behaviors that benefit the environment, including energy conservation (Castri et al., 2016), energy consumption (Kotsopoulos et al., 2016), environmental learning (Santos et al., 2016), recycling (Helmefalk & Rosenlund, 2019), carbon-reduction (Nor & Azhar, 2017), and other behaviors. PEB can be defined as "the sort of behavior that intentionally minimizes the negative impact that an action can have on the environment" (Kollmuss & Agyeman, 2002). When individuals believe that their actions contribute to the protection of the environment, they believe in the obligation of PEB (Stern et al., 1999).

The development of modern behavioral science has allowed people to abandon old habits and adopt new behaviors with numerous strategies (Walton, 2014). Use of gamification as a measure of changes in attitude and behavior has emerged as a trending

research topic, especially with the support of internet communication and social media (Seaborn & Fels, 2015). Integrating gamification into behavioral interventions refers to the utilization of gamification elements in real-life environments, such as school (Magista et al., 2018), home (Méndez et al., 2021) and workplace (Pucihar et al., 2017). People look for suitable challenges in said environments to enter a state of flow (Huber & Hilty, 2015). Hence, gamification can make users focus on "non-game activities" (Ro et al., 2017).
Additionally, gamification reduces psychological distance through the instant feedback system, which allows users to clearly recognize the role of their own behaviors (Wolf, 2020). The information presentation effectuated by gamification can enhance PEB when the psychological distance is reduced (Wolf, 2020), and users will even change their behavior for rewards (Ro et al., 2017). In parallel, users will voluntarily exhibit PEBs when there is no influence in terms of attitude or conscious (Ro et al., 2017). For instance, a pro-environmental application called Cool Choices uses gamification rewards to lead users to voluntarily participate in PEB of energy conservation (Ro et al., 2017).

According to the aforementioned status quo, further study of the context and conditions of the relationship between gamification and PEB is necessary. As such, a systematic literature review (SLR) was conducted in the present study to analyze and provide further understanding of the education effect of gamification on PEB. The differences and gaps in the literature were also investigated, new research directions were identified for solving the current problems. In the present study, the current contributions on gamification, PEB, and the former's effect on the latter were collected and examined. Three research questions were adopted for the present study:

i. What gamification elements could be use as learning tools for PEB?
ii. What specific PEBs could be learned via gamification?
iii. What theories could support the research on gamification and PEB?

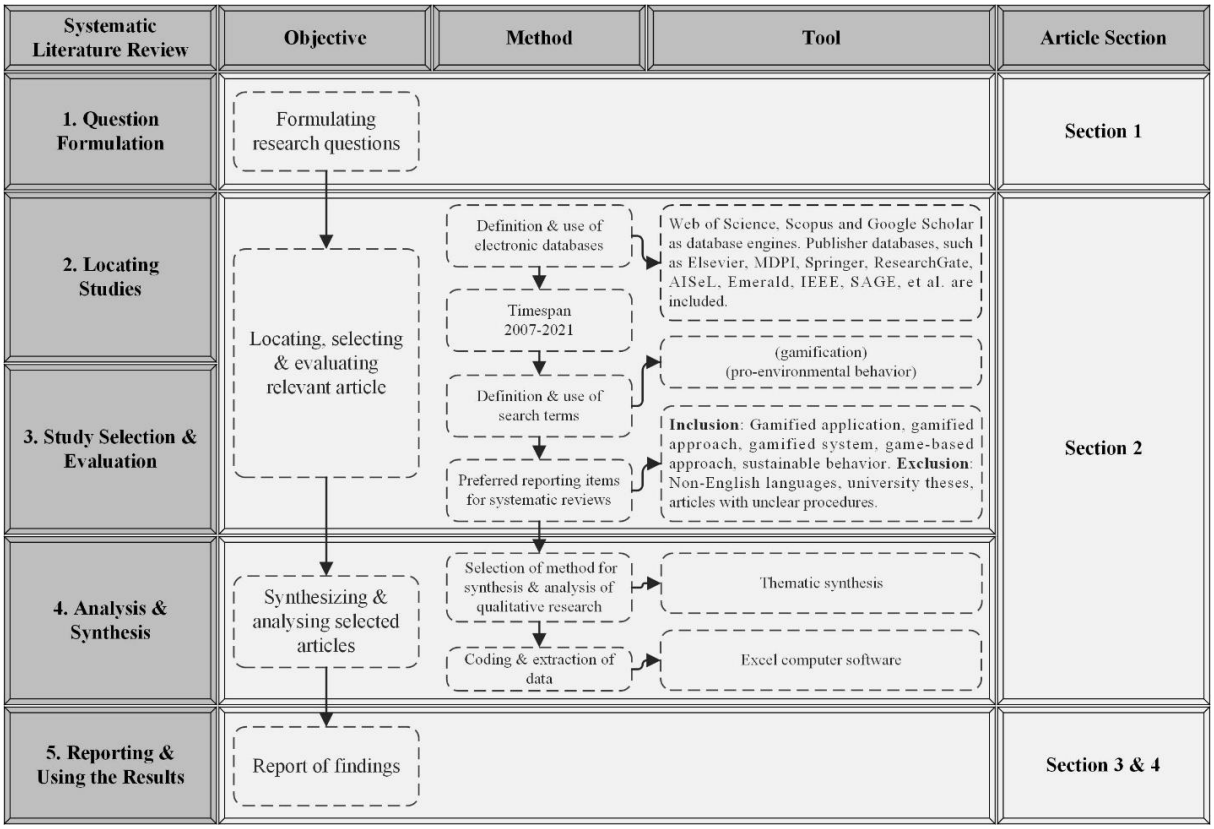
2. Methods

The aim of the present study was to determine and examine the research status of the education effect of gamification on PEB, and then perform classification to find potential gaps and differences, as well as the direction of further research. A systematic literature review allows for the further expansion of knowledge, allows for the boundaries of knowledge and the depth and breadth of existing research to be understood, and allows for research gaps to be identified (Xiao & Watson, 2019), while providing new contributions to the existing research foundation (Watson & Webster, 2020). The systematic literature review of the present study followed a "systematic, explicit, comprehensive and reproducible" process which provides a conclusion from reliable findings (Fink, 2019). The three research questions could be answered using a systematic literature review of the existing literature.

Denyer and Tranfield proposed that a systematic literature review has three stages (Tranfield et al., 2003), including: (1) planning the review; (2) conducting the review; and (3) reporting and dissemination. Accordingly, Saunders et al. (2019) also advocated solving the issue of transparency in the review conducting stage. A systematic literature review must explain in detail the operation process, especially the selection of databases and keywords. Garza-Reyes (2015) refined the review conducting process, emphasizing the importance of inclusion & exclusion processes for paper selection, and established a framework that was adapted in the present study (Figure 1). The preferred reporting

items for systematic reviews and meta-analysis (PRISMA) were also adapted from Moher et al. (2015) for the inclusion & exclusion processes (Moher et al., 2015).

Figure 1: The systematic literature review processes adapted from Garza-Reyes (2015)



2.1. Data Sources and Search Strategies

Academic publications are accessible by way of various database engines, including Web of Science, Scopus and Google Scholar. Opinions about said databases vary, with Falagas et al. (2008) arguing that Scopus provides higher coverage, while Wang and Waltman (2016) contend that the classification of journals on Web of Science is better. In the present study, both the Web of Science and Scopus databases were used, with Google Scholar acting as a support tool. Other publisher databases were searched, including Elsevier (sciencedirect.com), MDPI (mdpi.com), Springer (springerlink.com), ResearchGate (researchgate.net), AISeL (aisel.aisnet.org), Emerald (emeraldinsight.com), IEEE (ieeexplore.ieee.org) and SAGE (journals.sagepub.com).

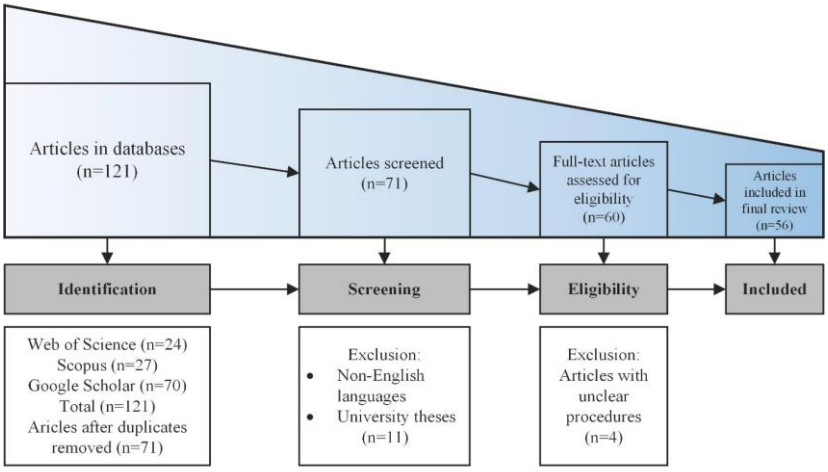
Through a preliminary search on the keywords of "gamification" and "pro-environmental behavior", all eligible articles were found to be published after 2015. Morganti et al. (2017) also indicated in a previous article that there is a scarcity of earlier studies since research in related fields is still in its infancy. The time of searching the electronic databases for the present study was September 2021, and thus, articles published before that date were included. As such, the timespan of the systematic literature review was taken from 2007-2021. To identify eligible articles, the following search terms were defined: (gamification) and (pro-environmental behavior). In order to better collect content related to the research field, similar concepts have also been included in the search scope, such as gamified application, gamified approach, gamified system, game-based approach, sustainable behavior, etc.

2.2. Inclusion and Exclusion Process

By following the PRISMA process of Moher et al. (2015), the search of the three electronic databases were completed, namely Web of Science (n=24), Scopus (n=27) and Google Scholar (n=70), and a total of 121 articles were included. After removing duplicates, 71 eligible articles remained and were further screened by reading the title and abstract based on the initial inclusion criteria. Articles (n=11) were excluded from the screening process if they were not written in English or were university theses. The selected articles included published academic journals, proceedings of international conferences, and book chapters, since Saunders et al. (2019) argued that such resources were the most reliable for literature reviews. University theses were excluded (Smith et al., 2008) due to being unpublished and having lack of innovation and insufficient depth.

After screening, the 60 articles were subjected to a full-text review considering the research questions. In the process, other standards on the characteristics and integrity of the framework were added (Soares et al., 2021). After the full-text review, articles with unclear procedures (n=4) were excluded (Soares et al., 2021), 56 articles were considered to be eligible for the present review. The overall processes of PRISMA are shown in Figure 2.

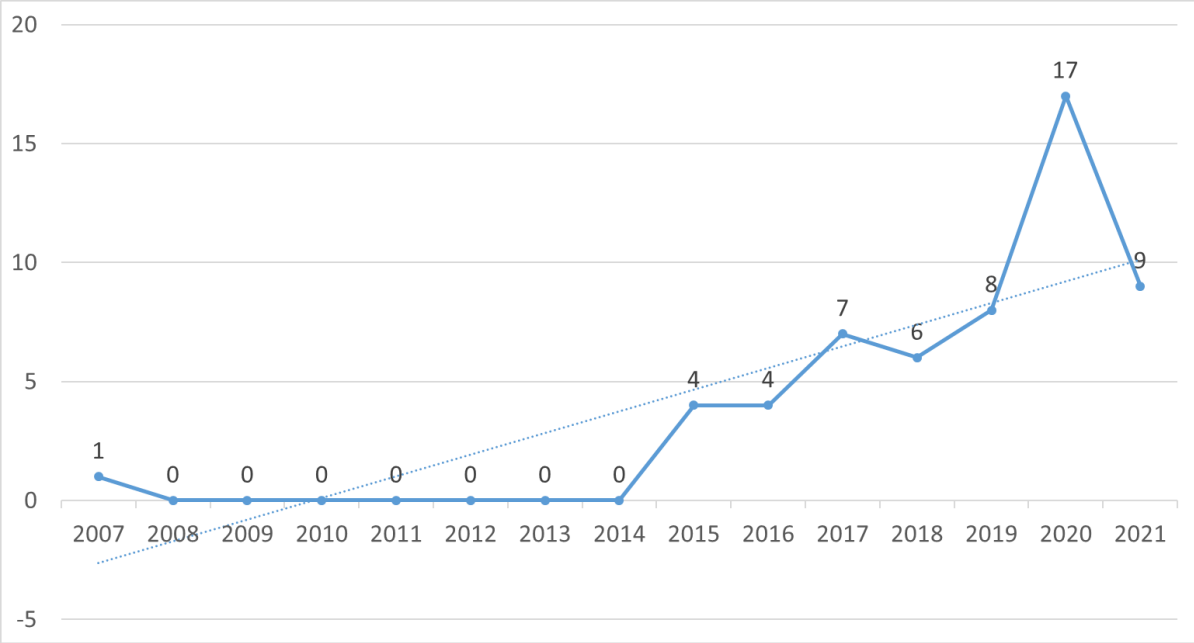
Figure 2: Preferred Reporting Items for Systematic Reviews (PRISMA) adapted from Moher et al. (2015)



2.3. Characteristics of Included Articles

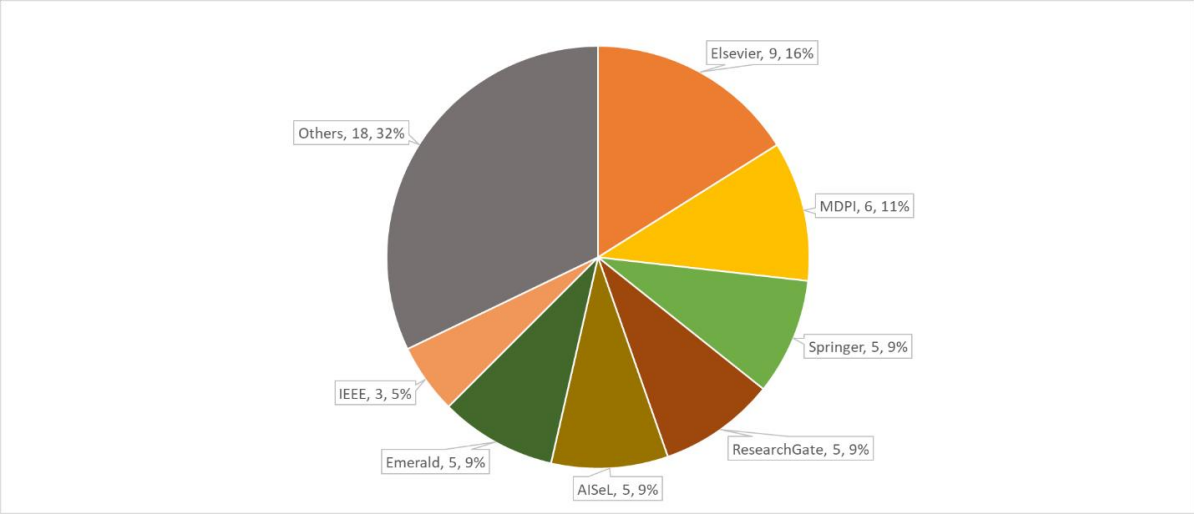
An observation can be made from Figure 3 that the first eligible article appeared in 2007. Since then, no eligible articles have appeared from 2008 to 2014. Since 2015, the number of eligible articles has shown an upward trend. As 2021 is not over at the time of writing, the year with the most studies that entered our review was 2020 (n=17). The present results reveal a large oscillation of articles on the subject in the last 5 years, indicating that the present research field is relatively new.

Figure 3: Frequency of publication per year



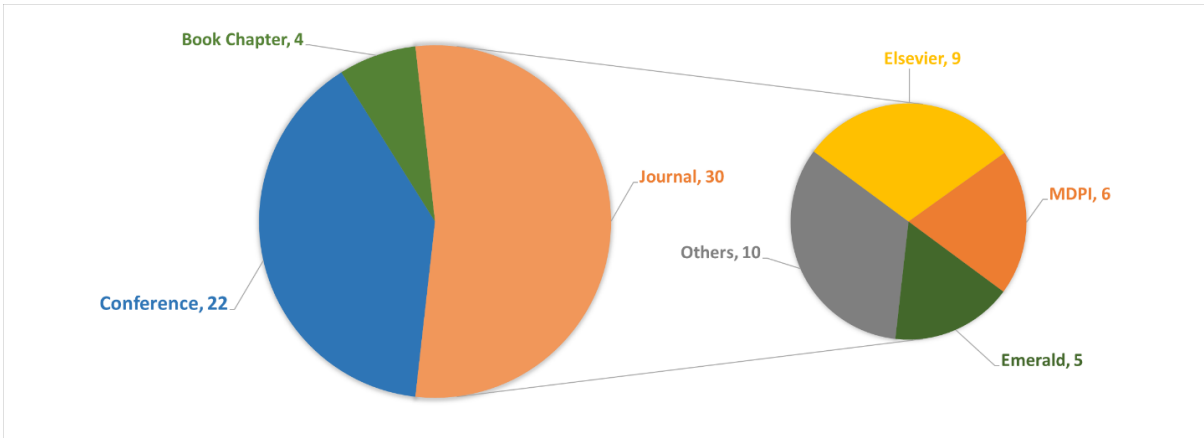
The contributions made by different publishers were analyzed. Elsevier had the maximum number of publications (n=9), followed by MDPI (n=6), Springer (n=5), ResearchGate (n=5), AISeL (n=5), Emerald (n=5) and IEEE (n=3). Publishers that only published a single eligible article were classified as Others. A summary of the contributions is illustrated in Figure 4.

Figure 4: Frequency of articles per publisher



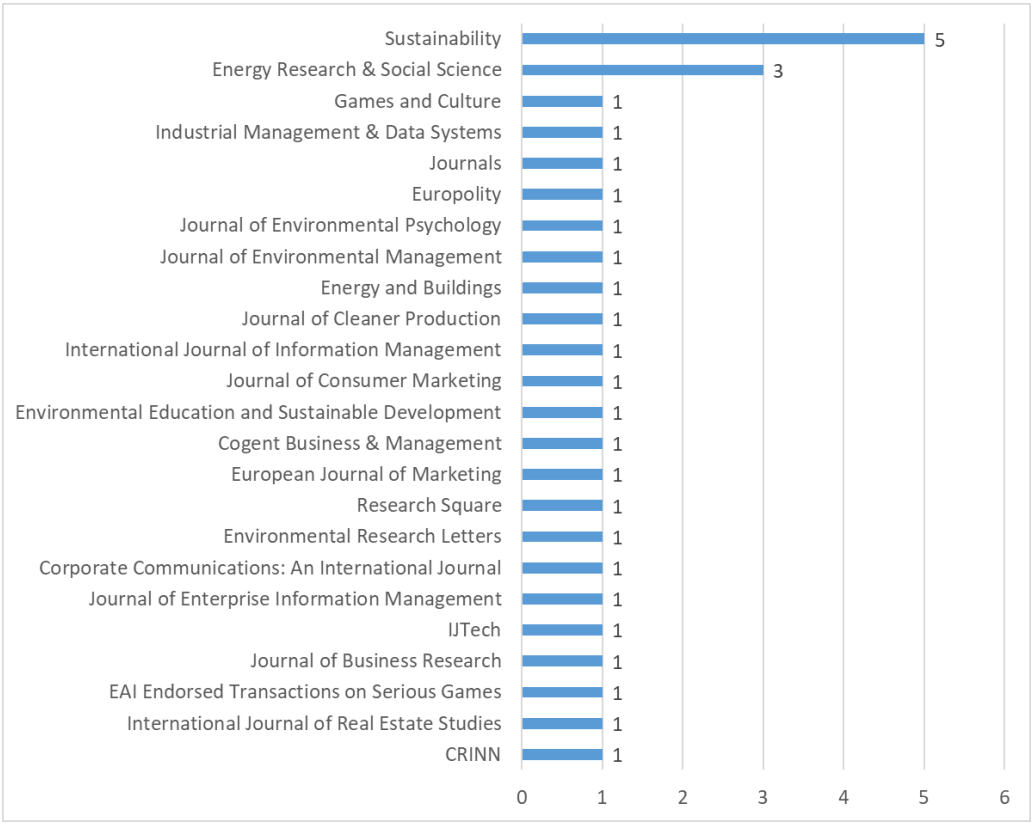
The categories of the articles were also analyzed. Journal publication was the category with the highest number (n=29). The other articles were proceedings of international conferences (n=22) and book chapters (n=5). As shown in Figure 5, Elsevier (n=9), MDPI (n=6), and Emerald (n=5) were the most commonly used publishers, followed by the other publishers that had only published a single article (SAGE; CRINN; UTM; EAI; IJTech; IOPscience; Research Square; Taylor & Francis; EE; and Hein Online) (n=10).

Figure 5: Overview of journal publication



Articles from academic journals are the most reliable for literature reviews (Saunders et al., 2019). Analysis on the articles published in journals was performed separately. Among 24 journals, 30 eligible articles were published, highlighting the applicability of the research topic in various fields. Figure 6 shows the analysis results of eligible articles in journals, the journals with a single publication were classified as Others (n=21). An observation can be made that Sustainability was the journal that had published the most eligible articles (n=5), and the subject of the present review covered a wide range of academic fields.

Figure 6: Distribution of articles by journal



2.4. Starting Point of Research Field

The findings of this systematic review show that as early as 2007, Pearce et al. (2007) proposed that games can be used in the field of environmental protection. In their journal paper "Sustainable Play: Toward a New Games Movement for the Digital Age" published in Game and Culture, they first proposed using meaningful games to try to solve the increasingly severe environmental and political problems in the digital age. In the paper, the researchers used some game cases to speculate that the new game movement can promote a pro-environmental, peaceful and stable society, and build a shared and sustainable environment (Pearce et al., 2007). Although this research did not give a clear solution, the estimation of future development trends can be considered as the starting point of this research field.

2.5. Characteristics of Articles from Sustainability

Sustainability, as an open access journal of environmental, cultural, economic, and social sustainability of human beings, provided a good research foundation for the present research. In Sustainability, 5 eligible articles were published on research fields of sustainable tourism (Negruşa et al., 2015), environmental learning (Santos-Villalba et al., 2020; Ouariachi Peralta et al., 2020), tourist recycling (Aguiar-Castillo et al., 2019) and Ant Forest (Wang & Yao, 2020) (Table 1).

Table 1: Characteristics of articles from Sustainability

Authors	Title	Application	Specific PEB	Theoretical Support	Gamification Elements
Negruşa et al. (2015)	Exploring Gamification Techniques and Applications for Sustainable Tourism	N/A	Sustainable Tourism	N/A	Competition, Feedback, Reward, Mission, Interaction
Santos-Villalba et al. (2020)	Higher Education Students' Assessments towards Gamification and Sustainability: A Case Study	N/A	Environmental Learning	Exploratory-Confirmatory Model	Reward, Points, Medals
Ouariachi Peralta et al. (2020)	Gamification Approaches for Education and Engagement on Pro-Environmental Behaviors: Searching for Best Practices	SaveOhno, JouleBug	Environmental Learning	Octalysis Framework	Meaning, Ownership, Social Influence, Achievement, Challenge, Credibility
Aguiar-Castillo et al. (2019)	Gamification as An Approach to Promote Tourist Recycling Behavior	WasteApp	Recycling Behavior	Technology Acceptance Model	Reward
Wang & Yao (2020)	Fueling Pro-Environmental Behaviors with Gamification Design: Identifying Key Elements in Ant Forest with the Kano Model	Ant Forest	N/A	Kano Model	Task, Social Interaction, Feedback, Reward

The 5 eligible articles from Sustainability all made clear conclusions, which are sorted and displayed in Table 2. The authors of the articles elaborated on the promotion of gamification to the PEB studied from their respective fields.

Table 2: Valuable findings in the articles from Sustainability

Title	Valuable Findings
Exploring Gamification Techniques and Applications for Sustainable Tourism	Gamification contributes to the tourist experience. Gamifying tourism services promote local communities by social interaction. Gamification improves entire community with cooperation between companies. Gamification shifts from a business-centric perspective to a truly sustainable perspective.
Higher Education Students' Assessments towards Gamification and Sustainability: A Case Study	Higher education students perceive gamification has positive effects on motivation. Higher education students accept green curriculums based on sustainable values and skills. Gamification in education has a positive impact on students' motivation and pro-environmental attitudes.
Gamification Approaches for Education and Engagement on Pro-Environmental Behaviors: Searching for Best Practices	Gamification approaches can educate and encourage pro-environmental behavioral change with motivations, drivers, and game attributes. SaveOhno and JouleBug are two successful practices for engaging users in behavioral change due to the powerful core drives and extrinsic and intrinsic motivations.
Gamification as An Approach to Promote Tourist Recycling Behavior	Gamified recycling applications effectively promote tourist recycling behavior. Gamification rewards must support the internalization of extrinsic motivation. User satisfaction has a positive influence on recommending applications.
Fueling Pro-Environmental Behaviors with Gamification Design: Identifying Key Elements in Ant Forest with the Kano Model	Gamification elements correlated with environmental sustainability facilitate the most user satisfaction. The social interaction module shows a trivial impact on user satisfaction. The reward module is an attractive element that led to the highest satisfaction. Short-term and long-term feedbacks have different impacts on user satisfaction.

3. Results and Discussion

Overall, only one eligible article (Maltseva et al., 2019) indicated the "insignificant effects of gamification on PEB" among all 56 eligible articles, while the other articles all reported positive results in various degrees. The frequency of the occurrence of keywords could provide further understanding of the current state of research in a certain field (Maltseva & Batagelj, 2020), and thus, word frequency analysis was conducted on the keywords of all eligible articles. When displaying the analysis results, the searching keywords (gamification) and (pro-environmental behavior) of the present review were eliminated, since said words appeared frequently and affected the other results. The word cloud in Figure 7 shows the results of the analysis. An observation can

be made that Sustainability, Serious Games, Behavior Change, Energy Conservation and Goal Framing Theory (GFT) were the fields that the authors most focused on.

Figure 7: Word cloud of keywords

In the remainder of this section, the results of the systematic revision process are presented according to the research questions.

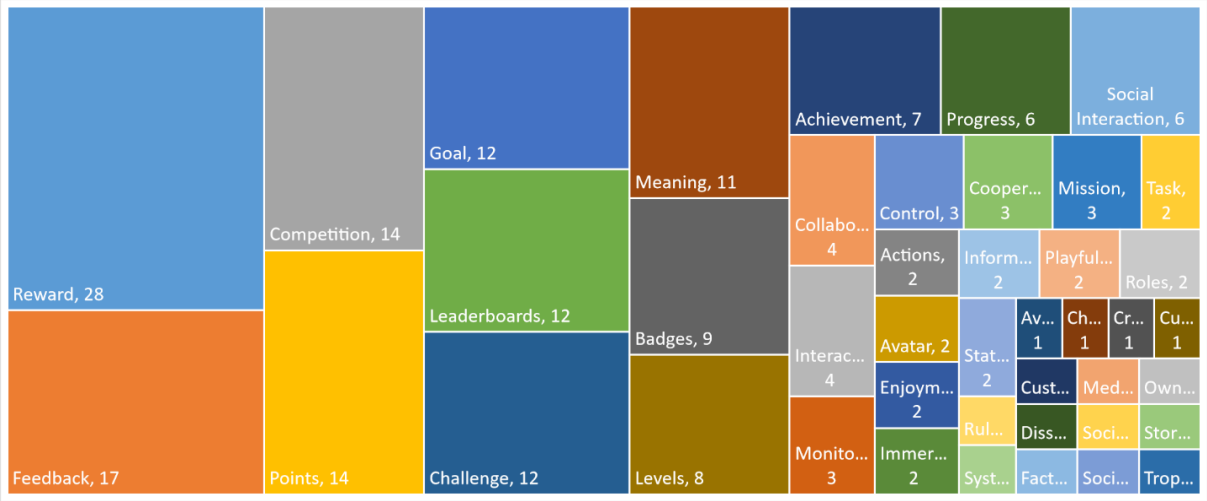
3.1. What gamification elements could be use as learning tools for PEB?

Aside from three articles (Maltseva et al., 2019; Pearce et al., 2007; Bagheri & Talimi, 2021), all eligible articles mentioned specific gamification elements as learning tool for PEB (n=53). All gamification elements in eligible articles that had a positive effect on PEB were coded, and the results are shown in Figure 8 through the word cloud.

Figure 8: Word cloud of gamification elements as learning tool for PEB

The results show that reward was the gamification element as learning tool for PEB that received the most concern from authors (n=28), followed by feedback (n=17), competition (n=14), points (n=14), goal (n=12), leaderboards (n=12), challenge (n=12), meaning (n=11), badges (n=9), and others. In order to better display all the results, a tree map (Figure 9) was used to show the frequency of occurrence of all gamification elements.

Figure 9: Tree map of all gamification elements as learning tool for PEB



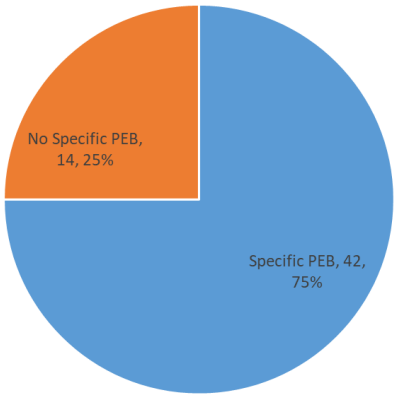
Reward as an action shaper (Radziszewski et al., 2021) received widespread concerned by authors. A gamified system built with rewards could enhance user engagement and develop behavior (Castelletti et al., 2018; Kotsopoulos et al., 2016; Pucihar et al., 2017; Helmefalk & Rosenlund, 2019; Radziszewski et al., 2021; Mulcahy et al., 2021; Kotsopoulos et al., 2017; AlSkaif et al., 2018; Aguiar-Castillo et al., 2019). Points (n=14), leaderboards (n=12), and badges (n=19) were often mentioned with the reward element in eligible articles (Cwil & Bartnik, 2018; Nor & Azhar, 2017; Helmefalk & Rosenlund, 2020; Kotsopoulos et al., 2018; Kotsopoulos et al., 2017; Souza et al., 2020; Ponce et al., 2020; Ro et al., 2017; Butnaru-Troncota, 2020). Said elements were also recognized as an extension of reward, and were clearly classified in the game theory of the Octalysis framework (Chou, 2015). The mention frequency in the articles shows the importance of the reward element in promoting PEB. Moreover, feedback, competition, and challenge were often mentioned in the same article (Cwil & Bartnik, 2018; Negruşa et al., 2015; Helmefalk & Rosenlund, 2019; Helmefalk & Rosenlund, 2020; Méndez et al., 2021; Méndez et al., 2020; Ponce et al., 2020; Wee & Choong, 2019; Morganti et al., 2017), being used to collaborate and jointly enhance intrinsic motivation on PEB (Wee & Choong, 2019). Said elements were often applied in conjunction with the self-determination theory (SDT) (Cwil & Bartnik, 2018; Wee & Choong, 2019) and the theory of planned behavior (TPB) (Méndez et al., 2021; Méndez et al., 2020). The meaning element (n=11) in gamification is a relatively general concept, and was mentioned in many eligible articles (Castelletti et al., 2018; Bardhan et al., 2015; Huber & Hilty, 2015; Oppong-Tawiah et al., 2020; Magista et al., 2018; Prakash & Manchanda, 2021; Souza et al., 2020; Ouariachi et al., 2020; Chen & Cai, 2019; Du et al., 2020; Morganti et al., 2017). In said articles, goal (n=12), achievement (n=7), task (n=3), avatar (n=2), and storyline (n=1) were often applied to express meaning to behavior. Meaning is also an important part of the Octalysis framework (Chou, 2015), in which "meaning" is given to specific actions (Huber & Hilty, 2015). At the same time, articles that mentioned meaning and related elements also mentioned the persuasive system (Castelletti et al., 2018; Bardhan

et al., 2015; Ebermann & Brauer, 2016; Huber & Hilty, 2015; Nor & Azhar, 2017; Oppong-Tawiah et al., 2020). The cognition of the meaning of PEB is essential for the gamification system to "persuade" users to change their behavior towards environmental protection.

3.2. What specific PEBs could be learned via gamification?

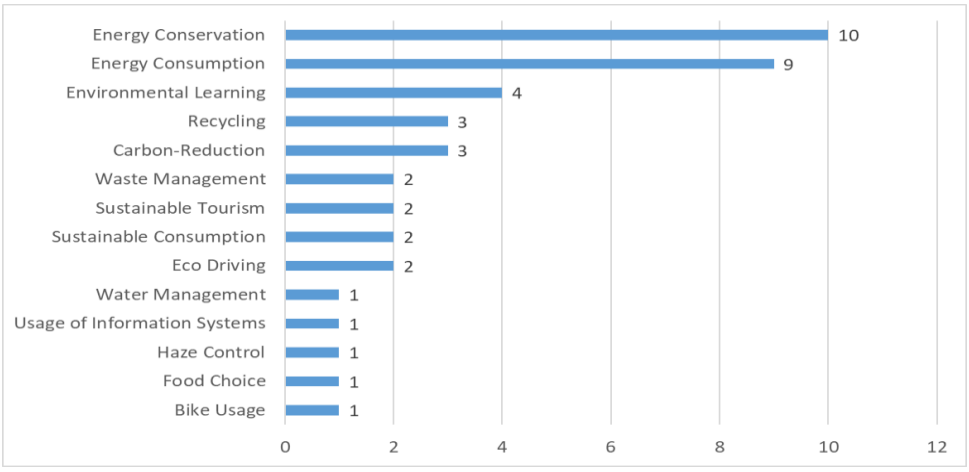
As shown in Figure 10, 42 articles were investigated on specific PEBs, accounting for 75% of the total eligible articles. Most authors explored the impact of gamification on a specific PEB, and the remaining 14 articles did not involve specific PEBs, but discussions on macro PEB were conducted (Kalz et al., 2015; Maltseva et al., 2019; Li et al., 2021; Shevchuk et al., 2019; Pearce et al., 2007; Radziszewski et al., 2021; Prakash & Manchanda, 2021; Seidler et al., 2020; Ke et al., 2019; Bergmann et al., 2017; Van Houdt et al., 2018; Wang & Yao, 2020; Van Houdt et al., 2020; Wolf, 2020).

Figure 10: Research ratio of specific PEBs could be learned via gamification



Among the PEBs mentioned in the eligible articles, energy conservation (n=10) and energy consumption (n=9) accounted for a large proportion. Said two concepts are quite similar and accounted for 34% of the eligible articles after being combined. According to the ranking, the specific PEBs following the aforementioned two were environmental learning (n=4), recycling (n=3), carbon-reduction (n=3), waste management (n=2), sustainable tourism (n=2), sustainable consumption (n=2), eco driving (n=2), and others. The complete results are shown in Figure 11.

Figure 11: Quantity order of specific PEBs could be learned via gamification

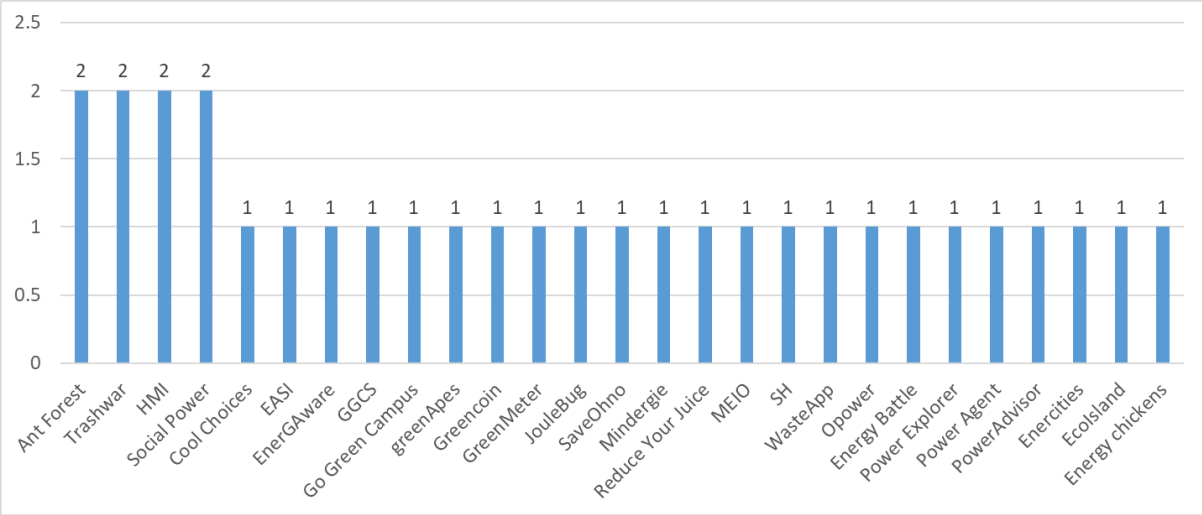


Energy conservation and energy consumption were often used in combination in eligible articles (Kotsopoulos et al., 2016; Pucihar et al., 2017; Chui & Wai, 2017; Kotsopoulos et al., 2018; Kotsopoulos et al., 2017; Günther et al., 2020; Wee & Choong, 2019). In such cases, energy conservation referred to reducing energy consumption. Environmental learning (Bagheri & Talimi, 2021; Santos-Villalba, 2020; Ouariachi Peralta, 2020) and environmental education (Santos et al., 2016) were also discussed together, mainly emphasizing the use of various gamification elements to enable students to acquire environmental intentions and PEBs through education. In addition, energy consumption was given a broader meaning, which is to improve energy efficiency (Casals et al., 2020; Morganti et al., 2017). In such context, the concepts of smart meter (Castri et al., 2016; Antonache et al., 2020; Ponce et al., 2020; Casals et al., 2020; AlSkaif et al., 2018) and smart home (Antonache et al., 2020; Méndez et al., 2021; Méndez et al., 2020) were always mentioned together with energy conservation and consumption, and would eventually be displayed in the form of HMI (Méndez et al., 2021; Ponce et al., 2020). As related concepts, recycling and waste management were often discussed together (Helmefalk & Rosenlund, 2019; Magista et al., 2018; Aguiar-Castillo et al., 2019). Researchers generally believe that gamified rewards can be a positive factor in promoting such behaviors (Helmefalk & Rosenlund, 2019; Helmefalk & Rosenlund, 2020; Aguiar-Castillo et al., 2019). Gamification applications have been demonstrated to promote the reduction of energy consumption and carbon emissions, so as to achieve the goal of improving energy efficiency (Casals et al., 2020).

The energy conservation behavior of users can be fostered by gamification applications, according to the systematic review of Morganti et al. (2017). The review also highlighted that three areas related to energy efficiency can be affected by gamification, including environmental education, consumer awareness, and PEB, in which the integrated intervention provided by games is a significant factor (Morganti et al., 2017). Gamification provides users with an interesting environment for activities, making users more willing to participate in energy-saving behaviors. Traditional energy-saving activities are information-intensive and uninteresting, owing to the amount of information being too large to stimulate user interest. However, with the addition of gamification elements, energy-saving activities have become more effective and meaningful in motivating users to participate (Wee & Choong, 2019).

In order to show the impact of serious games on various PEBs, different kinds of corresponding applications have also been investigated in eligible articles, which are displayed as analysis results (Figure 12) in the present study, with the addition of auxiliary information for specific PEBs. Among the gamification applications, Ant Forest, as an influential mobile application, received more concern (n=2), and indicating the importance thereof in haze control (Chen & Cai, 2019) and PEB promotion (Wang & Yao, 2020). Trashwar is a simple game that allows users to understand waste segregation, but through gameplay design it can educate users on recycling behavior (Bardhan et al., 2015; Morganti et al., 2017). Social Power is a social game that encourages user groups to save energy collectively through competition, and the group who saves more collectively will be rewarded. This not only promotes the scale of energy saving, but also promotes social interaction among users and improves collective environmental awareness (Castri et al., 2015; Morganti et al., 2017). Further, HMI (Human-Machine Interface) did not specifically refer to one application, but the key technology of application development (Méndez et al., 2021; Ponce et al., 2020).

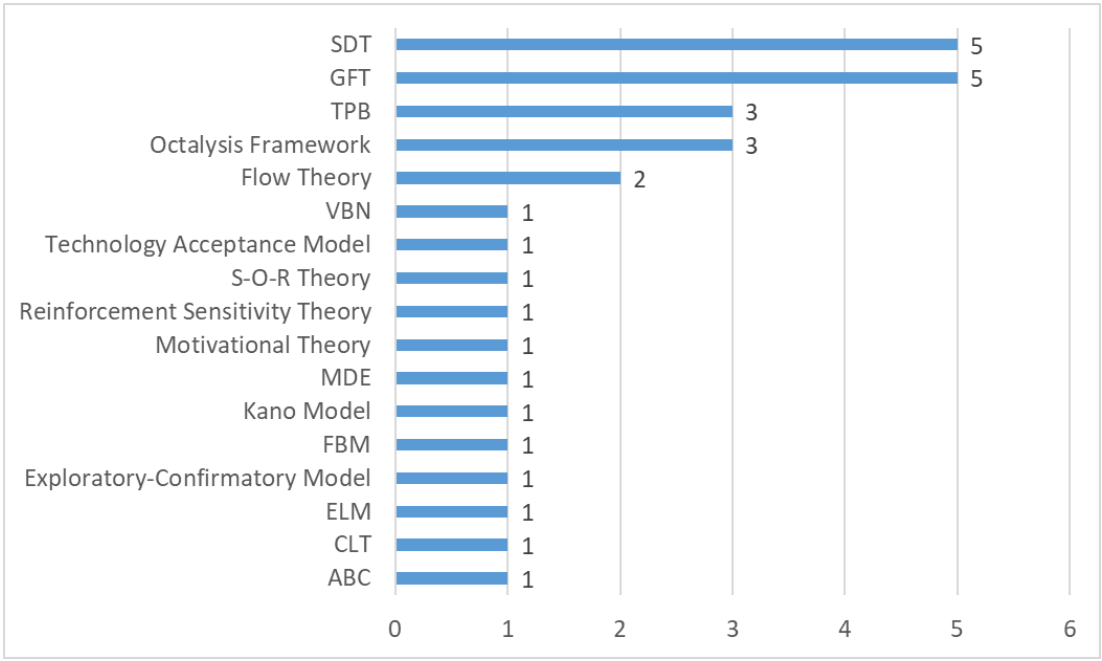
Figure 12: Quantity order of serious games used as learning tools for PEB



3.3. What theories could support the research on gamification and PEB?

There were 25 articles with categoric theoretical support in all eligible articles, accounting for 45% of the total number of articles. Among said articles, SDT and GFT were used the most as theoretical support (n=5). An observation can be made that the two theories had strong applicability in the research of gamification and PEB. Other commonly used theories included TPB (n=3), the Octalysis framework (n=3), and flow theory (n=2), as detailed in Figure 13. Authors usually use said theories to take user engagement motivation as a pointcut to explore the role of gamification as learning tools for PEB.

Figure 13: Quantity order of theories supporting studies on gamification and PEB



In the eligible articles, SDT was one of the most frequently applied theories when studying individual behaviors, and the identification of gamification elements was based on SDT to enhance users' intrinsic motivation (Cwil & Bartnik, 2018; Helmefalk &

Rosenlund, 2019; Helmefalk & Rosenlund, 2020; Wee & Choong, 2019; Van Houdt et al., 2018). SDT is a theory used to distinguish motivations for different reasons or different goals, which divides motivation into intrinsic motivation and extrinsic motivation (Ryan & Deci, 2000). Intrinsic motivation is essentially derived from fun, while external motivation is to obtain results (Ryan & Deci, 2000). According to SDT, the intrinsic motivation of individuals responds to three innate psychological needs, which are autonomy, competence, and relatedness (Ryan et al., 2006). Thus, gamification elements were applied in the articles based on SDT to satisfy the three needs of application users.

GFT was often applied to systematically study the process of multiple goals influencing PEBs (Ebermann & Brauer, 2016; Li et al., 2021; Seidler et al., 2020; Ke et al., 2019; Du et al., 2020). The basic principle of GFT is that the goals determine the individual's intention and their PEBs in a specific environment (Ke et al., 2019). GFT claims that the goals control or "frame" users' attention, evaluation and alternatives scenario (Steg et al., 2014). Three types of specific goals related to the PEB motivations are identified by GFT, including the normative goal "to act appropriately", the hedonic goal "to feel better right now" and the gain goal "to guard and improve one's resources" (Lindenberg & Steg, 2007). In GFT, hedonic values affect environmental beliefs, attitudes, preferences, and behaviors, in addition to the intensity of hedonic goals (Steg et al., 2014).

Combining social and behavioral sciences to predict and understand specific behaviors in certain environments, TPB is an effective theoretical framework for studying individual complex social behaviors (Ajzen, 1991). The intention of an individual to engage in a specific behavior according to the subjective norm, attitude toward the behavior and perceived behavioral control can be predicted (Ajzen, 1991). If the individuals can actually control their behavior, then the intention will be fulfilled when an opportunity arises (Ajzen, 2002). In addition to considering intentions, perceived behavioral control as an agent of actual control helps predict behavior (Ajzen, 2002). TPB explains behavior by factoring "subjective norm" as an important variable; therefore, feedback, challenge, and competition were often mentioned in combination as social product components in articles (Méndez et al., 2021; Méndez et al., 2020).

In the classification and analysis of gamification elements, the Octalysis framework was often applied in articles (Prakash & Manchanda, 2021; Ponce et al., 2020; Ouariachi Peralta et al., 2020). The framework was proposed by Chou (2015), and is a system created to develop gamification applications. Due to the late proposal thereof, the framework has been gradually applied in studies in recent years. The framework considers extrinsic, intrinsic, positive, negative motivations, and eight core drives, including: (1) epic meaning and calling; (2) development and accomplishment; (3) empowerment of creativity and feedback; (4) ownership and possession; (5) social influence and relatedness; (6) scarcity and impatience; (7) unpredictability and curiosity; and (8) loss and avoidance (Chou, 2015).

4. Conclusion

In the present study, a systematic literature review on gamification as a learning tool for PEB was conducted. Through the review, 56 articles published between 2015 and September 2021 were identified using processes adapted from Garza-Reyes (2015). The systematic literature review method was used to review a vast number of publications and enhance the trustworthiness of the present findings. The method was applied to answer three research questions.

The first question was "What gamification elements could be use as learning tools for PEB?". The diverse content and bibliometric analysis in Section 3.1 was used to answer the first question. The results show that reward was the most concerned gamification element, coupled with points, leaderboards, badges and other elements to motivate PEB of application users. Feedback, competition, and challenge elements were also mentioned often in terms of enhancing PEB motivation. In addition, the meaning element was often applied to drive goal-driven PEB.

The second question was "What specific PEBs could be learned via gamification?" The diverse content and bibliometric analysis in Section 3.2 was used to answer the second question. The results show that improving energy efficiency and reducing carbon emissions were the most concerned PEBs affected by gamification. Additionally, environmental learning and education, waste recycling and management were also major concerns. Gamification applications persuade users to engage in various PEBs through information-based campaigns.

The third question was "What theories could support the research on gamification and PEB?" The diverse content and bibliometric analysis in Section 3.3 was used to answer the third question. The results show that SDT, GFT, TPB, and the Octalysis framework were the most commonly applied theories to support research on gamification and PEB. SDT focuses on intrinsic motivation, GFT focuses on goal-driven behavior, TPB focuses on social norms, and the Octalysis framework focuses on the gamification-driven core.

A general claim found in the review is that gamification as a learning tool has a significant impact on PEB. Various gamification elements have been positive factors in promoting the PEB of application users. Despite many studies not accurately measuring the "learning" effect, gamification is undoubtedly a field worthy of further research.

There were several limitations to the present study, including the potential bias in performing analysis on articles, as the present authors' understanding of gamification is based on their own inherent point of view. In addition, the amount of literature on gamification and PEB is relatively small in mainstream databases. In order to expand the search scope, several articles from conferences and book chapters were included, which may lead to different levels of article quality and affect the research results. Moreover, the narrow selection of keywords is another limitation of the review, which may cause some articles related to the topic to be ignored.

The present research field is still in the early stages, with most research being reported in the last seven years. The present systematic review provides researchers with topical direction and offers clear avenues for future research, notably in gamification engagement, PEB retention, and pro-environmental application development. While several gaps in knowledge and future research directions have been highlighted in the present study, no prioritization was specified. However, existing research results seem to be better applied in the establishment of theories for the development of pro-environmental applications, which will allow for comprehensive understanding of gamification elements that be use as learning tools for PEB.

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Conflict of Interest

The authors declare no conflict of interest.

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