Gamified Project-Based Learning: A Systematic Review of the Research Landscape

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Gamified Project-Based Learning: A Systematic Review of the Research Landscape

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Abstract: The information era puts higher requirements on current students’ learning methods to develop 21st-century skills. Project-based learning (PBL) and gamified learning have been two effective learning approaches, leading to an innovative exploration of combining both to improve learning outcomes. This study presents a systematic review of the literature published on “gamified PBL” (GPBL) over the past six years, focusing on GPBL approaches, learning outcomes, technical tools and theories. The results show that the gamified approaches of project-based learning can be divided into four types: gamify structure and procedure of PBL, gamify content of PBL, integrate prefabricated educational/serious games in PBL, and make a game as the activity of PBL. Most of the studies affirmed the positive effects of GPBL in enhancing students’ learning outcomes, especially for learning experience and motivation. Adopted techniques and theories in the reviewed studies were also summarized. In conclusion, we acquired four findings based on the discussion: the characteristics of GPBL are diverse; design-based learning are an innovative and creative method used in GPBL; studies of GPBL emphasized collection and description of the whole-process data; technical issues should be paid great attention to. In addition, a number of suggestions for future research are provided in this review.

Keywords: gamified project-based learning; educational games; game elements; game making; project-based learning

1. Introduction

There is a need for education to adapt to a changing world and project-based learning is becoming increasingly popular because it meets this need [1,2]. Project-based Learning (PBL) is an effective learning approach that enables students to learn by doing via a project [3]. PBL is commonly applied in various disciplines from K-12 education to higher education, such as mathematics, science, medicine and social sciences [4] and is becoming increasingly popular in both research and practice. According to Baran et al. [5], PBL positively impacts students’ deep learning by engaging them in learning activities, making it easier to relate knowledge to everyday life and developing students’ higher-order skills [6]. However, the successful implementation of PBL has been beset with obstacles and skepticism. Several studies show that interest and motivation play significant roles in engaging students in PBL [7]. If the design of PBL lacks fun, students would lose attention and waste much time idly during the project. How to evaluate the results of PBL also confused many teachers and students as most PBL assessments are group-based and product-oriented [8,9]. More quantitative and individual evaluation methods and tools are needed. For these reasons, gamified learning for improving learning motivation and results [10] seems to provide new insights to address these issues.

Gamified learning is rapidly gaining importance in education, considering its effects on deep learning [11]. Although there is currently no exact definition of gamifying, any
The definition refers to the use of game elements (such as reward systems) as an incentive for participants to engage in tasks that they were not initially interested in [12]. The Horizon Report has listed gamified learning as one of the most effective instructional methods for future education since 2014 [13]. Digital badges were featured as a component of gamification in The Horizon Report 2015, which are expected to be widely used to motivate, track and visualize learners’ learning experiences [14]. Moreover, the report Innovating Pedagogy 2019 from the British Open University regards it as the top innovative pedagogy. It is suggested that gamified learning has significant positive effects in motivating learning, increasing academic performance, developing cognition and meta-cognition and improving learning experiences and social emotion [15–17]. Therefore, several studies have begun to explore the integration of gamified learning and PBL, leading to an innovative PBL approach—gamified PBL (GPBL). GPBL refers to using games, game elements or mechanics in project-based learning to improve learning outcomes. Markham [18] believed that applying game elements to project-based learning can engage learners and facilitate maximization of their skills and creativity, because game elements can provide learners with ‘ambitious’ tasks, clear goals, desirable tools, rich feedback, a collaborative environment, meaningful rewards, etc. It is also found that GPBL facilitates deep learning by creating learner-centered learning approaches, supporting students in interacting with others, providing authentic tasks and promoting meta-cognition strategies (e.g., planning, monitoring, regulating and time management) [19]. In addition, such a combination is also helpful for improving students’ learning emotions, such as learning motivation, satisfaction and self-efficacy [20]. Although it is suggested that gamified learning has great potential in improving the process and results of PBL, it is not clear how to design, implement and evaluate GPBL in relation to particular learning groups and disciplines. It is also acknowledged that the literature on GPBL is fragmented and lacks systematic analysis. Therefore, we conducted a systematic literature review of research studies on GPBL over the past six years to help educators understand GPBL comprehensively. Four research questions were proposed to guide the report of the review work:
1. What are the gamified approaches of PBL?
2. What are the learning outcomes addressed in GPBL studies?
3. What are the technical tools used in GPBL studies?
4. What are the theoretical contributions involved in GPBL studies?

2. Methods
2.1. Literature Search

We implemented and reported our systematic review in accordance with the PRISMA reporting guidelines and checklist as shown in Figure 1. This review mainly focuses on the empirical studies of GPBL from January 2015 to December 2020. To find the targeted literature, we searched three widely used digital academic databases related to education: Web of Science, ERIC and ScienceDirect. The search terms were derived from previous searches of PBL and gamified learning, which were the following: (“gamified learning” OR “game-based learning” OR “playful learning” OR “educational game” OR “gamification of learning”) AND (“Project-based learning” OR PBL). During the search process, two selection criteria were set in the search engine: (a) peer-reviewed SSCI journal articles; (b) published between January 2015 and December 2020. This search was finished on 1 May 2021 and the initial search yielded 397 articles.
2.2. Literature Screening and Article Identification

After the initial search, the articles are screened based on the following criteria: (a) full-text content; (b) empirical study; (c) the co-occurrence of gamified learning and PBL and excluding: (a) only mentioned PBL or gamified learning in research background and literature review, (b) incorrect concept of abbreviation (e.g., PBL, GPBL, GBL), (c) repetitive articles. At first, this review selected articles with full-text content. Secondly, empirical studies focusing on both gamified learning and PBL remained. Besides, studies that described PBL as problem-based learning were excluded. Third, to access quality reports of empirical studies, we assessed the eligibility of the reports and only included peer-reviewed SSCI journal articles. Finally, 34 articles that met the criteria were selected, one of which involved two experiments. Therefore, a total of 35 studies were reviewed (see Table S1 for a list of reviewed articles).

2.3. Analysis

All studies were coded and analyzed with the content analysis method. Content analysis focuses on the systematic analysis of explicit and implicit information in texts through classification, charting and comparison [21]. Following the systematic review guideline of Page et al. [22], we reported relevant characteristics of reviewed studies and further summarized the results regarding the gamified approach of PBL, learning outcomes and technology, as well as theoretical contributions. Two authors read the target articles separately and then coded the content in the qualitative analysis software NVivo 12.0. The agreement for coding had a Kappa coefficient of 0.82 (good agreement if Kappa > 0.75), indicating a good level of reliability. Disagreements between the two coders were resolved through discussion and re-examining until an agreement was reached. In addition, this study conducted a meta-analysis of quantitative data on learning outcomes by calculating effect sizes through Stata 16.0. The results of the meta-analysis can predict the effects of GPBL to some extent.
3. Results

3.1. Overview of Reviewed Studies

An overview of the reviewed studies is provided in Table S1. Geographically, the final set of 35 studies comes from European, Asia, North America, South America and Oceania. European countries had the highest number of studies (16 studies), followed by countries in Asia (nine studies), North America (six studies), South America (one study), Oceania (one study) and cross-country collaboration (two studies). For educational context, 28 studies focused on classroom teaching and learning, while only seven studies targeted learning outside the classroom. 33 studies reported their sample sizes, with the largest one containing 395 participants and the smallest containing only three. The information on educational stage and disciplines is shown in Table 1. There were 22 studies for university students, eight studies for secondary school students, three studies for primary students and two studies for both primary and secondary school students. The results show that the number of GPBL studies in higher education is significantly more than that in elementary education (including primary and second education). In higher education, GPBL is mainly applied in engineering and computer science disciplines, such as engineering and construction courses (six studies) and programming courses (eight studies). For primary and secondary education, GPBL is commonly used in engineering and science-related disciplines, such as STEM (one study), programming (three studies) and science (one study).

Table 1. Distribution of educational stage and courses/program.

<table>
<thead>
<tr>
<th>Educational Stage</th>
<th>Course/Program</th>
<th>Discipline</th>
<th>No. of Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>Engineering, Construction</td>
<td>Engineering</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Programming</td>
<td>Computer Science</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Entrepreneurship, Information System</td>
<td>Management</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Computer Supported Collaborative Learning, Physical Education</td>
<td>Education</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>History</td>
<td>History</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Geomorphology</td>
<td>Geography</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Game-making</td>
<td>Inter-discipline</td>
<td>2</td>
</tr>
<tr>
<td>Secondary Schools</td>
<td>Extracurricular Integrated Program</td>
<td>Inter-discipline</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Programming</td>
<td>Computer Science</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Physics, Chemistry</td>
<td>Science</td>
<td>2</td>
</tr>
<tr>
<td>Primary Schools</td>
<td>Science</td>
<td>Physical Science</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>STEAM</td>
<td>Inter-discipline</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Extracurricular Integrated Program</td>
<td>Inter-discipline</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Programming</td>
<td>Computer Science</td>
<td>1</td>
</tr>
</tbody>
</table>

The research paradigms fall into four types: single-group pre-post-test experiments (five studies), inter-group experiments (six studies), case studies (16 studies) and design-based studies (eight studies) (see Figure 2). Experimental design is a traditional and standard method to examine the effects of independent variables on targeted results. A case study aims to make a serious investigation of a specific subject by analyzing typical cases [23]. Unlike experimental studies, the 16 case studies focused on new and outly-
ing cases, which may shed new light on PBL. Besides, eight studies used design-based research, emphasizing developing solutions to problems through the process of design, implementation, evaluation and revision [24].

In terms of data gathering, more than half of the empirical studies (21 studies) used mixed methods to gather both quantitative and qualitative data and offer rich information about research issues. Mixed-method design is a widely-used research method in social, behavioral and educational science, which utilizes different tools and approaches to gather various data and support methodological triangulation [25]. However, it is necessary to consider distortions or cross-effects of the applied methodologies in the mixed research. Quantitative research focuses on the evidence gathering of academic achievement tests, questionnaires and scales, while qualitative research concentrates on in-depth interviews, observations and analysis of the artifacts. Data sources of the reviewed studies covered questionnaires and scales (27 studies), observations (18 studies), interviews (14 studies), artifacts (nine studies), tests (nine studies) and texts (seven studies).

3.2. Gamified Approach of PBL

There are generally two kinds of gamified-learning: gamification (of learning) that applies game elements/mechanics in a non-game situation [26,27] and game-based learning (which is facilitated by the use of serious games) [28]. According to Kapp [26], gamification approaches of learning can be summarized into two levels: for structure and for content. The result of total gamification is to utilize serious games. In addition, game design and development is also included in the scope of game-based learning [29,30]. Therefore, this paper proposes a framework for a gamified approach paradigm based on gamification degree. The reviewed studies were coded into four types according to the paradigm (see Figure 3).

Figure 2. Empirical research paradigm.

Figure 3. Gamified approach paradigm based on gamification degree.
3.2.1. Type 1: Gamify the Structure of PBL

The first gamified approach of PBL is to gamify the structure of PBL by using “BPL” (Badges, Points, Leaderboards and Levels) game elements. This approach is to package PBL into a competitive activity. These game elements are called superficial or shallow game elements in several pieces of literature [31], as they are viewed as a layer that is added to the core process of learning without altering the learning essence [32]. Almost all reviewed studies set up “BPL” elements more or less in PBL as they are typical characteristics of gamification. One-third of the studies used “BPL” elements to package their PBL activities. For example, Isabelle [33] introduced a web-based platform of Online Venture Challenge (OVC) in an undergraduate entrepreneurship education course. Game elements in the OVC include badges, points, real-time rankings, etc. Student teams can accomplish their learning tasks on OVC and start their entrepreneurial projects on Shopify (a global e-commerce platform for online businesses); the tasks completed on OVC and the profits on Shopify are all converted into points displayed in real-time on the leaderboard of OVC.

3.2.2. Type 2: Gamify the Content of PBL

Compared to the first type of shallow gamification, the second type of GPBL is to gamify the content of PBL, which can be called “deep gamification” to some extent. This gamified PBL approach is intended to modify PBL materials and methods by creating gaming situations and tasks, designing game mechanisms and rules, as well as connecting the gaming process to learning objectives [31]. For example, Warin et al. [34] applied a multi-role project (MRP) method in a Master’s-level Information System Project (ISP) course. The MRP has four main virtual roles: project team members, management experts, clients and business experts. In a manner similar to a role-playing game, students must solve real problems and improve their performance.

Similarly, Wu et al. [35] allowed students to participate in a construction management course by role-playing the consultant, project manager, owner and project engineer on a campus project. Throughout the course, students were assigned specific roles and project objectives in the cases. In the study of Hernández Gándara et al. [36], students were encouraged to form teams freely and design a team game to get hired by the Human Resources Director (played by the teacher). The majority of the game elements found in the second type of GPBL are role-playing, storyline and design tasks. Some research claims that deep gamification leads to enhanced intrinsic motivation rather than extrinsic incentives among students [37].

3.2.3. Type 3: Integrate Prefabricated Serious Games in PBL

Compared to Type 1 and Type 2 gamification, game-based learning aims to use serious games in educational contexts as a part of learning objectives [38]. Several reviewed studies introduced one or more ready-made educational/serious games in PBL. The roles of educational/serious games can be classified into knowledge acquirement, skill practice, problem-solving, creation tools, project management and learning evaluation. With the support of game environments, PBL takes place in a fun and practical system that allows students to immerse themselves in it to a significant degree. Precisely, the implementation of this GPBL consists of three strategies. The first is to utilize video games in the introductory part of PBL to build beforehand knowledge and skills. This strategy can address a significant issue of PBL: students feel bored and impatient to learn basic knowledge and skills independently compared to other team activities. It greatly contributes to the preparation for the follow-up project learning activities. For instance, Fuster-Guillo et al. [39] used Kahoot, a free e-quiz game platform, to help students master theoretical knowledge in a computer engineering course. Students were very interested in surpassing their peers and climbing the leaderboard. Alden et al. [40] allowed students to play an electronic game to acquire programming concepts before undertaking a formal programming activity. Gabriele et al. [41] designed a serious game using the software BrainFarm to teach students the fundamentals of robotics prior to project implementation. In Wang’s [42] comparative
experimental study, students learned about circuits and electricity prior to beginning a science toy-making project. Students were separated into two groups: the experimental group utilized augmented reality (AR)-based video games, while the control group utilized e-books. Utilizing educational/serious games to manage project progress is the second strategy. For instance, according to Punia et al. [43], students can set goals, communicate with others, share pictures and monitor project progress in a social video game. The third strategy is to use educational/serious games as a context for practical project implementation, particularly for problem and task situations. Callaghan [19] and Hewett et al. [44] organized secondary school students to create project artifacts by using Minecraft. Ke et al. [45] introduced the E-Rebuild game in a mathematical course so that students can experience architectural building and gain mathematical practice. Diaz-Lauzurica et al. [46] adopted Blockly, an online game with ten difficulty levels for each type of gaming activity, to teach programming.

3.2.4. Type 4: Make a Game as the Activity of PBL

PBL is characterized by the creation of a product for demonstration and evaluation. Therefore, the fourth type of GPBL is to make a game as the final task and visible goal of PBL. This type typically requires students to achieve project goals and gain knowledge and skills through game-making. Game-making includes digital game-making [47–57] and non-digital game-making [5,55]. Digital game making is most relevant to programming courses. For example, Yoon et al. [58] asked students to develop AI modules based on the game Angry Birds. In addition, technical tools mentioned in the studies include Unity Technologies 2019 [47], Scratch [51,56], Create@School APP and Project Management Dashboard (PMD) [50], and Powerpoint [54].

The majority of non-digital game making is based on real-world games, which integrate subject-specific knowledge with game content. Furthermore, non-digital games need to provide tools and materials as game props. According to Rodríguez-Oroz et al. [59], students in each group are responsible for collecting information about a specific landform. Students must work together to create a board game about knowledge of a country’s landform and play the game together in class. Similarly, the making and playing of board games were also used in a history course [60]. It is noted that this is a special case that in that the course was about game design and development and a PBL activity was used [53]. It is important to look into the goal of the game as an activity to see if it is being used as a means to learn something else. In this way, we can easily understand and judge the fourth type of GPBL.

3.3. Learning Outcomes

In total, 31 studies reported the learning outcomes of their studies (see Table S1), while the remaining four studies focused on explaining the implementation process and techniques of GPBL. The P21 Framework for 21st Century Learning was used as the basis for the coding framework of the reviewed studies’ learning outcomes [61]. In addition to the existing learning outcomes listed in this framework, three additional learning outcomes have been added: subject knowledge and achievement, learning motivation and meta-cognition. Finally, six categories of learning outcomes were presented as shown in Table 2: A-Learning and Innovation Skills; B-Information, Media and Technology Skills; C-Life and Career Skills; D-Subject Knowledge and Achievement; E-Learning Experience and Motivation; and F-Meta-Cognition and Self-Regulated Learning Skills.
<table>
<thead>
<tr>
<th>Category</th>
<th>Core Abilities and Skills</th>
<th>Author (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Learning and Innovation Skills</strong></td>
<td>Critical Thinking and Problem-solving Skills</td>
<td>Callaghan (2016) [19]; Yoon et al. (2015) [58]; Isabelle (2020) [33]; Mantawy et al. (2019) [62]; Hewett et al. (2020) [44]; Díaz-Lauzurica et al. (2019) [46]; Arnb et al. (2019) [55]; Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>Creativity and Innovation Skills</td>
<td>Hewett et al. (2020) [44]; Callaghan (2016) [19]; Gaeta et al. (2019) [50]; Osman et al. (2020) [54]; Rajkovic et al. (2019) [60]</td>
</tr>
<tr>
<td></td>
<td>Cooperation and Communication Skills</td>
<td>Hewett et al. (2020) [44]; Chua et al. (2017) [63]; Shih et al. (2017) [64]</td>
</tr>
<tr>
<td><strong>B: Information Media and Technology Skills</strong></td>
<td>Computer and Programming Skills</td>
<td>Fuster-Guilló et al. (2019) [39]; Díaz-Lauzurica et al. (2019) [46]; Alden et al. (2020) [40]; Punia et al. (2020) [43]; Altanis et al. (2018) [57]; Francese et al. (2015) [65]; Gaeta et al. (2019) [50]</td>
</tr>
<tr>
<td></td>
<td>Media Literacy</td>
<td>Costa et al. (2018) [51]; Osman et al. (2020) [54]</td>
</tr>
<tr>
<td><strong>C: Life and Career Skills</strong></td>
<td>Entrepreneurial Skills</td>
<td>Isabelle (2020) [33]</td>
</tr>
<tr>
<td></td>
<td>Social Skills</td>
<td>Osman et al. (2020) [54]; Ke et al. (2019) [45]; Hewett et al. (2020) [44]; Chua et al. (2017) [63]; Altanis et al. (2018) [57]</td>
</tr>
<tr>
<td></td>
<td>Engineering Expertise</td>
<td>Warin et al. (2015) [34]; Chua et al. (2017) [63]; Mantawy et al. (2019) [62]</td>
</tr>
<tr>
<td><strong>D: Subject Knowledge and Achievement</strong></td>
<td>Knowledge Test</td>
<td>Wang (2020) [42]; Baran et al. (2018) [5]; Ke et al. (2019) [2 items] [45]; Rodríguez-Oroz et al. (2019) [59]; Osman et al. (2020) [54]; de-Juan et al. (2016) [66]; Shih et al. (2017) [64]; Topalli et al. (2018) [56]</td>
</tr>
<tr>
<td></td>
<td>Self-Assessment</td>
<td>Baran et al. (2018) [5]; Yoon et al. (2015) [58]; Isabelle (2020) [33]</td>
</tr>
<tr>
<td></td>
<td>Competition Results</td>
<td>Yoon et al. (2015) [58]</td>
</tr>
<tr>
<td></td>
<td>Focus Group Interviews</td>
<td>Rodríguez-Oroz et al. (2019) [59]</td>
</tr>
<tr>
<td></td>
<td>Project Reports</td>
<td>de-Juan et al. (2016) [66]; Wu et al. (2016) [35]</td>
</tr>
<tr>
<td><strong>E: Learning Experience and Motivation</strong></td>
<td>Satisfaction</td>
<td>Ke et al. (2019) [45]; Gaeta et al. (2019) [50]; Francese et al. (2015) [65]; Gelonch-Bosch et al. (2019) [67]; Isabelle (2020) [33]; Mantawy et al. (2019) [62]; Shih et al. (2017) [64]; Warin et al. (2015) [34]; Altanis et al. (2018) [57]; Hernández Gándara et al. (2020) [36]; Rodríguez-Oroz et al. (2019) [59]; Yoon et al. (2015) [36]; Fuster-Guilló et al. (2019) [39]</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
<td>Gabriele et al. (2017) [41]; Wang (2020) [42]; Díaz-Lauzurica et al. (2019) [46]; Ke et al. (2019) [45]; Arnb et al. (2019) [55]; Chua et al. (2017) [63]; de-Juan et al. (2016) [66]; Altanis et al. (2018) [57]; Fuster-Guilló et al. (2019) [39]</td>
</tr>
<tr>
<td></td>
<td>Participation</td>
<td>Callaghan (2016) [19]; Gelonch-Bosch et al. (2019) [67]; Isabelle (2020) [33]; Wu et al. (2016) [35]; Hernández Gándara et al. (2020) [36]</td>
</tr>
<tr>
<td></td>
<td>Interest</td>
<td>Wang (2020) [42]; Díaz-Lauzurica et al. (2019) [46]; Yoon et al. (2015) [58]</td>
</tr>
<tr>
<td></td>
<td>Playfulness</td>
<td>Gabriele et al. (2017) [41]; Baran et al. (2018) [5]; Alden et al. (2020) [40]; Kapralos et al. (2015) [53]</td>
</tr>
<tr>
<td></td>
<td>Excitement</td>
<td>Callaghan (2016) [19]</td>
</tr>
<tr>
<td></td>
<td>Engagement</td>
<td>Callaghan (2016) [19]</td>
</tr>
</tbody>
</table>
Table 2. Cont.

<table>
<thead>
<tr>
<th>Category</th>
<th>Core Abilities and Skills</th>
<th>Author (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Independence</td>
<td>Ke et al. (2019) [45]; Chua et al. (2017) [63]</td>
</tr>
<tr>
<td></td>
<td>Self-Efficacy</td>
<td>Isabelle (2020) [33]; Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td>Chua et al. (2017) [63]</td>
</tr>
<tr>
<td></td>
<td>Perseverance</td>
<td>Rajkovic et al. (2019) [60]</td>
</tr>
</tbody>
</table>

Figure 4 shows the number of corresponding studies for each type of learning outcome. The number of Category E (26) ranks first among other categories, followed by Category-A (13) and Category-D (12). The other three types have a similar proportion. Learning outcomes in Category-E are suitable for all types of GPBL in Section 3.2. The proportion of Type-4 studies for Category-A and Category-B is more than for other types. This means that making-game as a design-based learning (DBL) can help develop learners’ innovative and creative literacy.

Figure 4 of corresponding studies for each type of learning outcome.

30 studies stated that GPBL leads to positive learning outcomes, while only one study reported that the students feel disappointed with the course activities \[60\]. According to this study, these students disliked competition activities and were unwilling to explore the unknown. There were 38 quantitative variables of results reported in reviewed studies, of which 14 variables were reported with p values. Our study further explored the overall effect size of reviewed study results by using the meta-analysis for 38 continuous variables in Stata 16.0. The results of the heterogeneity tests indicated a high level of data heterogeneity, so a random-effects model was used to calculate the effect size. As different measures were used for the learning outcome in each study, the Cohen method, which belongs to the Standardized Mean Difference (SMD) method, was used to calculate the effect size in this study. The results (see Table 3) show an overall effect size of 0.58 (95% confidence interval: 0.34 to 0.82), implying that GPBL has a significant degree of positive effects on learning. Category-D had the greatest effect size (0.87), followed by Category-F (0.47) and Category-B (0.45).
Table 3. Effectiveness test of GPBL.

<table>
<thead>
<tr>
<th>Cate Gory</th>
<th>Number of Effects</th>
<th>Effect Value Cohen</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Q-Value</th>
<th>df</th>
<th>P</th>
<th>T²</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>0.27</td>
<td>0.12</td>
<td>0.42</td>
<td>10.96</td>
<td>5</td>
<td>0.05</td>
<td>0.00%</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>0.45</td>
<td>0.31</td>
<td>0.59</td>
<td>6.69</td>
<td>6</td>
<td>0.35</td>
<td>11.8%</td>
</tr>
<tr>
<td>D</td>
<td>19</td>
<td>0.87</td>
<td>0.45</td>
<td>1.29</td>
<td>150.03</td>
<td>18</td>
<td>0.00</td>
<td>95.4%</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>-0.08</td>
<td>-0.513</td>
<td>0.36</td>
<td>32.19</td>
<td>4</td>
<td>0.00</td>
<td>92.16%</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>0.47</td>
<td>0.23</td>
<td>0.71</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Over all</td>
<td>38</td>
<td>0.58</td>
<td>0.34</td>
<td>0.82</td>
<td>359.25</td>
<td>37</td>
<td>0.00</td>
<td>94.34%</td>
</tr>
</tbody>
</table>

Note: N/A refers to not applicable.

3.4. Technology Applications

22 of the 35 studies (61%) reported the use of technical tools in GPBL, which can be classified into four types based on their functions (as shown in Table 5). The first type is digital games, such as Angry Birds, Kahoots and Coding-4Girls, which were utilized in the third gamification approach described above. The second type is Course/Project Management Platform (such as Online Venture Challenge, Moodle), which can be used for process management of PBL activities. The third type and fourth type are General Technical Tool (such as PowerPoint, Google Earth, Dropbox) and Professional Technical tool (such as SketchUp, Shopify) respectively, which can be used to support the completion of output. For example, in the studies of Engström et al. [47] and Kapralos et al. [53], students used a game development engine, Unity, to develop their designed games as the artifact of their GPBL. Besides Unity, such development software includes Scratch, Github, mBlock, etc.

Table 4. Category of technical tools.
Table 5. Category of technical tools.

<table>
<thead>
<tr>
<th>Category</th>
<th>Name</th>
<th>Property</th>
<th>Author (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional technical Tool</td>
<td>PlanGrid</td>
<td>construction productivity software</td>
<td>Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>SketchUp</td>
<td>3D modeling computer program</td>
<td>Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>Sefaira</td>
<td>building energy efficiency analysis software</td>
<td>Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>Autodesk</td>
<td>design software</td>
<td>Wu et al. (2016) [35]</td>
</tr>
<tr>
<td></td>
<td>On-Screen Takeoff</td>
<td>construction estimating software</td>
<td>Wu et al. (2016) [35]</td>
</tr>
<tr>
<td>Programming</td>
<td>Scratch</td>
<td>graphic programming software</td>
<td>Costa et al. (2018) [51]; Topalli et al. (2018) [56]</td>
</tr>
<tr>
<td></td>
<td>mBlock</td>
<td>graphic programming software</td>
<td>Shih et al. (2017) [64]</td>
</tr>
<tr>
<td></td>
<td>Github</td>
<td>Internet hosting platform</td>
<td>Francese et al. (2015) [65]</td>
</tr>
<tr>
<td></td>
<td>Crear@School App</td>
<td>graphic programming application</td>
<td>Gaeta et al. (2019) [50]</td>
</tr>
<tr>
<td></td>
<td>Unity</td>
<td>game engine</td>
<td>Engström et al. (2020) [47]; Kapralos et al. (2015) [53]</td>
</tr>
</tbody>
</table>

3.5. Theoretical Contributions

Most of the studies discussed the theoretical basis of GPBL in order to guide the research design and learning practice. Some studies introduced classic learning theories and game making theories. Learning theories include constructivism theory, discovery learning theory, flow theory, cognitive-contextual theory, self-determination theory and other learning science theories. Regarding game-making theories, some studies cited Gamechangers’ five stages of game-design thinking [49,55].

In addition to citing from existing theories, many studies tried to create a theoretical contribution by proposing conceptual and process modes of GPBL. The conceptual modes are mainly used to present the key concepts that involve objects, methods and artifacts in GPBL. Ke et al. [45] proposed a concept of a digital game-based makerspace, which described the interaction between learners and tools, as well as the moderating role of learner autonomy; Isabelle [33] proposed an idea of gamified entrepreneurship education, which linked a global e-commerce platform with a gamification platform that could track students’ entrepreneurial performance. Students were permitted to participate in actual entrepreneurial exercises and gain entrepreneurial experience. Warin et al. [34] implemented the Multi-Role Project (MRP) method in a STEM course. MRP’s theoretical framework is comprised of five principles: distribution of responsibilities, regular team interactions and solicitations, anticipation and continuous improvement, positive interdependence and alternating individual/group work and open communication and content management. Romero et al. [49] proposed a creative game-making pedagogy which consists of five levels: creative learning situations, creative learning activity, learning environment that encourages creativity, learning environment encouraging creative learning activities and creative use of digital technology. The multiple levels should be considered as a whole to promote students’ creativity. Gestwicki et al. [48] proposed a full-immersion academic studio system based on six implementations of design-based research. The system’s seven components—subject, tools, object, outcome, rules, community and division of labor—provided a theoretical foundation for the management of GPBL instruction. Gelonch-Bosch et al. [67] summarized the hands-on learning approach commonly used in engineering courses to form the seven-stage mode: course context, development and testing tools, reference processing chain, competition rules, system enhancement, student evaluation and learning methodology evaluation. Wang [42] divided PBL into three processes (problem-driven, inquiry and creation) and discussed the strategies of adopting a playful approach to knowledge building during the problem-driven process (prior to project inquiry). Hewett et al. [44] created a double loop game-based design model to explain how learners think critically, create, communicate and collaborate in Minecraft. Alden et al. [40] utilized a novel platform in educational robotics (ER) and STEM courses with five phases: problem presentation, brainstorming, thematic challenges (design mini-games), problem-solving and checking other solutions. Osman et al. [54] presented a project-based instructional design framework that uses game
making as a learning outcome, which contains five guiding principles (knowledge construction, collaboration, exploration, learning through design and technological literacy) and five activity phases (inquire, discover, produce, communicate and review). Altanis et al. [57] divided the GPBL teaching process into six stages: introduction, understanding, design, development, testing and assessment and refinement. Taking a programming course for secondary school students as an example, in the first stage, teachers provide students with the information of course outline, objectives, timelines and technical tools. Students then play with cards to understand Natural User Interaction (NUI) and design a preliminary prototype of a Kinect game. In the development stage, students begin to create a game and test it internally and externally, continuing to refine it based on feedback.

4. Discussion

This paper constructs a panorama of current GPBL research (see Figure 5) through a systematic review and analysis of 35 empirical studies. The panorama shows a whole picture of the current state of GPBL research and practice, including its theories, design strategies, research paradigms, technical tools, learning outcomes and disciplines.

![Figure 5. Panorama of current empirical research on GPBL.](image-url)
4.1. Overall Trend of GPBL Research

This paper reviewed the empirical studies of GPBL over the previous several years. Concerning the geographical dimension, reviewed studies came from a wide range of countries, while European countries ranked number one. This result is similar to that of Subhash and Cudney [68], which reported that Spain and Germany can be seen as the countries leading in gamified learning, especially in higher education contexts. This may be related to culture, while few studies discussed the influence of cultural diversity on GPBL. As for sample size, it greatly ranged from a few to several hundred samples, with more than a third of the studies using no more than 20 samples. The limited sample size implies that GPBL has not been considered a kind of standardized instruction. However, existing studies varied widely regarding learning objectives and design strategies, showing that GPBL has great potential to benefit group study. Consistent with Junior et al. [69], most reviewed studies were conducted in higher education. However, it is worth noting that GPBL may be frequently adopted in primary schools of STEM education due to the use of gamified technical tools such as Minecraft, Scratch, etc. Additionally, reviewed studies stated a variety of theoretical frameworks for different kinds of GPBL.

In terms of research paradigms, eight of reviewed studies implemented design-based research. Compared to traditional experimental methods, design-based methods are becoming increasingly prevalent in the fields of educational technology and science learning [70]. In addition, few studies compared the difference between the GPBL and PBL groups to explain what gamified approaches bring for PBL. More than half of the studies used mixed qualitative and quantitative data collection techniques to explain the learning process in depth. Methodological triangulation design seeks to investigate the research topic from diverse perspectives and weigh the benefits and weaknesses of each method [71]. Most of the studies focused on the collection and evaluation of learning process data, such as manuscripts [48], questionnaires [55], activity diary [46], learning report [34] and assessment [36], which reflects the guiding ideology of process evaluation, encouraging students’ self-exploration and active participation and focusing on applying subject knowledge and developing hands-on skills. It is noteworthy that more than a quarter of the studies reported on students’ project artifacts [47,48,62], arguing that project artifacts reflect students’ overall learning effectiveness.

4.2. The Approach of Integrating Game or Gamification into PBL

Regarding the classification of GPBL, there was a lacuna in previous review works [69]. A study proposed a Gamification Taxonomy in educational contexts which divides gamification into five dimensions: performance, ecological, social, personal and fictional [72]. This work makes sense to a large extent, but it needs further analysis for different learning modes. Therefore, the reviewed work proposed a gamified approach paradigm based on gamification degree (see Figure 3) and summarized four types of GPBL. This classification integrates gamification learning and game-based learning into the framework of gamified learning [68]. Generally speaking, gamified learning consists of two forms: gamification of learning and game-based learning [68]. The former means applying game elements/mechanics in a non-game learning situation while the latter refers to using games in educational contexts, such as serious/educational games [26]. Serious/educational games in PBL attempt to incorporate a full game. Correspondingly, this review work adds gamification into PBL and distinguishes two methods of gamification (gamification of content & gamification of structure) according to Kapp [26], which refers to the first and second types in the Section 3.2. These studies apply game elements (e.g., badges, points, leaderboard, levels, rewards, narrative, portfolio, progress bar, adventure map, avatar) to PBL, which inspires teachers to integrate various gamified activities and tools with subject knowledge and skills. Game elements are widely used in different steps of PBL, such as project management [33], hands-on inquiry [35] and project evaluation [33,67]. It is well-accepted that gamified activities can be divided into e-gamified and non-electronic [73]. Traditional non-electronic gamified activities which are more acceptable to teachers and parents require
fewer technologies and equipment and are easier to implement in the primary classroom. E-gamified activities, on the other hand, provide immediate feedback, increase interactivity and save on activity materials and preparation time for instructional activities.

Previous literature reviews mainly focused on studies of integrating serious/educational games into PBL, referring to the third type of GPBL in Section 3.2. It typically fulfills the instructor role to some extent but requires a high cost of technology and device resources. Consistent with the previous conclusion, simulation and virtual reality games seem to be most prevalent in conjunction with PBL [61]. Making a game as a PBL activity in the fourth type of GPBL study guides students to experience design-based learning (DBL), which was proposed by Doreen Nelson [74]. Design-based learning is a cyclical and iterative learning process in which learners transfer knowledge and skills in new situations and develop higher-order thinking and problem-solving skills around a “design” task or goal, resulting in a solution or product that meets the requirements of learning objectives [74]. Daring-Hammond [8] distinguished three inquiry-based learning modes: project-based learning, problem-driven learning and design-based learning. This paper identifies design-based learning as an effective way to support GPBL [50,57,58]. The self-designed artifacts can reveal the knowledge and skills gained by students. It is hard to say which one is more developed or sophisticated among the four types of GPBL. The choosing of GPBL approaches is a systematic instructional design considering various variables, such as discipline, objectives, learners and existing devices and resources.

4.3. Evaluation of Learning Outcomes

The reviewed results show that applying games, game elements, or game mechanisms in project-based learning can effectively enhance PBL experience and learning outcomes. The potential of GPBL is to combine the advantages of both gamified learning and PBL.

The affordance of GPBL permits: a learner-centered environment, collaboration, curricular content, authentic task, multiple expression modes, emphasis on time management and innovative assessment [75], resulting in achieving personal learning goals [19]. The great majority of studies focused not only on the acquisition of knowledge and competencies by GPBL, but also on students’ experiences of the learning process, such as motivation [41,42,46], satisfaction [45,50,65], as well as engagement [19,33]. These experiences have been proved to be effective in promoting academic achievement. Previous literature review work (e.g., Junior [69], Subhash and Cudney [68]) mainly reported the results of GPBL in cognitive, emotional and social areas. Based on bibliographic coding and content analysis, this study finds that several studies reported the effects of gamification in improving students self-regulated learning abilities. Therefore, we added a new theme of “meta-cognition and self-regulated learning skills” in learning outcomes, which is an important and sustainable ability in the lifelong learning time. Among the six categories of learning outcomes, Category E-“learning experience and motivation” is the most frequently reported, which reflects the outstanding advantages of GPBL in stimulating learning motivation and optimizing the learning experience. Category A-“Learning and Innovation Skills” is ranked second, indicating that the researcher was also concerned with developing higher-order thinking in students. Category D-“Subject knowledge and achievement” is ranked third, reflecting the core requirement of innovative pedagogy to align with curriculum objectives. However, little is known regarding the moderating effect of sample size on research results. Simultaneously, many studies seldom describe the research’s effectiveness and lack explanations of the learning mechanisms involved [63,65]. Moreover, the results of some studies on learning experiences have been investigated using only questionnaires [39,41,50,59,63] which lack reliability and validity tests, while such results often need to be investigated through qualitative research methods such as personal interviews for validation.
4.4. Technical Support

In most reviewed studies, technical tools are utilized in different stages of GPBL activities. During the implementation of GPBL, information technology empowers learning through enriching learning tools and innovating learning culture. On the one hand, various IT tools and resources are used to support the GPBL instructions, such as game making software \[47,51\], virtual game scenarios and interactions \[19,44\]. On the other hand, technology-enabled GPBL embodies a new learning culture that emphasizes a degree of playfulness and interaction in PBL. Technology provides students with a variety of ways to gather information as well as express their ideas, and enables them to learn, collaborate, solve the problems they are tackling \[63,76–80\], to effectively improve learning outcomes \[81,82\] and finally to achieve meaningful learning \[83\]. Considering the importance of technology, some technological matters such as technical tools outdated and aging hardware devices \[35\], software functional limitations \[42,50,58\], network crashes or slowness and the inability of supporting multiple devices simultaneously \[50\] mentioned in reviewed studies cannot be neglected. Besides, there is a need to investigate the effective practices in implementing online GPBL to avoid the impact of unforeseen events such as the COVID-19 epidemic \[58\]. Besides, in Junior’s review work \[69\], it states that simulation and virtual world games appear to be most used in conjunction with PBL in STEM-related higher education, but the biggest challenge is the high cost of such emerging resources and environments.

4.5. Theoretical Implications

The theoretical contributions of the reviewed studies focus on the two concerns of GPBL: learning and gaming. On the one hand, classical learning theories including constructivism theory, discovery learning theory, flow theory and cognitive-contextual theory, were introduced to guide the instructional design of GPBL. Some studies also cited widely-used game-design theories, e.g., Gamechangers’ five stages \[49,55\]. On the other hand, several new theoretical principles of GPBL were proposed. First, some new concepts were proposed and defined, such as digital game-based makerspace \[45\] and gamified entrepreneurship education \[33\]. Second, innovative methods, strategies and pedagogies of GPBL were summarized, such as Multi-Role Project (MRP) method \[34\] and game-making pedagogy \[49\]. Third, a few process-based GPBL modes have emerged, such as Gelonch-Bosch et al. \[67\], Wang \[42\], Hewett et al. \[44\], Osman et al. \[54\] and Altanis et al. \[57\]. These modes outline the features, elements or phases of unique GPBL in different learning contexts. The extraction of process-based GPBL modes makes this innovative pedagogy more practical and operable, so that the followers of GPBL easily understand how to imitate and implement it. However, most summarized modes derive from certain content or contexts, leading to the doubts about generalization ability. Few studies discussed the unique learning mechanism of GPBL when compared to gamified learning or PBL from a theoretical perspective.

5. Limitations and Conclusions

While this review work presents the current research into GPBL, several limitations should be recognized First, although we implemented a systematic search for the topic, we excluded several low-quality articles and only retained SSCI-index papers. As a result, it may overlook a number of exceptional papers. Second, this review work did not distinguish primary education and higher education when analyzing reviewed content regarding gamified approaches and learning outcomes.

This systematic review helps instructional designers and researchers understand the process and effects of GPBL. Several significant findings were underlined to guide the development of GPBL. First, it appears that GPBL can be subdivided into four distinct types, reflecting the diverse characteristics of GPBL. Second, some GPBL studies emphasized design-based learning as an innovative and creative learning method. Thirdly, the majority of reviewed studies focused on the collection of data regarding the learning process and the
description of learning outcomes, with project artifacts serving as a significant data source. Fourth, it is crucial to address certain technical issues that may hinder the effectiveness of learning activities.

Based on the current research state of GPBL, we offer several recommendations for future development of GPBL. First, it is significant to construct a systematic framework of GPBL to guide design and implementation. The key to the effectiveness of games or gamification in learning is not a “yes/no” question, but a comprehensive result of complex interaction among various variables. Second, teachers’ competency for GPBL should improve for implementation of this innovative and quality pedagogy. Gamified instruction helps transform teachers’ role and improve teacher-student relationship. Third, it is important to strengthen the theoretical underpinnings through interactive design, in particular, to explain the learning mechanism (e.g., how GPBL works, how gamified learning functions in PBL). The practical and research fields (such as disciplines, learners and learning objectives) can be further expanded under the guideline of learning science theories. Finally, the evaluation of GPBL should be re-designed beyond traditional educational tests. A scientific evaluation system of GPBL based on curriculum objectives can be established with rigorous assessment instruments. It would be convincing if the effects of GPBL on high-order thinking and competency can be demonstrated.

**Supplementary Materials:** The following supporting information can be downloaded at: [https://www.mdpi.com/article/10.3390/su15020940/s1](https://www.mdpi.com/article/10.3390/su15020940/s1). Table S1. Summaries of the 35 selected studies.

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