Designing Engaging Games for Education: A Systematic Literature Review on Game Motivators and Design Principles

Teemu H. Laine and Renny S. N. Lindberg

***Abstract*—Effective educational interventions require sufficient learner engagement, which can be difficult to achieve if the learner is inadequately motivated. Games have been shown to possess powerful motivators that fuel a person's desire to engage in unattractive activities, such as learning theoretical material. However, to design an educational game that is capable of providing motivated engagement is a challenging task. Previous research has proposed various game motivators and game design principles to alleviate this, but a comprehensive synthesis has yet to appear. In this article, we conducted a systematic literature review that yielded two major contributions: 1) a taxonomy of 56 game motivators in 14 classes; and 2) a taxonomy of 54 educational game design principles in 13 classes, with linkages to the identified game motivators. As a minor contribution, we have also presented a classification of gamification-related terms and proposed different strategies for applying gamification. The results of this article are available for educational game designers and researchers to use as a practical toolkit for the creation and evaluation of motivating educational games that keep players engaged. Moreover, this article is the first step toward the creation of a unified gamification framework.**

***Index Terms*—Design principles (DPs), educational games, game design, gamification, motivation, serious games, taxonomy.**

I. Introduction

EDUCATION is facing such tremendous global challenges that the United Nations has included quality education in the Sustainable Development Goals [1] in the hope that researchers, businesses, and other organizations would help increase accessibility to quality education through development of new educational technologies, methods, and tools. Yet even educational technologies that are referred to as "smart," such as artificial intelligence powered adaptive tools for learning new skills or knowledge [2], can lose their effectiveness and purpose if they fail to motivate learners to engage in long-term usage. Moreover, encouraging people to change their habits or lifestyles, for example by educating people about climate change with the help of games [3], can be particularly challenging to achieve. A key factor in achieving such fundamental changes in one's life is motivated engagement.

In the context of this article, *engagement* is defined as the level of involvement that the learner exhibits toward the learning process, whereas *motivation* is defined as the reason for the learner to become and remain engaged in a learning activity. We make a distinction between *extrinsically motivated engagement* and *intrinsically motivated engagement*, as they can yield different results in successfully reaching the target goal, especially when the goal requires long-term commitment and perseverance. Extrinsically motivated engagement is linked to extrinsic motivation [4], which is experienced through rewards from external sources (e.g., money, grades, praise, and avoidance of punishment). This type of engagement is fairly easy to establish, but challenging to maintain over a long period of time. In contrast, intrinsically motivated engagement stems from intrinsic motivators [4]–[6], such as challenge, curiosity, and cooperation, that contribute to the person's genuine enjoyment and satisfaction when performing the activity. Consequently, intrinsically motivated engagement is likely to last longer and even help the person reach the flow state [7] in which they are completely immersed in the activity. A challenge is to find a way raise and maintain motivation—whether extrinsic or intrinsic—in people toward activities that they are not necessarily passionate about, such as learning a difficult theory or cycling to school in winter conditions.

Good examples of motivated engagement can be found in the realm of video games. A significant body of research [5], [6], [8]–[12] has shown that video games can possess motivators that keep the players engaged over long periods of time. Inspired by the motivational pull of video games, researchers have attempted to adapt game elements to educational interventions [13]–[17]. This process of applying game design elements to nongame contexts is referred to as *gamification* [18]. Yet anyone who has played games—for entertainment, education, well-being, or work—knows that there is a difference between a good and a bad game, with the latter tending to lack the motivational power of the former. Moreover, research has shown that gamifying educational interventions guarantees neither intrinsic motivation nor positive learning outcomes [19]. Designing motivating games is an art form on which many good books have been published by professional

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game designers (e.g., [20]–[23]). These books provide useful advice for developing video games primarily for entertainment; they lack the perspective of gamification for education, which possesses unique challenges and restrictions, such as integration of learning content and theories. Moreover, these books are largely based on the practical game design experiences of their authors and disregard the existing rich body of research into educational games.

Researchers have proposed design frameworks and design principles (DPs) to facilitate educational game development (e.g., [24]–[26]), but there is a gap in research regarding systematic collection and synthesis of DPs and underlying motivators for educational games. A few surveys have been conducted on gamification design frameworks [27]–[29]; although these studies can be of value for readers interested in gamification, their depths are limited, they do not consider the specific challenges that educational games entail and/or they do not cover DPs and motivators. Therefore, in this article, we set out to conduct a systematic literature review on game DPs and game motivators with a specific focus on games for education. By conducting this review, we seek to answer the research questions: First, what are the motivators that contribute to engaging educational games? and second, what are the game DPs that contribute to engaging educational games? To answer these research questions, we applied the systematic literature review method [30]. We synthesized the information in the reviewed studies into 56 motivators in 14 classes and 54 DPs in 13 classes. As a minor contribution, we proposed a classification of terms related to gamification and different strategies in which gamification can be applied. The results of this article provide a solid reference for researchers and developers who seek to create engaging educational games.

The rest of the article is organized as follows. In Section II, we analyze various terms that have been used in the context of gamification and propose a classification of these terms, followed by an account of previous reviews on gamification and game design. Next, in Section III, we provide a detailed explanation of the systematic literature review methodology that we employed. The results are then described in Sections IV and V: the first proposes a taxonomy of game motivators; and the second presents a taxonomy of educational game DPs. Finally, we provide our interpretations of the findings in Section VI and wrap up the study in Section VII.

II. Background

A. On Defining Gamification

The popular definition of gamification—"the use of game design elements in nongame contexts"—was published by Deterding *et al.* [18], who also provided an account of the history and meaning of gamification as a phenomenon. Following this definition, entertainment and sports are examples of game contexts, whereas education, health care, and marketing exemplify nongame contexts. We extend this definition by proposing that game design elements can be applied through different strategies in the gamification process. At one extreme, game elements, such as points and badges, are simply glued on top of an existing activity (e.g., a teacher assigns points to students for completing homework). At the other extreme, a game is designed with a sole focus on the game itself and is then applied to a nongame context (e.g., Minecraft [31] in classrooms). Other strategies fall between these extremes, such as designing a game for learning programming concepts (e.g., LightBot [32]). It is noteworthy that gamification does not imply the presence of a digital game, although that often is the case. Moreover, gamification of education automatically guarantees neither motivation nor positive learning outcomes [19].

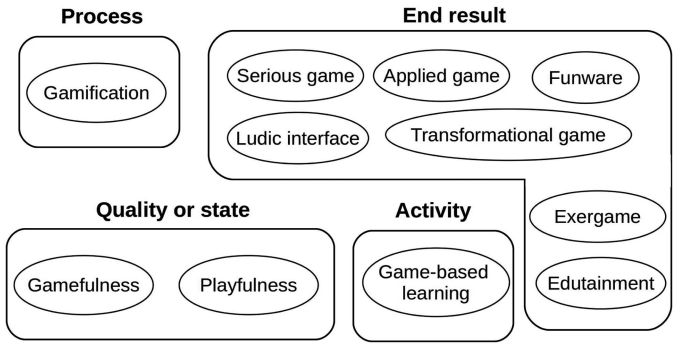

Fig. 1. Classification of terms related to gamification.

The concept of gamification has been used across a wide range of fields, the most prominent application areas being education and training [13]–[17], business [33]–[36], and well-being [37]–[40]. Given the popularity of the concept, it is not surprising that several other terms have emerged that can be thought to complement gamification, such as serious game [41], applied game [42], educational game [43], transformational game [44], exergame [45], funware [46], edutainment [47], gamefulness [48], playfulness [49], game-based learning [50], and ludic interface [51]. The main difference between these terms and gamification is that the latter describes a (design) process, whereas the former describe an end result (serious game, applied game, educational game, transformational game, exergame, funware, edutainment, ludic interface), a quality or state (gamefulness, playfulness), or an activity (game-based learning). This nonexhaustive classification is illustrated in Fig. 1, which will be useful when working in the area of gamification.

B. Previous Reviews on Gamification Design

Gamification design has attracted much attention from researchers since the term was established. A body of literature has been dedicated to analyzing and mapping research efforts in the gamification of education [37], [52]–[57]. Similarly, many design frameworks and approaches have been proposed for making the application of gamification efficient and effective. We discovered and analyzed three previous literature reviews on gamification frameworks and design with the goal of identifying a gap in research to be filled by this article.

Mora *et al.* [28] reviewed 40 studies that proposed a gamification design framework (until 2016) with the purpose of applying gamification in higher education. The covered frameworks were divided into categories of learning, business,

health, and generic, according to their respective areas. For each reviewed framework, the authors presented a citation, background (area), target audience, a definition of gamification, and a short description of the framework. They also compared 27 of the 40 frameworks through 24 of the aspects possessed by many of the frameworks, divided into six categories. Although this literature review provides a good overview of different gamification design frameworks, it does not contain in-depth information on game motivators or principles related to the design of educational games.

In another literature review, Ávila-Pesántez *et al.* [27] analyzed serious game design approaches (one model, three frameworks, seven methodologies) proposed by 11 studies in the context of higher education made between 2008 and 2016. The design approaches covered were described briefly and then compared in terms of stages. The most significant outcome of this study is the categorization of 31 different game design stages, grouped into four phases (analysis, design, development, and evaluation), with the features/issues/aspects identified for each phase. Some of the aspects of the design phase have relevance to the DPs presented in this article, but they are not explained in detail. Moreover, game motivators are not covered by Ávila-Pesántez *et al.*

Many gamification approaches target younger audiences, such as school children or higher education students. However, aging populations in developed countries [58] have prompted researchers to investigate designing games for older adults. A study by de Vette *et al.* [29] reviewed six theoretical frameworks for gamification in business and academia as well as four studies that discuss methods for developing gamification solutions for older adults. Furthermore, the authors investigated how user/player classification taxonomies could be used to tailor games for older adults. This article is of value when designing games for older adults, but it does not provide answers to our research questions. The coverage of the study is also rather narrow, although the authors do describe the reviewed studies in a greater depth than that offered by the other reviews presented earlier.

In summary, although previous studies have addressed important issues regarding gamification design, there remains a gap in research regarding game DPs and motivators that contribute to user engagement, especially in the context of education. Next, we present the systematic literature review methodology that was applied to fill this gap.

III. Methodology

We adapted the methodology proposed by Kitchenham and Charters [30] who described detailed guidelines for planning, conducting, and reporting systematic literature reviews in software engineering. Fig. 2 illustrates our adaptation of this method; the first two stages are described in the following sections and the last stage is represented by this article.

A. Planning

1) Identification of the Need for a Review: This study belongs to the multidisciplinary project "Sustainable Innovations for Children Transporting Actively (SICTA)." One of the project's aims is to develop new knowledge for designing motivating and engaging games to support children's behavior change regarding daily active school transport while providing them with curriculum-based learning tasks. As shown in Section II-B, we searched for studies that would synthesize previous research on game motivators and gamification DPs. Although some previous literature reviews on design frameworks and principles were discovered, they did not thoroughly cover the aspects related to educational game design and, thus, indicated a need for this review.

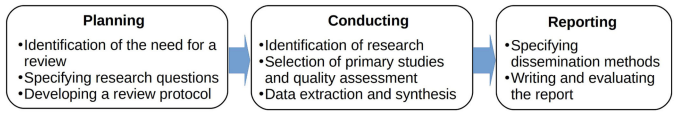

Fig. 2. Systematic literature review methodology used in this article (adapted from [30]).

2) Specifying the Research Questions: We defined the following research questions to guide this literature review.

1) What are the motivators that contribute to engaging educational games?
2) What are the game DPs that contribute to engaging educational games?

3) Developing a Review Protocol: Our review protocol for systematic data collection and analysis (see Table I) specifies the target databases for searching, the strategy used for searching and the inclusion criteria as well as the data extraction and synthesis strategies. The complete list of used keyword combinations is omitted to keep the length of the table manageable. The details of implementing the protocol are explained in the next section.

B. Conducting

After the planning was finished, we followed Kitchenham and Charters' [30] systematic literature review guidelines to conduct our literature review over several steps, which are described in the following sections. Two researchers first conducted the steps independently and their results were compared and negotiated at the end to form the final set of results.

1) Identification of Research: In this step, we searched online academic research databases for studies to be reviewed (see Table I). The literature searches were conducted during March 2019 at the Luleå University of Technology and from December 2019 to January 2020 at the Vrije Universiteit Brussel. Both institutions have subscriptions to all major scientific publishers. The search begun with a predefined list of keywords, with additional keywords added to the list during the search. For each keyword combination, we downloaded the first 50 results, excluding duplicates and clearly irrelevant studies. Content-based filtering was not applied at this step. Some studies were behind pay walls; we attempted to find alternative sources for these studies, for example by asking their authors through ResearchGate and e-mail. The rate of duplicates increased toward the end of the search; for example, studies discovered from Google Scholar often reappeared when searched from the ACM Digital Library, IEEE Xplore,

TABLE I
REVIEW PROTOCOL

Component	Description
Search databases	Google Scholar, ACM Digital Library, IEEE Xplore, ScienceDirect, Springer
Search strategy	Use different combinations (Boolean ANDs and ORs) of keywords on title, abstract, keywords, and body text: gamification, serious game, game-based learning, educational game, learning game, behavior change, design model, design framework, design principles, design guidelines, motivator, motivation, survey, review; time period 2000-2019; download the first 50 search results for each keyword combination; ignore duplicates when found.
Inclusion criteria	The following inclusion criteria were devised: (i) the study must be written in English; (ii) the study must be presented in a peer-reviewed journal, conference proceedings, doctoral thesis; (iii) the study must present game motivators or principles/guidelines for designing or creating games (literature review studies were also accepted for the purpose of verifying the research gap); (iv) the application area of gamification must be education or generic. For example, gamification in the context of business was excluded; (v) the guidelines/principles and motivators must be validated by implementing a game, evaluating existing games, or grounding in a theory.
Data analysis	We devised an iterative workflow for data analysis, comprising study selection and quality assessment as well as data extraction and synthesis. The workflow is described in detail in the next section.

and Springer. As a result, we acquired 684 studies, excluding identified duplicates and clearly irrelevant studies, to be processed in the next step.

2) Selection of Primary Studies and Quality Assessment: We narrowed the set of studies to be analyzed by selecting only studies relevant to game motivators or game DPs. To evaluate the quality of the downloaded studies and their relevance to our research questions, we applied a criteria-driven iterative workflow as follows.

1) Read through titles and abstracts of the downloaded studies and apply the inclusion criteria (see Table I). Exclude studies that do not meet the inclusion criteria.
2) Skim through the contents of the studies that passed the first round and apply the inclusion criteria again. Follow relevant references.
3) Read through the studies that survived the second round and perform final filtering based on the inclusion criteria.

During this process, more duplicates were removed when they were identified. As a result of this step, 11 studies on game motivators and 41 studies on game DPs were selected to be analyzed in the next step.

3) Data Extraction and Synthesis: The purpose of this step was to systematically analyze the selected studies to extract and synthesize data that would allow us to answer the research questions. First, we devised data extraction categories covering various aspects of the selected studies, including authors, publication year, title of the study, publication forum, field (education, generic), DPs or game motivators proposed, and comments. After the categories were created, two researchers independently analyzed the studies and filled in their respective spreadsheets.

The raw data on game motivators and game DPs had to be synthesized to answer the research questions. The goal of the synthesis step was to create taxonomies that combined and organized previous research findings; thereby, providing comprehensive overviews on game motivators and DPs. For game motivators, data synthesis was conducted by analyzing the descriptions of each motivator in the source studies before identifying classes to be used for grouping the motivators (e.g., the "social interaction" class covers motivators related to relationships and social interaction). For DPs, we performed data synthesis in an iterative manner by analyzing each study as follows.

1) Define a descriptive label for a discovered DP.
2) If a similar label exists for another DP, consider merging the DPs under the same label.
3) After all DPs are labeled, identify classes under which the labels can be grouped (e.g., "challenge" and "creativity").
4) Revise the labels and classes, merging further if appropriate.

Finally, we used our interpretations of the results to establish links between the motivators and the DPs, providing a rationale to explain the links.

The analysis results of two researchers were compared and negotiated to form two final taxonomies, which are presented in the following section. The interrater reliability (IRR) percentages for the motivators and motivator classes were 81% and 61%, respectively. The lower IRR percentage for the motivator classes is more due to combined classes than to different classes. The IRR percentages for DPs and their classes were 74% and 77%, respectively. The comparison of DPs was based on their conceptual similarities rather than on their verbatim descriptions.

IV. MOTIVATION IN GAMES

The motivational pull of digital games has intrigued researchers since the video gaming market started proliferating after the advent of affordable home computers in the early 1980s. In our literature review, we identified a body of published research at the intersection of motivation and games. As early as 1981, Malone investigated in his seminal paper how the captivating effects of computer games could be harnessed to make learning interesting and fun [6]. He discovered three intrinsic motivators that captivating games possess: 1) *challenge*; 2) *fantasy*; and 3) *curiosity* (sensory and cognitive). A few years later, Malone and Lepper [5] amended the taxonomy of intrinsic motivators for learning with *control*, *cooperation*, *competition*, and *recognition*, thus considering games as inherently social interaction devices. Even though the games that Malone and Lepper analyzed are vastly different from the games of the 21st century, the motivators that they discovered are still valid and have been verified, albeit sometimes with different terms, in other studies [8]–[12], [55], [59]–[61]. These studies proposed a number of additional motivators that complement Malone and Lepper's

taxonomy. Table II presents our taxonomy of the 56 identified motivators that can contribute to motivated engagement in educational games. The motivators are divided into 14 classes (C) based on their similarities; each class is described briefly.

Many of the motivators in Table II were originally defined as intrinsic; if a game successfully employs (some of) them, therefore, players may find the gameplay internally rewarding and thereby stay engaged. This is particularly useful in educational games that require learner engagement beyond classroom hours. However, game mechanics that are meant to support these motivators (e.g., points and badges for *achievement*) can produce different motivational results that depend on the context of use (e.g., extrinsic motivation toward a game played in a classroom versus intrinsic motivation toward a game played at home). Consequently, the motivators listed in Table II can support either extrinsic or intrinsic engagement.

Educational game designers can use these motivators as a starting point for conceptualizing new game-based interventions, as well as for evaluating existing games. However, creating a game by throwing together, for example, cooperative challenges, points, feedback, and some rules still does not guarantee motivated learner engagement. Designing an educational game that fulfills the potential of intrinsic motivation is a highly demanding task that can be facilitated by educational game DPs that are grounded in experience and research.

V. Educational Game DPs

Many of the identified motivators are abstract and may therefore be difficult to apply in practice. To alleviate this, previous research has produced DPs, many of which can be connected to the aforementioned motivators. We discovered and analyzed 41 studies on principles and guidelines for designing games. We synthesized the analyzed data and proposed 54 DPs in 13 classes (see Fig. 3). The resulting taxonomy is presented in detail in the following sections. In addition to describing the identified DPs with supporting research, we indicate—based on our interpretation of the results—the game motivators presented in Table II to which they link. These connected motivators are written in *italics* next to the design pattern class names in Fig. 3, followed by detailed explanations in their respective sections. Principles related to design process, user experience, and user interface are omitted, as we plan to cover them in subsequent studies. Finally, it is noteworthy that these DPs are not rules; they are meant to be helpful suggestions that designers can follow as deemed appropriate for the educational game design problem at hand.

A. Challenge

This class consists of principles for designing game challenges that aim to engage diverse players. All these DPs are connected to the namesake motivator, the *goals* motivator (as solving challenges leads to goals), and the *feedback* motivator (as the player receives feedback upon attempting to solve challenges); other connections also exist, however, as explained below.

DP 1: Provide challenges at various adjustable difficulty levels [12], [24], [26], [43], [55], [66]–[83]—In order to cater for various skill levels of diverse players, games should contain challenges at multiple difficulty levels, starting from tutorials and beginner-level challenges. Games should challenge the player to the extent of their abilities while avoiding challenges that are too easy or too difficult [43]. The adaptation of challenge difficulty level can be manual (e.g., the player selects the desired difficulty level), preprogrammed (e.g., the game gradually increases difficulty as the player advances), or dynamic (e.g., analyze the player's actions to determine the appropriate difficulty level). In addition to the *challenge* motivator, this DP relates to *control* if the player can directly or indirectly control the difficulty level.

DP 2: Favor simple challenges over complex challenges [24], [67]—If a game challenge is overly complex, it may discourage the player, thus resulting in decreased engagement. This DP therefore suggests breaking complex challenges into smaller tasks; this is particularly important for young [24] and older [67] players.

DP 3: Provide enough time to solve challenges [70], [81], [84]—Adequate time should be allocated for solving game challenges. This DP is of emphasized importance with very young and older adult players, as well as players with impaired sensory or cognitive capabilities who have special usability requirements for gameplay. Moreover, providing sufficient time is helpful for reflection in a learning environment [85]. However, in certain learning scenarios (e.g., a laboratory class with limited time) a fast-paced gameplay might be justified [81].

DP 4: Raise curiosity by interesting and unpredictable challenges [72], [86], [87]—A game that repeats similar challenges may eventually start to feel boring. This DP alleviates this issue by suggesting the addition of variation and surprise in game challenges, thereby nurturing the *curiosity* motivator. As interest is a subjective quality, a game designer should acquire an understanding of the interests of their target players.

DP 5: Allow challenges to be repeated [24], [81]—Challenges containing learning content should be repeatable, thus allowing the learner to try out different strategies [81] and reach the learning goals [24]. Similarly, if the game aims to develop a skill or change a behavior, repeatable challenges can be beneficial. This principle relates to the *control* motivator if the player can choose the number of repetitions.

B. Control

This class covers DPs related to control in gameplay. The term "control" is analyzed from two perspectives: the player's granted ability to make choices in gameplay; and the input mechanisms through which the player interacts with the game. All the DPs presented below connect to the *control* motivator, as they aim to enhance the player's perception of control in the game, and to the *feedback* motivator, as the player's actions to control the game should result in appropriate feedback (see Section V-F). Moreover, the DPs on control mechanisms relate to *sensory curiosity*, as the player may use various sensory modalities to control the gameplay.

DP 6: Use input modalities that are suitable for target players and contexts [66], [68], [69], [88], [89]—The player's control over a game should be enabled through input modalities that satisfy the usability and safety requirements of the target

TABLE II
TAXONOMY OF MOTIVATORS ASSOCIATED WITH EDUCATIONAL GAMES

C	Motivators	Description
Challenge	Challenge [5], [10]–[12], [59], [61], Feedback [12], [55], [59], [61], Goal Orientation [55], Goals [11]	*Challenge* is a motivator that emerges when the player is presented with a task that is suitable to the player's skill level. This motivator, one of the key components of the flow state [7], can be found in most games, including board games, digital games, and sports. Furthermore, challenge is tightly connected to *goals* and *feedback* on the player's performance on solving challenges, which may contribute to increased self-esteem [5]. Challenges are typically created by the game designer but can also be made up by the player (for example, when the player wants to finish the game with unconventional controllers or create handicaps to the gameplay not originally intended by the designers). What is perceived as challenging varies drastically from player to player, but as long as the challenge feels fair to the player it can be a powerful motivator.
Competence	Achievement [55], [59], Advancement [9], [59], Challenge [5], [10]–[12], [59], [61], Competence [8], [59], Competition [5], [9], [55], Goals [11], Knowledge Improvement [61], Performance [60], Player Skills [12], Status [60]	*Competence* is one of the basic psychological needs defined by the Self-Determination Theory [62]; it relates to acquiring new skills or abilities by conquering *challenges* and reaching *goals* [8]. In games, *competence* is often perceived through winning a *competition*, collecting *achievements*, *advancing* to higher levels, or developing the player's own (or their avatar's) *skills* or *knowledge*. These, in turn, can be reflected to the player's *status* within or outside the game world. *Challenge* is a driving force behind developing competence when the challenge is suited to the player's skill level.
Competition	Competition [5], [9]	*Competition* is a motivator that arises when the player has to compete with other players to reach a goal. Competition can be interpersonal (i.e., competing against other players), intrapersonal (i.e., competing against oneself) or collaborative (e.g., team battles). Multiplayer games often use competition as a driving force, which is concertized by leaderboards and achievement systems. Moreover, competition in these games can be combined with *cooperation* (e.g., team-based competitions).
Control	Agency [60], Autonomy [8], Control [5], [11], [12], [59], [61], Customization [9], Intuitive Controls [8]	The *control* motivator emerges when the player is provided with the freedom to influence the game world and its events. It is one of the key components of the flow state [7]. There are numerous ways in which control can manifest, from control enabled within the bounds of the game world's rules (e.g., dialogue options, game control options, methods to solve a problem, changing the landscape, choosing a story path to follow) to modifying the look and feel of the game through *customization*. Moreover, some games have prolonged their lifetimes by being modifiable by the player community. The Elder Scrolls V: Skyrim and Minecraft, for instance, are well known for this.
Curiosity	Cognitive Curiosity [5], [6], Cognitive Restlessness [10], Discovery [9], [59], Mystery [11], Navigation [59], Sensory Curiosity [6], Sensory Stimuli [11], Surprise [59]	*Curiosity* can be ignited by various factors, such as the desire to *navigate* every nook and cranny of an area and *discover* more about the game world, the interest in figuring out how the artificial intelligence of the game works, or the sensations triggered by audio-visual or tactile interfaces. Consequently, curiosity can be divided into *cognitive curiosity* and *sensory curiosity* [6]. The former is the desire for knowledge and the interest that is raised by the process of acquiring that knowledge. According to Malone and Lepper [5], cognitive curiosity can be stimulated by game activities that exhibit incomplete or inconsistent information, for example, thus increasing the player's thirst for knowledge. Sensory curiosity or stimuli refers to the interest that is triggered by sensations (e.g., light, sound, touch). This motivator is present in modern multimodal game systems that use gesture-based interaction and rich multimedia facilities (e.g., a virtual reality environment with hand- and eye-gesture controllers).
Emotions	Moral Sense/Altruism [59], Tension [59], Thrill [59]	Some motivators can evoke a range of *emotions* that can make the experience more memorable. Examples of these are *tension* and *thrill*, which are based on the player's anticipation of future game events. Tension appears when the player anticipates a dramatic event in a game, such as a large battle that is about to break out or a significant resource that is at risk of being lost. Thrill is similar, but it emerges just when the dramatic event happens (e.g., the thrill of a big battle). Tension and *curiosity* are related, as both involve the anticipation of future game events. There are also games that aim to appeal to the player's inherent *moral* qualities. These include games that want the player to feel good about helping others (*altruism*) and games that plunge players into morally ambiguous situations where there are no right answers, thus evoking a mixed set of emotions from the choices given.
Fantasy	Appearance [59], Believability [60], Cognitive, Curiosity [5], [6], Discovery [9], [59], Fantasy [5], [10], [11], [59], Mystery [11], Narrative [55], Nostalgia [59], Role-Playing [9]	*Fantasy* refers to the mental images of physical or social situations that are not present in the real world [5]. Methods for providing fantasy are numerous, varying from classic *role-playing* game experiences with rich *narratives* and diverging storylines to more visual experiences where the *appearance* of the game is used to fire the player's imagination. Fantasy invokes *curiosity*, thus feeding the player's desire to *discover* what comes next. There is no limit to the types of fantasies and the ways in which they are represented in games; the player can even be empowered to influence the game's fantasy.

(Continued)

C	Motivators	Description
Feedback	Feedback [12], [55], [59], [61]	Together with *challenge* and *control*, *feedback* is a key component of the flow state [7]. Everything that the player does in a game results in some sort of feedback, such as instant feedback to game controls, responses from dialogues with non-player characters, and game activities recorded in a game log. Feedback is particularly motivating when it is provided on performed *challenges* in a timely and clear manner, thus contributing to the sense of *control* [12]. Therefore, this motivator is often coupled with clear *goals*; that is, feedback provided by the game should indicate to the player the distance to the goal and when the goal is reached.
Immersion	Concentration [12], [61], Escapism [9], [60], Fun [55], [59], Immersion [9], [12], [55], [59], [61], Involvement [60], Pastime [60], Presence [8], Relaxation [59], Sensory Curiosity [6]	*Immersion* is the state in which the player is concentrated in gameplay to such an extent that they may lose self-awareness and the perception of time [63]. These characteristics make immersion similar to the flow state [7], which is why the two concepts are sometimes used interchangeably, even though certain differences exist [63]. Immersion is also known in the gaming circles as the "one more turn" phenomenon. Moreover, a player who knows that they like the game might be inclined to pass time or escape real-world situations by knowingly immersing themselves in it. The difference between *escapism* and *pastime* is that the former refers to exiting the real world in order to relax or get a break from real-world problems [9], whereas the latter focuses on killing time as a pastime activity [60]. Additionally, virtual reality game environments in particular can trigger *sensory curiosity*, thus contributing to immersion and the feeling of *presence* in the virtual world [64].
Novelty	Appearance [59], Novelty [59], Technology [10], [59]	The *novelty* of a game or a technology used in the game can be a motivator, especially when playing the game for the first time. For example, the novel gameplay enabled by the combination of augmented reality, location-awareness, and popular culture characters was among the factors contributing to the success of Pokémon GO [65]. This motivator tends to be short-lived because the initially perceived novelty will eventually wear off; additional motivators are therefore required to maintain player engagement. However, as the example of Pokémon GO demonstrates, novelty can be maintained by regularly updating the game with new content.
Rules and Goals	Clear Goals [11], [12], [59], [61] Goal Orientation [55], Mechanics [9], Rules/Goals [11], [55]	All games have *rules* that govern the activities and events that take place in the game world. Rules set the boundaries for the game, including what the *goals* of the game are and how to reach them. For rules to be motivating, they must be: (i) clear, so that the player knows how the game world can be manipulated; (ii) flexible, so that the gameplay does not become overly limiting; and (iii) synchronized with goals and feedback so that they support each other [11]. Some players may be motivated just by the opportunity of studying the underlying game rules and mechanics [9], but the goals in most games exist as something for the player to strive for. Games often have several goals that are to be reached in a sequence or arbitrarily. Goals can also be intermediary (e.g., find a key to open a door) or final (e.g., kill the boss to rescue the princess), yet all goals must be clearly presented to the player [11], [12], [59], [61]. Sometimes rules and goals are changed mid-game (e.g., the discovery of the Flood parasite in Halo: Combat Evolved); this can confuse the player, but if well done can provide memorable gameplay experiences.
Real World Relation	Navigation [59], Nostalgia [59], Physical Movement [59]	This class consists of motivators that emerge from the linkages between the real world and a game world. For example, *navigation* in location-based games can become motivating if players can relate the game events to familiar real-world surroundings. Similarly, references to familiar places or events can trigger *nostalgic* memories in players. Additionally, *physical movement* during gameplay can be a motivator in fitness and rehabilitation games that involve body movement.
Social interaction	Cooperation [5], Relatedness [8], Relations [10], Relationship [9], Recognition [5], Sociability [60], Socializing [9], Social Interaction [12], [61], Status [60], Teamwork [9], [59]	Social interaction covers interpersonal motivators that stem from the psychological need of *relatedness*, which is explained in the Self-Determination Theory as the need to feel belongingness and connectedness with others [4], [62]. It is about forming relationships, belonging to a group, interacting with others, and cooperating to achieve a goal. Social interaction can happen, for example, through joint actions in the game world, community building around the game world, and synchronous (e.g., chat) or asynchronous (e.g., discussion board) communication. *Cooperation* (with or without *competition*) is a basic form of social interaction in multiplayer games. It is often accompanied by the *recognition* and *status* that emerge when the player's efforts and accomplishments are acknowledged by others [5]. Recognition can take place within (e.g., in-game chat, leaderboards) or outside (e.g., discussion forums, online guilds, e-sports tournaments) the game world. Non-players, such as teachers or parents, can also be sources of recognition [24].
Usefulness	Knowledge Improvement [61], Usefulness [59]	Perceived *usefulness* of a game can become a powerful motivator, especially when the game has a purpose other than entertainment, such as skill training, knowledge improvement, or rehabilitation. In order to support this motivator, the player should be made aware of what they can gain from playing the game. Therefore, usefulness links to the *goals* of the game, of which the player must be made aware before they can perceive the game's usefulness.

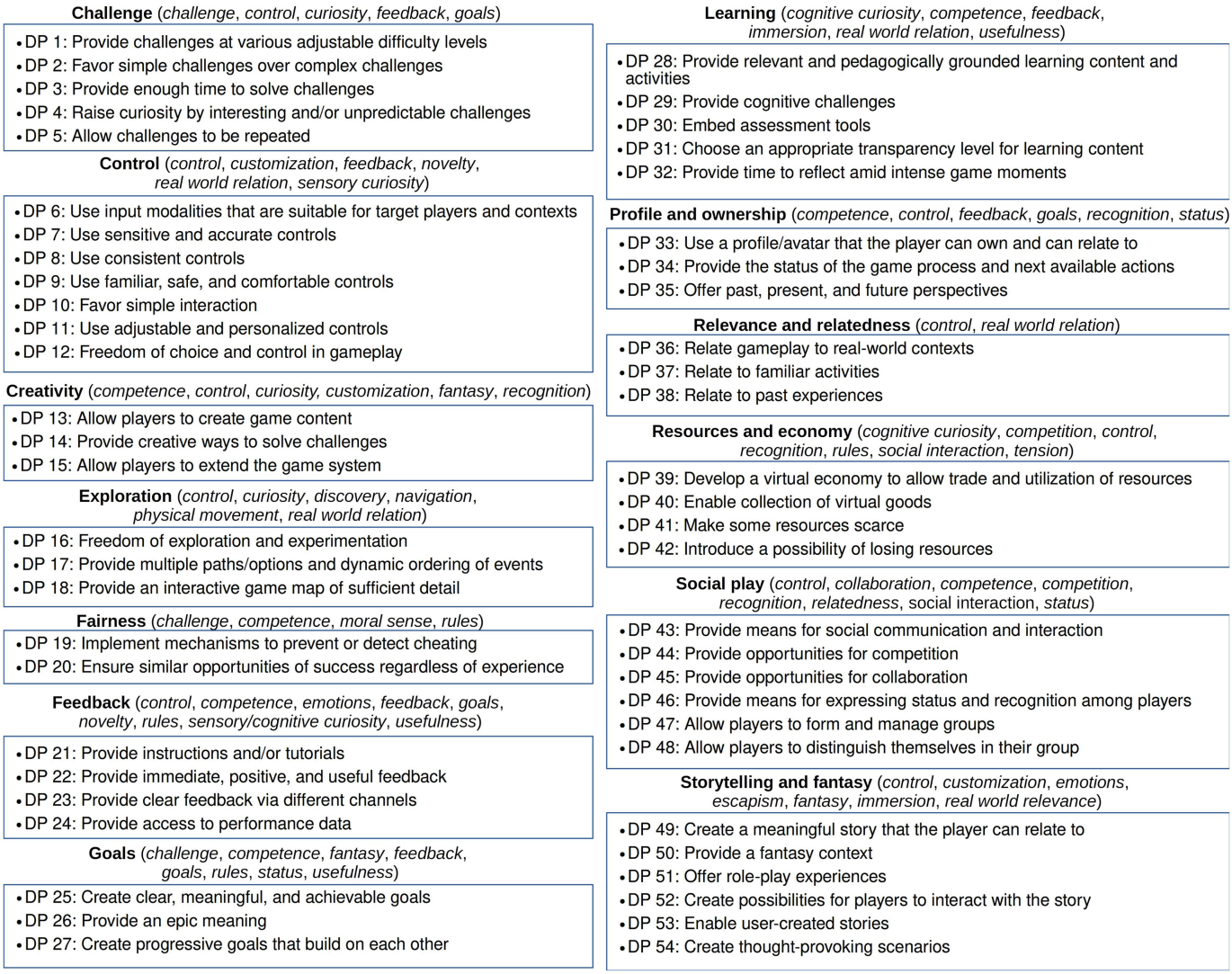

Fig. 3. Taxonomy of educational game DPs.

audience and the usage context (e.g., a young child playing while walking to school). A choice should be given to the player if multiple alternative input modalities are available. The game designer may consider implementing a natural interface using touch, gestures, or voice [68], [69], [89] when the game aims at audiences or usage contexts where traditional user interfaces are unsuitable, such as games for older adults and those based on movement [68]. Additionally, games that are aimed at older adults should take into account their special usability requirements [68], [84]. This principle relates to the *novelty* motivator, as unconventional methods of controlling the game may have a novelty effect on the player.

DP 7: Use sensitive and accurate controls [89], [90]—Game controls should be sensitive, so that the result of providing input is immediately available to the player [89], [90]. Moreover, the result should accurately correspond to the given input (e.g., the arm of an avatar should mirror the player's arm) [89]. Failing to fulfill this DP, for example by having laggy feedback on input controls, may cause lowered usability and player disengagement.

DP 8: Use consistent controls [90], [91]—The provided game controls, once chosen and adjusted for the player, should be kept consistent over multiple game sessions. A typical way to do this is to allow the player to save and load game control settings. Using consistent controls enables the player to master the controls quickly and thereby develop their skills. If additional controls are introduced later in the game, they should be presented clearly, for example through a tutorial.

DP 9: Use familiar, safe, and comfortable controls [66], [69], [89], [92]—To lower the learning curve of a game, it is recommended to use controls that are familiar to the player from previous experience. This is particularly important when developing games for older adults, where using familiar interaction methods, such as natural interaction, is encouraged [92]. This DP connects to the *real-world relation* motivator when familiarity stems from real-world experiences. Moreover, playing the game should be a safe and comfortable experience; care must therefore be taken to ensure that game controls do not introduce a risk of injury (e.g., physical movement in a game, traffic in a location-based game) [66]. The designer should therefore be aware of the target

players' condition and the gameplay context, as well as restrictions related to these [69]. This is particularly important in games based on physical movement, where proper warm-up and fall prevention/protection measures are recommended [89].

DP 10: Favor simple interaction [66], [67], [92]—Aligned with common usability guidelines [93], the game's user interface should be based on simple, intuitive interaction so as to help decrease the player's cognitive load and consequently allow the player to focus on the game's learning content. This is particularly important when target users have impaired physical or cognitive abilities [66], [67].

DP 11: Use adjustable and personalized controls [55], [66]–[69], [73], [74], [84], [89], [90]—The player should be enabled to adjust the game controls to match their needs and preferences. This covers both choosing the control mechanism (e.g., keyboard+mouse versus touch screen) and adjusting the parameters of the chosen mechanism (e.g., sensitivity of a motion sensor). Adjustment can be manual (e.g., manual calibration of an eye tracker), semiautomatic (some adjustments are manual, some automatic), or automatic (e.g., adjustable control parameters based on the player's profile). This DP relates to the *customization* motivator, as the player is given the power to customize their interaction experience.

DP 12: Freedom of choice and control in gameplay [12], [25], [43], [72], [73], [76], [78], [82], [86], [87], [94], [95]—To support the *control* motivator, it is important to provide the player with the freedom to make choices in the game. This can happen by various means, such as providing alternative paths to reach a goal [82], [86], [94], providing various things to do and different methods for doing them [72], allowing the player to influence the game system [25], and allowing the player to control the pace of the game [82]. However, one should not provide too many choices, as to do so may defeat the purpose of giving control [73]; some constraints may also be needed to help the player focus on the learning activity [82]. This principle relates to the *customization* motivator, as it may allow the player to influence how the game system works.

C. Creativity

A common factor of all DPs in this class is that they aim to foster creativity and self-expression in players. The shared purpose of these DPs is to avoid one-size-fits-all gameplay experiences and to provide the means for players to contribute to game content and even to the game system itself. All principles in this class connect to the *control* and *customization* motivators because increased use of creativity implies more freedom and choices for the player to influence the gameplay experience.

DP 13: Allow players to create game content [72], [86]—This principle encourages designers to build tools for players to create new content for the game and possibly share the content with other players. The purpose of this is to support the player's self-expression [72] and empowerment [23]; in turn, these can manifest in a number of motivators, which are as follows.

1) *Customization*: For the power to change the game content.
2) *Fantasy*: When the content creation involves storytelling and/or fantasy elements.
3) *Competence*: As the player's competence grows with content creation expertise.
4) *Recognition*: When the player receives credit for the created content.

DP 14: Provide creative ways to solve challenges [24], [81]—A motivating challenge is one that can be met in a number of different ways (e.g., stealth versus aggressive attack) [81]. This principle therefore recommends challenges that can be met in multiple creative ways. In addition to its obvious connection to the *challenge* motivator, this principle connects to *curiosity* (both cognitive and sensory), as curiosity has been shown to have a positive effect on creative problem-solving and performance [96].

DP 15: Allow players to extend the game system [72]—The designer should grant the player a limited ability to make changes to the game world and the rules that govern it. Example realizations of this principle are player-created plugins and mods that improve, enhance, or extend the game world or the gameplay in some way [72]. Modifying the game system can boost the player's perceived *competence* and may also result in *recognition* from other players. Additionally, this principle connects to the *control* and *customization* motivators, as it grants the player the power to customize the game system.

D. Exploration

This class comprises DPs whose purpose is to promote the player's exploration of the game world and its contents, as well as the real-world context used in some games (e.g., location-based games). The DPs in this class promote the *discovery*, *navigation*, and *control* motivators, as the player may experience an elevated sense of being in control when making discoveries and navigating in the game world. The *curiosity* (sensory and cognitive) motivators are also supported, as exploration may require both the sensory and cognitive faculties of the player.

DP 16: Freedom of exploration and experimentation [25], [72], [76], [79], [81], [82]—The player should be able to explore the game world and experiment with its features in a comfortable manner without feeling fear of serious consequences [72]. Freedom of exploration can also be useful when the goal is to learn about or simulate a real-world context [25], [81], [82]; it can also involve solving a mystery [76]. In addition to the aforementioned motivators, this principle also supports the *real world relation* and *physical movement* motivators when the game involves real-world exploration and movement (e.g., location-based games).

DP 17: Provide multiple paths/options and dynamic ordering of events [24], [72], [73], [86], [94], [95], [97]—To make the game more diverse and surprising, this DP suggests that the game should offer multiple paths for the player to succeed [24] and multiple methods of traversing those paths; however, these methods should not exceed the player's capacity (e.g., skill level) [72] and the number of paths or options given to the player to choose from should not be too high [73]. Additionally, the game events along a chosen path should be dynamically ordered according to the player's actions and possibly other information, such as their interests, skill level, and context attributes [94], [95].

DP 18: Provide an interactive game map of sufficient detail [86]—Regardless of whether the game is placed in the real world or a virtual world, it should provide tools to help the player navigate. Interactive game maps are useful tools for this, as they can contain relevant up-to-date information connected to specific parts of the game world, available for access and manipulation by the player. Parts of the game map can be hidden, as in Fog of War, to promote *discovery* and *curiosity*. The detail level of the map should correspond to the requirements of the game. Moreover, the game map can also include nonnavigational information, such as challenges (e.g., completed, ongoing, and available missions) and the player's status. If the game map portrays a real-world location, then the *real-world relation* motivator is supported.

E. Fairness

Here, we present DPs that aim at ensuring that gameplay can be enjoyed by all players in a fair manner. This class links to universal DPs (out of scope in this article) that aim at providing equal access to all users [98]. The DPs of this class relate to the *moral sense* motivator, as fairness is ultimately a construct of morality.

DP 19: Implement mechanisms to prevent or detect cheating [72], [87], [91], [99]—The goal of cheating (including hacking) is to gain an advantage in a game by employing strategies that either break or bend the game's rules. This is particularly important in multiplayer games, where cheating can disrupt the gameplay of a large number of players. Although some players may be motivated by the opportunity to cheat in a game, cheating in general can reverse the positive effects of games and discourage players [99]. Therefore, the game system should be protected against cheating and other forms of unwanted manipulation [72], [91]. This DP relates to the *rules* motivator because game rules lose importance when they can be circumvented by cheaters.

DP 20: Ensure similar opportunities of success regardless of experience [72]—Beginners and experienced players should all be able to approach a game easily, so all are offered fair opportunities of progressing in the gameplay. Consequently, the game should allow new players to feel motivated even when they are surrounded by veteran players [72]. This principle relates closely to the *challenge* motivator, as well as to the DPs under the challenge class (see Section V-A), which provide suggestions on how to create challenges that are suitable for different players. Moreover, this principle supports the *competence* motivator, as even new players can feel competent from early on.

F. Feedback

The following DPs cover the aspects of game design that define how the game system reacts to the player's inputs. When the input modalities to control the game are diverse (see Section V-B), it is important to ensure that provided feedback is timely and useful. All principles in this class connect to the namesake motivator and to the *control* motivator, as feedback is typically followed by the player's attempt to control the game. Additionally, these DPs link to the *competence* motivator, as the player can feel more competent as a result of receiving high-quality feedback on their actions. If the given feedback is related to a goal, then the *goals* motivator may also be supported.

DP 21: Provide instructions and/or tutorials [71], [72], [78], [90]—A game should offer sufficient instructions to ensure that the player is aware of the game controls and how to proceed in the game. This is particularly important at the beginning of the game (onboarding) where a tutorial should be provided for new players [72]. Moreover, players who are not experienced with the game genre and controls (e.g., older adults playing a game with gesture controls) may require additional instructions/tutorials. This principle relates to the *rules* and *novelty* motivators, as good tutorials help the player learn about the game's rules, technology, and features.

DP 22: Provide immediate, positive, and useful feedback [12], [24], [26], [43], [55], [66]–[69], [71]–[73], [75]–[78], [81], [84], [87], [89], [90], [95]—This DP emphasizes the importance of timely and constructive feedback to the player's actions. The feedback should be positive [55], [73] and, even in the case of the player's failure to complete an action, encouraging and constructive rather than negative, especially when the player is inexperienced [66], [84]. Positive feedback can support the *emotions* motivator class. Provided feedback should also be useful; it should describe the position and progress of the player in the game and where to go from there (i.e., available actions) [72], [81].

DP 23: Provide clear feedback via different channels [43], [67], [68], [72], [82]—This principle goes hand-in-hand with DP 22; the immediate, positive, and useful feedback may not reach the player if it is delivered in an unclear manner or via a contextually inappropriate channel. Unclear feedback may be understood incorrectly or not at all. Clarity of feedback can be increased by delivering it through multiple modalities, such as visual, auditory, and haptic, thus allowing the receiver to decide upon the most appropriate modality in a given context [67], [68]. These communication channels should correspond to the real-world context [82]. In addition to the motivators listed earlier, this DP supports *curiosity*, as provided feedback may be not only informative but also multimodal.

DP 24: Provide access to performance data [43], [68], [83], [86]—The game system should provide an interface through which the player and the educator can access—in real-time or retrospectively—performance data that are associated with gameplay and possibly visualized [68], [86]. These data may include but are not limited to learning activity performance, gameplay statistics, chat logs, and sensor data collected through multiple channels. The collected data can also be integrated into assessment strategies as well as used for adaptation [43]. Additionally, cooperative multiplayer games should provide not only group statistics but also statistics on individual achievements (e.g., "points earned" for the group and "most points earned by" for the best player in the group). Such games may also show a play reel of the highlights that occurred during game play. Allowing players to observe and analyze their own or other players' performances helps support the *usefulness* and *cognitive curiosity* motivators.

G. Goals

Goals are among the fundamental building blocks of games and these DPs can be helpful for constructing intriguing and

useful goals in educational games. In addition to supporting the *goals* motivator, these DPs help strengthen *challenge* (because goals are typically intertwined with challenges), *rules* (because reaching goals is governed by game rules), and *competence* (because the player may feel increased competence and self-esteem after reaching a goal). Additionally, reaching goals is typically followed by some form of *feedback*, which may also have a motivating effect.

DP 25: Create clear, meaningful, and achievable goals [12], [43], [55], [67], [68], [72]–[74], [76], [77], [81], [84], [86]–[88], [99]—Game goals should be clear [12], [43], [55], [67], [72], [81], [87], [99]; if they are not, the player may get "lost" and consequently may drop their engagement in the game. Furthermore, game goals and content should be meaningful to the player [68], [72], [84] and aligned with the player's personal goals [87]. Educational games should be able to convince the player that there is a deeper meaning in playing beyond entertainment. The meaning should be aligned with the narrative of the game and its goals [68]; consequently, the game content and activities should be designed so that they raise the player's interest in reaching the goals that lead to fulfillment of the meaning. Goals should also be made achievable [72] so that the player knows what needs to be done to reach them. Finally, the designer should align game elements to target goals so as to utilize the motivational pull of games [73]. Examples of game elements that can be coupled with goals include points, badges, and progress bars [77]. This DP can be reinforced by providing relevant feedback to the player about reaching the goals. Furthermore, it supports the *usefulness* motivator as meaningfulness often translates to perceived usefulness in educational games.

DP 26: Provide an epic meaning [26], [72]—One thing that makes some games particularly memorable is that they have an extraordinary, even epic, meaning as the ultimate goal of the game. *Epic meaning* means that players feel the need to be part of something bigger than themselves, such as saving the environment [26]. An epic meaning can connect to the *status* motivator, for example when the player is trusted with a task that nobody else can do and the fate of the world depends on it. To create an epic meaning, storytelling (see Section V-M) is often employed, thus promoting the *fantasy* motivator.

DP 27: Create progressive goals that build on each other [24], [26], [72], [81]—Following the divide-and-conquer strategy and aligned with DP 2, this DP suggests that rather than presenting a few large goals, the game should have several smaller goals, which can be divided into levels that progressively build on each other and lead to more complex goals [24], [26], [72], [81]. Too-large goals may demoralize the player, especially in the early stages of gameplay. Therefore, while a complex goal may be revealed, the player should also be made aware of what steps (subgoals) lie ahead on the road toward that complex goal.

H. Learning

In this section, we describe DPs that are focused on supporting the learning process. All of these promote the *usefulness* and *competence* motivators when the player feels that they have gained knowledge or skills with the game. The *real-world relation* motivator may also be strengthened if the learning content has real-world connections.

DP 28: Provide relevant and pedagogically grounded learning content and activities [43], [70], [71], [74], [80]–[82], [85], [86]—To increase the effectiveness of an educational game, its learning content and activities should be designed to be relevant from two perspectives: they should be relevant to the target context (e.g., a classroom, a forest, or an urban area) and they should be relevant to the chosen game genre and mechanics (e.g., location-sensitive learning content in a location-based game). Moreover, learning content and activities should be grounded on an appropriate instructional theory [71], [80], such as constructivism or situated learning, and (when appropriate) utilize real scientific data [81], [82], thus increasing the educational potential of the game.

DP 29: Provide cognitive challenges [74], [81], [88]—The challenges of an educational game should be of cognitive nature so as to stimulate *cognitive curiosity* and thereby facilitate the player's knowledge and skill acquisition processes. Examples of simple cognitive challenges are quizzes and puzzles that can be solved relatively quickly [74]. More demanding cognitive challenges may require the player to synthesize previously covered learning materials, knowledge, or skills, and apply problem solving or critical thinking skills [81].

DP 30: Embed assessment tools [43], [78], [81]—Providing sufficient assessment tools is essential in any learning environment. Educational games should have embedded assessment instruments for educators that are based on recorded game events and player behavior [43], [81]. These instruments can also be made available to the player, thus enabling self-monitoring of their learning process and thereby promoting the *feedback* motivator. If the learning content and the assessment tools in the game are based on a curriculum, the assessment can be used to evaluate the student's academic performance against the curriculum goals [43].

DP 31: Choose an appropriate transparency level for learning content [82], [86]—For younger learners, game designers should avoid evoking the "broccoli covered with chocolate" feeling that may emerge when learning content is in the spotlight [100]. This DP suggests that the transparency of the learning content should be tailored for the target audience and the context of use. For example, in the case of young children, the learning content could be presented subtly, embedded in game mechanics [86], whereas in the context of higher education, the game might present realistic, scientific information using professional vocabulary [82]. This DP may aid the *immersion* motivator when learning content does not obstruct the overall gameplay experience.

DP 32: Provide time to reflect amid intense game moments [85]— Every game needs a "breather" between intensive gameplay periods. In educational games, the intensive periods should focus on practicing and training skills, whereas the less intensive phases can be used for thought and reflection [85]. For example, after a level is finished, the game could provide a summary of the level's content with links to learning objectives. This DP may connect to the *usefulness* motivator when the learner feels that the

reflection phase aids learning. It also may connect to the *feedback* motivator if the reflection phase comprises feedback elements.

I. Profile and Ownership

The DPs in this class relate to providing access to individual gameplay data through the player's profile. Therefore, these DPs link to those on feedback (see Section V-F) and consequently to the *feedback* motivator. The *competence* motivator is also supported when the player's profile portrays the skills, abilities, or goals achieved by the player. Additionally, granting players ownership to their profiles increases the *control* motivator, as being aware of one's gameplay data, status, and next actions can reinforce the feeling of control. Moreover, if the achievements in the player's profile are visible to other players, these DPs can promote the *status* and *recognition* motivators.

DP 33: Use a profile/avatar that the player can own and can relate to [43], [55], [68], [72], [76], [86], [94]—The player should be given the ability to record gameplay data to their profile, thus promoting ownership [72] and enabling gameplay adaptation [43], [68]. The profile can be linked to owned virtual goods, such as awarded badges and purchased items [72], which further promotes ownership. The profile can be coupled with an avatar that represents the player in the game world and that can evolve over time [43], [76]; however, the avatar should be recognizable to the player [94]. Moreover, the game's built-in assessment tools (DP 30) can store assessment results to the player's profile.

DP 34: Provide the status of the game process and next available actions [72], [90]—Connected to the DPs on feedback, this principle encourages the provision of means for the player to observe the status of their game process [90] and next available actions related to it [72]. The status information can be embedded in the player's profile or presented as a dedicated feature (e.g., a game journal).

DP 35: Offer past, present, and future perspectives [94]—This DP is related to status information (DP 34); players should be able to observe their past, present, and future selves, which helps to trigger change processes (e.g., behavior change, achieving learning goals) [94]. The ability to observe the evolution of one's knowledge, skills, or abilities helps to boost the *competence* and *goals* motivators. This DP is particularly useful for game-based interventions that aim at achieving substantial learning outcomes, skill improvement, or behavior change over time.

J. Relevance and Relatedness

A common goal of the DPs in this class is to help make the game more relevant to the player's context, previous knowledge, and/or past experiences. These linkages allow the game designer to utilize the rich resources of the real world; the player benefits from this by building a better understanding of the dynamics between the game's activities and their own real-world context. Therefore, these DPs promote the *real-world relation* motivator.

DP 36: Relate gameplay to real-world contexts [25], [74], [81], [86], [88], [92], [101]—Educational games can benefit from references to real-world contexts, which can provide resources (e.g., physical locations, objects, people) that may not be available in context-agnostic settings, such as classrooms. Therefore, by grounding a game to a real-world context, the game's relevance to the player's relevant surroundings increases. In educational games, real-world contexts, and realism in general, can provide enhanced learning experiences, for example, through content involving a real-world location [25], culture [92], or problem [81]. Simulation games exemplify a genre where realism comes first, even at the expense of playability [101]. Finally, if the game is based on a real-world location, the designer should take into account environmental conditions, such as weather and lighting, and provide the necessary navigational aids [86].

DP 37: Relate to familiar activities [67], [92] – It may be helpful to relate the game activities to real-world activities with which players are already familiar, such as daily activities or those based on sports or hobbies. This is especially important when the target audience comprises older adult players [67], [92]. Moreover, the game design should be aligned with the target players' cultural context, thus further strengthening the familiarity factor [92]. Applying this DP lowers the game's learning curve, allowing players to grasp the gameplay faster and thereby promoting the *control* motivator.

DP 38: Relate to past experiences [25], [67], [94]—The game should foster connections to the player's past experiences, thus deepening their engagement [25]. These connections may be implicitly woven into game content and activities (e.g., by basing the game's difficulty level settings on previous game sessions), and/or explicitly presented to the player, for example through their profile (see Section V-I).

K. Resources and Economy

These DPs target game mechanics that involve game resources, such as points, badges, achievements, and other virtual property, with the goal of engaging players in long-term use. These principles support a number of motivators, which are as follows.

1) *Cognitive curiosity*: Through the anticipation toward resources that are yet to be acquired.
2) *Competition*: Through the comparison of owned resources with those of other players.
3) *Recognition*: Through interplayer rankings based on the acquired resources.
4) *Rules*: As they govern how resources are implemented in the game.
5) *Control*: When the player can control and manipulate their resources.

DP 39: Develop a virtual economy to allow trade and utilization of resources [55], [72], [78], [81], [83]—Many successful games have a built-in virtual economy that allows players to earn resources and then utilize them in various ways, such as building in-game structures [81] or purchasing virtual items [55]. It is also possible to allow exchange of game resources for outside rewards [72], such as service coupons. A well-designed virtual economy system can engage players in long-term use and promote the *social interaction* motivator if players trade with each other.

DP 40: Enable collection of virtual goods [26], [72], [75], [78], [83]—Ownership is one of the key drives of attractive games [23]; to promote it, this DP proposes creating a system of virtual goods (e.g., points, coins, badges, or medals) that players can collect through game activities. The goal of this principle is to incentivize continuous gameplay. In educational games, these collectables can be related to acquired skills and/or knowledge, thus demonstrating the player's status in the game world. Collected goods can be linked to the player's profile (see Section V-I) and, if a trading system is implemented (DP 39), exchanged with the game system or with other players. Moreover, these collectables can be used to influence the gameplay, such as unlocking a closed game section or gaining a temporary advantage.

DP 41: Make some resources scarce [72]—Game resources that are abundantly available are not perceived to be as prestigious as resources that are difficult to acquire. This DP suggests that some game resources should be made difficult to acquire or achieve [72]. The rationale for this is that players become more engaged in the game in order to get a rare resource. However, a resource should not be made too scarce or else the player may perceive that acquiring it is a hopeless endeavor. Modern games have used this DP successfully in the form of loot boxes, which may contain scarce items, but more commonly yield objects of abundance. Loot boxes have been controversially compared to being akin to gambling when real money is involved. Nonetheless, loot boxes are powerful motivational tools that should be used with due consideration.

DP 42: Introduce a possibility of losing resources [72]—The fear of losing the ownership of a resource has been recognized as one of the key drives of attractive games [23]. Loss avoidance is typically implemented by creating a sense of urgency; the player must perform an action (e.g., complete a learning mission) within a given time frame (e.g., once a day) in order to keep the resource [72]. This DP promotes the *tension* motivator due to the pressure created by the impending resource loss.

L. Social Play

As humans are inherently social beings [102] and social interaction has been recognized to be one of the key motivators for learning [5], game designers should ensure that their games provide sufficient support for social interaction among players. The DPs in this class, all of which promote the *social interaction* motivator, can be useful for achieving socially engaging game experiences.

DP 43: Provide means for social communication and interaction [12], [24], [25], [43], [55], [69], [72]–[74], [76], [77], [80], [82], [83], [87], [94], [95]—This, one of the most fundamental and often proposed DPs, suggests that the game should offer tools for players to connect and interact socially [72] while eliminating factors that hinder social interactions [73]. Social interaction can take place in-game (e.g., chat, multiplayer activities) and/or outside the game (e.g., online discussion forum). In general, social interaction should be implemented among players, but interaction between players and nonplayers (e.g., personified game characters) can also be seen as a form of motivating social interaction [43], [82]. The DPs below are built upon this principle.

DP 44: Provide opportunities for competition [26], [43], [55], [67], [70], [74]–[76], [78], [80], [83], [86], [94]—Games should use competition as a powerful incentive for the player to engage in gameplay against other players, against themselves, or against the game system [67], [74]. Competition can be synchronous (i.e., players compete against each other simultaneously) or asynchronous (i.e., players compete against previously recorded achievements, such as leaderboards). Competition can be combined with cooperation, as in group-based competitive challenges, which combine the two basic modes of social gameplay (competition and collaboration) [94]. This DP supports the *competition* motivator and can also strengthen the *competence* and *recognition* motivators through achieved victories.

DP 45: Provide opportunities for collaboration [43], [55], [71], [72], [74], [76]–[78], [80], [83], [86], [94]—Collaborative game activities are a great way of supporting the formation of groups and even friendships among players, which can contribute to longer engagement. The game should therefore offer activities whereby a group of players work together as a team in order to reach a common goal [43], [55], [72], [77]. Collaborative activities may also elicit tension among players, which in turn can facilitate group interaction and decision-making on a plan to move forward [83]. In-game collaboration can be facilitated by providing tools for communication and interaction both inside and outside the game (DP 43). This DP connects to the *cooperation* motivator; it also supports *recognition* through acknowledgment and celebration of one's status and achievements in the group.

DP 46: Provide means for expressing status and recognition among players [24], [26], [78], [86], [94]—Social dynamics among players can be invigorated by providing them with access to each other's status and means of expressing recognition. This is especially important within and between groups (DP 47), where the player's reputation can influence their actions in the game world. In educational games, it is important that recognition can come from different sources, such as other players, teachers, and parents [24]. This DP connects to the *status* and *recognition* motivators and may help the player perceive increased *competence*.

DP 47: Allow players to form and manage groups [55], [94]—Players should be able to form and join groups so as to promote group-based identification, as well as to foster cooperation and competition [94]. Many popular online games use this principle to facilitate multiplayer game experiences and community building around the game world; this can help keep players engaged in the game. Group membership allows the player to feel *relatedness* and meaningfulness, which can translate to increased *recognition*, whereas the ability to manage groups supports *control*.

DP 48: Allow players to distinguish themselves in their group [83]— Players in a group should be given complementary abilities and roles that help them become distinguished in the group. This technique is beneficial for demonstrating how individuals make their group stronger when they work together [83]. This DP contributes to the *status* and *recognition* motivators through distinguished memberships. The *competence* motivator is also promoted by highlighting individual

assessment alongside that of the team, as the player might learn about their personal weaknesses or strengths.

M. Storytelling and Fantasy

Storytelling has been an important tool for social interaction and information sharing throughout the human history. It has also been recognized to possess many advantages as an instruction method, such as getting learners more involved and making learning content more memorable [103], as well as promoting interaction among learners [104]. The DPs in this class help game designers make their games more engaging through the means of storytelling and fantasy. They support the *fantasy*, *escapism*, and *immersion* motivators, as intriguing stories may immerse the player in the game world [105], providing them with a break from the real world.

DP 49: Create a meaningful story that the player can relate to [25], [55], [72], [76], [78], [79], [81], [86]–[88], [106], [107]—Educational games should employ a meaningful story with which the player can relate [72], [87]. To ensure the story's appropriateness, the designer must know the game's target players (e.g., older adult players may not be intrigued by a story based on superheroes). Moreover, the use of humor is encouraged, especially in educational games, as humor has been shown to benefit learning [88]. The game's story can be based on a real-world scenario [25], [81] or it can be made of fantasy elements [76], [86], [106]. In the former case, the story can strengthen the *real-world relevance* motivator. The narrative can also provide opportunities for positive role models [107] through significant characters who may represent an ethnic minority group, sexual orientation, or gender.

DP 50: Provide a fantasy context [76], [79], [80], [86], [95], [106]—Designers should consider using fantasy in their games because it is one of the core intrinsic motivators [5]. Whether or not the game is based on the real world, employing a fantasy context can be useful for several reasons, which are as follows.

1) Fantasy allows more freedom for storytelling and supporting media than a purely real-world context does.
2) Fantasy promotes the *fantasy* and *escapism* motivators.
3) Fantasy is particularly attractive to younger players.

Overlaying a fantasy context on top of a real-world context is especially suitable for games that are based on a real-world environment [76], [86].

DP 51: Offer role-play experiences [55], [78]—To further increase the player's involvement and thereby immersion, this DP proposes that the game should allow the player to assume the role of a character in the story. The role can be: assigned (i.e., the game assigns a role to the player); selected (i.e., the player selects a role among precreated roles); or created (i.e., the player creates a role from scratch or based on a template). The role can influence how the gameplay progresses; it can also be connected to the player's profile and avatar (see Section V-I). This principle supports the *customization* and *control* motivators when the role can be selected and modified by the player.

DP 52: Create possibilities for players to interact with the story [72]—Rather than having a linear predetermined flow in the story, the story should be interactive, so that the player can have a meaningful part in it [72] (e.g., by role-playing). Interactive storytelling is more demanding than predetermined storytelling for the game designer or story writer, as the story needs multiple different variations to respond to the player's choices. This DP supports the *control* motivator, as the ability to affect the narration of the story increases the perceived feeling of control.

DP 53: Enable user-created stories [25]—Aligned with the DPs of the creativity class, this DP proposes that users should be given opportunities to create and share stories, thus promoting ownership and long-term use [25]. Here, the term "users" refers to players (e.g., students) and to other stakeholders (e.g., educators). Implementing this DP may require the creation of a dedicated story editor tool, so it is important to decide upon the format of the story at an early stage of the game development process. When the game allows players to create their own stories, the *control* and *customization* motivators are promoted.

DP 54: Create thought-provoking scenarios [108]—Games can be an excellent method of throwing the player into a thought-provoking situation where there are no clear answers. For example, choosing whether or not to make a sweatshop more profitable at the expense of its workers can become a memorable and thought-provoking experience [108]. This DP connects to the *emotions* motivator class when the scenario elicits an emotional response in the player.

VI. Discussion

As main contributions of this article, we proposed one taxonomy that combines 56 previously identified game motivators into 14 classes and another that presents 54 synthesized educational game DPs in 13 classes. Moreover, we established linkages between the identified motivators and DPs. The results offer educational game designers a practical toolkit that can help promote motivated engagement in their games. Although the numbers of motivators and DPs may seem overwhelming, it is noteworthy that not all of them need to be used at once. In fact, trying to combine all of them may result in a chaotic experience both for the designer (e.g., balancing game rules) and the player (e.g., increased gameplay complexity). Moreover, although this article was conducted by using a systematic literature review method, it is possible that there are more motivators and DPs to be added. We, therefore, ask game designers not to consider these taxonomies as complete, but as a good starting point that can be amended in the future.

In addition to proposing two taxonomies, we divided 12 previously used terms that relate to gamification into classes based on what they describe: process, end result, quality or state, and activity. This classification shows the richness of the field, as a single phenomenon can be observed from multiple different perspectives. Although not exhaustive, this classification can serve as a foundation on which future studies can be built. For example, one future study could focus on exploring the effectiveness of the end result of gamification (i.e., the game being used by its target users), whereas another could focus on the process of creating the game (e.g., requirements elicitation, design, implementation, testing). Moreover, game designers can adopt different strategies (i.e., depths) of

gamification, as we proposed in Section II-A, depending on their respective objectives and available resources.

The findings of this study complement previous literature reviews (see Section II-B) as follows. First, the analysis of gamification frameworks by Mora *et al.* [28] can be combined with our results to identify those frameworks that support the presented motivators and the DPs. Consequently, these frameworks can be ranked and suggestions made as to which framework is best suited for which purpose. Second, Ávila-Pesántez *et al.*'s [27] proposal of 31 game design stages can, to some extent, be mapped to the proposed DPs. However, this mapping would focus largely on the "design" stage because we omitted other aspects of the design process (e.g., requirements elicitation and analysis, implementation, and testing) from this review. In summary, the results presented here have the potential to be combined with previous research to open new research venues.

Habgood [109] identified two fundamental approaches for utilizing game elements in educational software to engage learners: First, the extrinsically motivating "chocolate-covered broccoli" approach that attempts to make existing learning content more engaging with game elements; and second, the intrinsically motivating integrated approach that produces a deep merger of game mechanics and learning content, with the former leading the design process. The first approach may be enough to provide "school fun" in scenarios where the teacher aims to provide different learning activities to complement ordinary lessons. The integrated approach can increase the time that students spend freely on the game [109], but successful promotion of intrinsic motivation by gamification is not guaranteed [19]. Many educational games use the integrated approach with the same game design elements (e.g., points, badges, leaderboards, competition, collaboration, storytelling, and chance) on which intrinsically motivating commercial games are based; however, they still can fail to be intrinsically motivating and perhaps do not need to be, if the goal of the game is to provide an extrinsically motivating classroom activity (i.e., "school fun"). Habgood's categorization can be thought to be a simplified version of the idea of different gamification strategies that we described in Section II-A. The DPs that we proposed can help educational game designers to implement these strategies in order to ensure learner engagement at least through extrinsic, but hopefully also through intrinsic, motivation. Involving learners as codesigners in the game creation process and ensuring that sufficient resources are allocated to the game design process may be useful in achieving the latter objective [110].

The proposed taxonomies can be used by educational game designers to create games that have an elevated potential of creating motivated learner engagement. However, such an outcome is not automatically guaranteed because successful game design is a process that extends beyond what was covered by our literature review. As Ávila-Pesántez *et al.* [27] illustrated, there are typically four phases in a game design process—analysis, design, development, and evaluation—that all contribute to the end result. Our DPs and motivators can serve as tools in the design phase and can also be utilized to evaluate the motivational potential of educational games. However, a more detailed evaluation tool based on the motivators and DPs remains to be developed. We advise the reader to combine the taxonomies proposed in this article with a suitable game design process methodology—possibly involving end-users as co-designers—to increase the likelihood of creating an intrinsically motivating educational game. Additionally, once the game has been created and deployed, more guidelines are needed for its end-users to ensure appropriate and effective usage.

We followed a detailed systematic literature review methodology to discover previously proposed DPs and guidelines, specifically focusing on the domain of education, but also accepted generic gamification studies as sources. Consequently, other game design focus areas were omitted from this study, such as business [111], [112], cultural heritage [113], and software engineering [114], [115]. It is possible that these studies have additional DPs and motivators that can complement our results; we recognize this as a limitation of the study. Therefore, if a game under design is targeted at fields other than education, we recommend amending our results with game design studies that explicitly focus on the target area. Another limitation of the study is that our interpretation of the results was used to establish the linkages between the identified motivators and DPs. A future study, for example one that applies the DPs and measures what motivators emerge as a result, is needed to test these links and to identify new links.

VII. Conclusion

At the beginning of this article, we established that motivated engagement is essential in educational interventions. Furthermore, games are known to possess a range of motivators that, when properly implemented, may help in achieving and maintaining motivated engagement over a long period. However, game design research in the context of education lacks a thorough account of game motivators and DPs that can help boost learners' motivation and long-term engagement. To fill this gap, we conducted a systematic literature review to answer two research questions: First, "what are the motivators that contribute to engaging educational games?"; and second, "what are the game DPs that contribute to engaging educational games?" Consequently, we synthesized the literature review findings and proposed interlinked taxonomies: a taxonomy of game motivators (56 motivators in 14 classes); and a taxonomy of educational game DPs (54 principles in 13 classes), with links to related motivators. Additionally, as a minor contribution, we proposed a categorization of 12 terms related to gamification and different strategies through which gamification can be implemented.

This article is the first comprehensive attempt to collect, organize, and synthesize scientific knowledge on game motivators and DPs for educational game researchers and practitioners. Designers of educational games can utilize the results of this study to create games that enable motivated learner engagement and to evaluate the motivation potential of educational games. The high numbers of discovered motivators and DPs suggest that (educational) game design is a vibrant research field. Moreover, the results indicate that many of the motivators and DPs have strong support in previous research; applying them in designing an educational game is

therefore likely to help increase the game's motivational impact. Another impact of these results is that the process of designing of educational games can become faster when important DPs are available from a single source. There remains work to be done in charting the field of educational game design. Therefore, as a future work, we plan to complement this systematic literature survey by focusing on analyzing previously proposed conceptual and process-oriented gamification frameworks, game mechanics, and technologies for gamification; the results of these analyses will then be synthesized and combined with the results of this study in order to propose a generic gamification framework for education. Moreover, we plan to utilize the taxonomies proposed in this article to develop, and then to evaluate, a novel game to engage children in changing their behavior on active school transport while providing them with informal learning activities. Finally, the presented DPs and motivators are not specific to educational stages (e.g., elementary, secondary, tertiary, lifelong); an interesting future research avenue, therefore, is to explore which DPs and motivators are particularly suitable for each stage.

References

[1] United Nations, "Transforming our world: The 2030 agenda for sustainable development," United Nations, General Assem. Resolution, New York, NY, USA, Tech. Rep. A/RES/70/1, 2015.

[2] K. Almohammadi, H. Hagras, D. Alghazzawi, and G. Aldabbagh, "A survey of artificial intelligence techniques employed for adaptive educational systems within e-learning platforms," *J. Artif. Intell. Soft Comput. Res.*, vol. 7, no. 1, pp. 47–64, Jan. 2017, doi: 10.1515/jaiscr-2017-0004.

[3] J. S. Wu and J. J. Lee, "Climate change games as tools for education and engagement," *Nature Climate Change*, vol. 5, pp. 413–418, Apr. 2015, doi: 10.1038/NCLIMATE2566.

[4] M. R. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary Educ. Psychol.*, vol. 25, no. 1, pp. 54–67, Jan. 2000, doi: 10.1006/ceps.1999.1020.

[5] T. W. Malone and M. R. Lepper, "Making learning fun: A taxonomy of intrinsic motivations for learning," *Aptitude, Learn. Instruction*, vol. 3, pp. 223–253, 1987.

[6] T. W. Malone, "Toward a theory of intrinsically motivating instruction," *Cogn. Sci.*, vol. 5, no. 4, pp. 333–369, Oct. 1981, doi: 10.1207/s15516709cog0504_2.

[7] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*, 1st ed. New York, NY, USA: Harper & Row, 1990.

[8] M. R. Ryan, C. S. Rigby, and A. Przybyiski, "The motivational pull of video games: A self-determination theory approach," *Motivation Emotion*, vol. 30, pp. 347–363, Dec. 2006, doi: 10.1007/s11031-006-9051-8.

[9] N. Yee, "Motivations for play in online games," *Cyberpsychol. Behav.*, vol. 9, no. 6, pp. 772–775, Dec. 2006, doi: 10.1089/cpb.2006.9.772.

[10] E. L. Nygren, T. H. Laine, and E. Sutinen, "Dynamics between disturbances and motivations in educational mobile games," *Int. J. Interactive Mobile Technol.*, vol. 12, no. 3, Jul. 2018, Art. no. 120, doi: 10.3991/ijim.v12i3.8490.

[11] R. Garris, R. Ahlers, and J. E. Driskell, "Games, motivation, and learning: A research and practice model," *Simul. Gaming*, vol. 33, no. 4, pp. 441–467, Dec. 2002, doi: 10.1177/1046878102238607.

[12] P. Sweetser and P. Wyeth, "GameFlow: A model for evaluating player enjoyment in games," *ACM Comput. Entertainment*, vol. 3, no. 3, pp. 1–24, Jul. 2005, doi: 10.1145/1077246.1077253.

[13] J. Martí-Parreño, E. Méndez-Ibáñez, and A. Alonso-Arroyo, "The use of gamification in education: A bibliometric and text mining analysis: Gamification in education," *J. Comput. Assisted Learn.*, vol. 32, no. 6, pp. 663–676, Dec. 2016, doi: 10.1111/jcal.12161.

[14] M. Qian and K. R. Clark, "Game-based learning and 21st century skills: A review of recent research," *Comput. Human Behav.*, vol. 63, pp. 50–58, Oct. 2016, doi: 10.1016/j.chb.2016.05.023.

[15] T. M. Connolly, E. A. Boyle, E. Macarthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," *Comput. Educ.*, vol. 59, no. 2, pp. 661–686, Sep. 2012, doi: 10.1016/j.compedu.2012.03.004.

[16] P. Fotaris, N. Pellas, I. Kazanidis, and P. Smith, "A systematic review of augmented reality game-based applications in primary education," in *Proc. 11th Eur. Conf. Game-Based Learn.*, Graz, Austria, Oct. 2017, pp. 181–191.

[17] T. Laine, "Mobile educational augmented reality games: A systematic literature review and two case studies," *Computers*, vol. 7, no. 1, pp. 28–28, Mar. 2018, doi: 10.3390/computers7010019.

[18] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: Defining 'gamification'," in *Proc. MindTrek Conf.*, Tampere, Finland, Sep. 2011, pp. 9–15, doi: 10.1145/2181037.2181040.

[19] M. D. Hanus and J. Fox, "Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance," *Comput. Educ.*, vol. 80, pp. 152–161, Jan. 2015, doi: 10.1016/j.compedu.2014.08.019.

[20] J. Schell, *The Art of Game Design: A Book of Lenses*, 2nd ed. Boca Raton, FL, USA: CRC Press, Nov. 2014, doi: 10.1201/b17723.

[21] S. Rogers, *Level Up! The Guide to Great Video Game Design*, 2nd ed. Chichester, U.K.: Wiley, 2014.

[22] K. Salen and E. Zimmerman, *Rules of Play: Game Design Fundamentals*. Cambridge, MA, USA: MIT Press, 2003.

[23] Y. Chou, *Actionable Gamification: Beyond Points, Badges, and Leaderboards*, Milpitas, CA, USA: Octalysis Media, 2015.

[24] J. Simões, R. D. Redondo, and A. F. Vilas, "A social gamification framework for a K-6 learning platform," *Comput. Human Behav.*, vol. 29, no. 2, pp. 345–353, Mar. 2013, doi: 10.1016/j.chb.2012.06.007.

[25] S. Nicholson, "A RECIPE for meaningful gamification," in *Gamification in Education and Business*, T. Reiners and L. C. Wood, Eds. Cham, Switzerland: Springer, 2015, pp. 1–20, doi: 10.1007/978-3-319-10208-5_1.

[26] C. Gonzalez and M. Area, "Breaking the rules: Gamification of learning and educational materials," in *Proc. 2nd Int. Workshop Interact. Des. Educ. Environ.*, Angers, France, Jul. 2013, pp. 47–53, doi: 10.5220/0004600900470053.

[27] D. Ávila-Pesántez, L. A. Rivera, and M. S. Alban, "Approaches for serious game design: A systematic literature review," *Comput. Educ. J.*, vol. 8, no. 3, pp. 1–11, Sep. 2017.

[28] A. Mora, D. Riera, C. González, and J. Arnedo-Moreno, "Gamification: A systematic review of design frameworks," *J. Comput. High Educ.*, vol. 29, no. 3, pp. 516–548, Dec. 2017, doi: 10.1007/s12528-017-9150-4.

[29] F. de Vette, M. Tabak, M. D.- van Weering, and M. Vollenbroek-Hutten, "Engaging elderly people in telemedicine through gamification," *JMIR Serious Games*, vol. 3, no. 2, Dec. 2015, Art. no. e9, doi: 10.2196/games.4561.

[30] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," School Comput. Sci. Math., Keele Univ., Keele, U.K., Tech. Rep. EBSE-2007-01, 2007.

[31] Mojang, "Minecraft." [Online]. Available: https://www.minecraft.net/, Accessed: Jul. 6, 2020.

[32] LightBot, Inc., "LightBot." [Online]. Available: https://lightbot.com/, Accessed: Jul. 6, 2020.

[33] A. Uskov and B. Sekar, "Serious games, gamification and game engines to support framework activities in engineering: Case studies, analysis, classifications and outcomes," in *Proc. IEEE Int. Conf. Electro/Inf. Technol.*, Milwaukee, WI, USA, Jun. 2014, pp. 618–623.

[34] K. Robson, K. Plangger, J. H. Kietzmann, I. McCarthy, and L. Pitt, "Is it all a game? Understanding the principles of gamification," *Bus. Horiz.*, vol. 58, no. 4, pp. 411–420, Jul. 2015, doi: 10.1016/j.bushor.2015.03.006.

[35] D. Vashisht, M. B. Royne, and S. S., "What we know and need to know about the gamification of advertising: A review and synthesis of the advergame studies," *Eur. J. Marketing*, vol. 53, pp. 607–634, Apr. 2019, doi: 10.1108/EJM-01-2017-0070.

[36] H. Warmelink, J. Koivisto, I. Mayer, M. Vesa, and J. Hamari, "Gamification of the work floor: A literature review of gamifying production and logistics operations," in *Proc. Hawaii Int. Conf. Syst. Sci.*, Jan. 2018, pp. 1108–1117, doi: 10.24251/HICSS.2018.139.

[37] M. Papastergiou, "Exploring the potential of computer and video games for health and physical education: A literature review," *Comput. Educ.*, vol. 53, no. 3, pp. 603–622, Nov. 2009, doi: 10.1016/j.compedu.2009.04.001.

[38] C. M. Bleakley, D. Charles, A. Porter-Armstrong, M. D. J. McNeill, S. M. McDonough, and B. McCormack, "Gaming for health: A systematic review of the physical and cognitive effects of interactive computer games in older adults," *J. Appl. Gerontol.*, vol. 34, no. 3, pp. NP166–NP189, Apr. 2015, doi: 10.1177/0733464812470747.

[39] M. Tabak, M. Dekker-van Weering, H. van Dijk, and M. Vollenbroek-Hutten, "Promoting daily physical activity by means of mobile gaming: A review of the state of the art," *Games Health J.*, vol. 4, no. 6, pp. 460–469, Dec. 2015, doi: 10.1089/g4h.2015.0010.

[40] D. Johnson, S. Deterding, K.-A. Kuhn, A. Staneva, S. Stoyanov, and L. Hides, "Gamification for health and wellbeing: A systematic review of the literature," *Internet Interventions*, vol. 6, pp. 89–106, Nov. 2016, doi: 10.1016/j.invent.2016.10.002.

[41] D. Djaouti, J. Alvarez, and J.-P. Jessel, "Classifying serious games: The G/P/S model," in *Handbook of Research on Improving Learning and Motivation Through Educational Games*. Hershey, PA, USA: IGI Global, 2011, pp. 118–136, doi: 10.4018/978-1-60960-495-0.ch006.

[42] R. Schmidt, K. Emmerich, and B. Schmidt, "Applied games—In search of a new definition," in *Entertainment Computing—ICEC 2015*, vol. 9353, K. Chorianopoulos, M. Divitini, J. Baalsrud Hauge, L. Jaccheri, and R. Malaka, Eds. Cham, Switzerland: Springer, 2015, pp. 100–111, doi: 10.1007/978-3-319-24589-8_8.

[43] L. A. Annetta, "The "I's' have it: A framework for serious educational game design," *Rev. General Psychol.*, vol. 14, no. 2, pp. 105–113, Jun. 2010, doi: 10.1037/a0018985.

[44] S. Culyba, *The Transformational Framework: A Process Tool for the Development of Transformational Games*. Pittsburgh, PA, USA: ETC Press, 2018, doi: 10.1184/R1/7130594.

[45] A. E. Staiano and S. L. Calvert, "Exergames for physical education courses: Physical, social, and cognitive benefits," *Child Develop. Perspectives*, vol. 5, no. 2, pp. 93–98, Jun. 2011, doi: 10.1111/j.1750-8606.2011.00162.x.

[46] D. Takahashi, "Funware's threat to the traditional video game industry," [Online]. Available: https://venturebeat.com/2008/05/09/funwares-threat-to-the-traditional-video-game-industry/, Accessed: Jul. 6, 2020.

[47] K. Katsaliaki and N. Mustafee, "Edutainment for sustainable development: A survey of games in the field," *Simul. Gaming*, vol. 46, no. 6, pp. 647–672, Dec. 2015, doi: 10.1177/1046878114552166.

[48] R. N. Landers, G. F. Tondello, D. L. Kappen, A. B. Collmus, E. D. Mekler, and L. E. Nacke, "Defining gameful experience as a psychological state caused by gameplay: Replacing the term 'gamefulness' with three distinct constructs," *Int. J. Human-Comput. Stud.*, vol. 127, pp. 81–94, Jul. 2019, doi: 10.1016/j.ijhcs.2018.08.003.

[49] J. Stenros, "Playfulness, play, and games: A constructionist ludology approach," Ph.D. dissertation, School Inf. Sci., Univ. Tampere, Tampere, Finland, 2015.

[50] J. Hamari, D. J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, and T. Edwards, "Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning," *Comput. Human Behav.*, vol. 54, pp. 170–179, Jan. 2016, doi: 10.1016/j.chb.2015.07.045.

[51] M. Fuchs, "Ludic interfaces: Driver and product of gamification," *GAME: Italian J. Game Stud.*, vol. 1, pp. 19–26, 2012.

[52] D. Dicheva, C. Dichev, G. Agre, and G. Angelova, "Gamification in education: A systematic mapping study," *J. Educ. Technol. Soc.*, vol. 18, no. 3, pp. 75–88, Jul. 2015.

[53] C. D. Ennis, "Implications of exergaming for the physical education curriculum in the 21st century," *J. Sport Health Sci.*, vol. 2, no. 3, pp. 152–157, Sep. 2013, doi: 10.1016/j.jshs.2013.02.004.

[54] E. M. Whyte, J. M. Smyth, and K. S. Scherf, "Designing serious game interventions for individuals with autism," *J. Autism Develop. Disorders*, vol. 45, no. 12, pp. 3820–3831, Dec. 2015, doi: 10.1007/s10803-014-2333-1.

[55] F. F.-H. Nah, V. R. Telaprolu, S. Rallapalli, and P. R. Venkata, "Gamification of education using computer games," in *Human Interface and the Management of Information. Information and Interaction for Learning, Culture, Collaboration and Business*, vol. 8018, D. Hutchison, *et al.*, Eds. Heidelberg, Germany: Springer-Verlag, 2013, pp. 99–107, doi: 10.1007/978-3-642-39226-9_12.

[56] F. Faiella and M. Ricciardi, "Gamification and learning: A review of issues and research," *J. e-Learn. Knowl. Soc.*, vol. 11, no. 3, pp. 13–21, Sep. 2015, doi: 10.20368/1971-8829/1072.

[57] J. Majuri, J. Koivisto, and J. Hamari, "Gamification of education and learning: A review of empirical literature," in *Proc. 2nd Int. GamiFIN Conf.*, Pori, Finland, May 21–23, 2018, pp. 11–19.

[58] United Nations, "World population ageing 2017—Highlights," United Nations, Dept. Econ. Social Affairs, Population Division, New York, NY, USA, Tech. Rep. ST/ESA/SER.A/397, 2017.

[59] T. H. Laine and H. Suk, "Designing educational mobile augmented reality games using motivators and disturbance factors," in *Augmented Reality Games II*, V. Geroimenko, Ed. Cham, Switzerland: Springer, 2019, pp. 33–56, doi: 10.1007/978-3-030-15620-6_2.

[60] F. De Grove, V. Cauberghe, and J. Van Looy, "In pursuit of play: Toward a social cognitive understanding of determinants of digital play: In pursuit of play," *Commun. Theory*, vol. 24, no. 2, pp. 205–223, May 2014, doi: 10.1111/comt.12030.

[61] F.-L. Fu, R.-C. Su, and S.-C. Yu, "EGameFlow: A scale to measure learners' enjoyment of e-learning games," *Comput. Educ.*, vol. 52, no. 1, pp. 101–112, Jan. 2009, doi: 10.1016/j.compedu.2008.07.004.

[62] E. L. Deci, *Intrinsic Motivation* (Perspectives in Social Psychology). New York, NY, USA: Plenum, 1975, doi: 10.1007/978-1-4613-4446-9.

[63] L. Michailidis, E. Balaguer-Ballester, and X. He, "Flow and immersion in video games: The aftermath of a conceptual challenge," *Frontiers Psychol.*, vol. 9, Sep. 2018, Art. no. 1682, doi: 10.3389/fpsyg.2018.01682.

[64] J. J. Cummings and J. N. Bailenson, "How immersive is enough? A meta-analysis of the effect of immersive technology on user presence," *Media Psychol.*, vol. 19, no. 2, pp. 272–309, 2016, doi: 10.1080/15213269.2015.1015740.

[65] A. K. Tang, "Key factors in the triumph of Pokémon GO," *Bus. Horiz.*, vol. 60, no. 5, pp. 725–728, Sep./Oct. 2017, doi: 10.1016/j.bushor.2017.05.016.

[66] K. M. Gerling, J. Schild, and M. Masuch, "Exergame design for elderly users: The case study of SilverBalance," in *Proc. 7th Int. Conf. Comput. Entertainment Technol.*, Taipei, Taiwan, Nov. 2010, pp. 66–69, doi: 10.1145/1971630.1971650.

[67] I. T. Paraskevopoulos, E. Tsekleves, C. Craig, C. Whyatt, and J. Cosmas, "Design guidelines for developing customised serious games for Parkinson's disease rehabilitation using bespoke game sensors," *Entertainment Comput.*, vol. 5, no. 4, pp. 413–424, Dec. 2014, doi: 10.1016/j.entcom.2014.10.006.

[68] M. Pirovano, "The design of exergaming systems for autonomous rehabilitation," Doctoral dissertation, Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Milan, Italy, 2015.

[69] R. Planinc, I. Nake, and M. Kampel, "Exergame design guidelines for enhancing elderly's physical and social activities," in *Proc. Int. Conf. Ambient Comput., Appl., Serv., Technol.*, Porto, Portugal, 2013, pp. 58–63.

[70] M. Zhang *et al.*, "The framework and implementation of virtual network marathon," in *Proc. IEEE Int. Symp. VR Innov.*, Mar. 2011, pp. 161–167.

[71] F. Laamarti, M. Eid, and A. El Saddik, "An overview of serious games," *Int. J. Comput. Games Technol.*, vol. 2014, pp. 1–15, Oct. 2014, doi: 10.1155/2014/358152.

[72] G. F. Tondello, D. L. Kappen, E. D. Mekler, M. Ganaba, and L. E. Nacke, "Heuristic evaluation for gameful design," in *Proc. Annu. Symp. Comput.-Human Interaction Play Companion*, Austin, TX, USA, Oct. 2016, pp. 315–323, doi: 10.1145/2968120.2987729.

[73] R. van Roy and B. Zaman, "Why gamification fails in education and how to make it successful: Introducing nine gamification heuristics based on self-determination theory," in *Serious Games and Edutainment Applications*, M. Ma and A. Oikonomou, Eds. Cham, Switzerland: Springer, 2017, pp. 485–509, doi: 10.1007/978-3-319-51645-5_22.

[74] T. Laine and C. I. Sedano, "Distributed pervasive worlds: The case of exergames," *Educ. Technol. Soc.*, vol. 18, no. 1, pp. 50–66, Jan. 2015.

[75] M. Böckle, I. Micheel, M. Bick, and J. Novak, "A design framework for adaptive gamification applications," in *Proc. 51st Hawaii Int. Conf. Syst. Sci.*, Jan. 2018, pp. 1227–1236, doi: 10.24251/HICSS.2018.151.

[76] Y.-R. Shi and J.-L. Shih, "Game factors and game-based learning design model," *Int. J. Comput. Games Technol.*, vol. 2015, pp. 1–11, Jul. 2015, doi: 10.1155/2015/549684.

[77] B. Huang and K. F. Hew, "Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts," *Comput. Educ.*, vol. 125, pp. 254–272, Oct. 2018, doi: 10.1016/j.compedu.2018.06.018.

[78] S. Arnab *et al.*, "Mapping learning and game mechanics for serious games analysis," *Brit. J. Educ. Technol.*, vol. 46, no. 2, pp. 391–411, Mar. 2015, doi: 10.1111/bjet.12113.

[79] R. Hunicke, M. LeBlanc, and R. Zubek, "MDA: A formal approach to game design and game research," in *Proc. Challenges Game AI Workshop*, San Jose, CA, USA, Jul. 25–26, 2004, pp. 1–5.

[80] C. Harteveld, R. Guimarães, I. S. Mayer, and R. Bidarra, "Balancing play, meaning and reality: The design philosophy of LEVEE PATROLLER," *Simul. Gaming*, vol. 41, no. 3, pp. 316–340, Jun. 2010, doi: 10.1177/1046878108331237.

[81] Y. Wang, P. Rajan, C. S. Sankar, and P. K. Raju, "Let them play: The impact of mechanics and dynamics of a serious game on student perceptions of learning engagement," *IEEE Trans. Learn. Technol.*, vol. 10, no. 4, pp. 514–525, Oct.–Dec. 2017.

[82] M. Ney, C. Goncalves, and N. Balacheff, "Design heuristics for authentic simulation-based learning games," *IEEE Trans. Learn. Technol.*, vol. 7, no. 2, pp. 132–141, Apr.–Jun. 2014.

[83] V. Wendel, M. Gutjahr, S. Göbel, and R. Steinmetz, "Designing collaborative multiplayer serious games: Escape from Wilson Island—A multiplayer 3D serious game for collaborative learning in teams," *Educ. Inf. Technol.*, vol. 18, no. 2, pp. 287–308, Jun. 2013, doi: 10.1007/s10639-012-9244-6.

[84] W. Ijsselsteijn, H. H. Nap, Y. de Kort, and K. Poels, "Digital game design for elderly users," in *Proc. Conf. Future Play*, Nov. 2007, pp. 17–22, doi: 10.1145/1328202.1328206.

[85] B. Marne, J. Wisdom, B. Huynh-Kim-Bang, and J.-M. Labat, "The six facets of serious game design: A methodology enhanced by our design pattern library," in *21st Century Learning for 21st Century Skills*, vol. 7563, D. Hutchison *et al.*, Eds. Heidelberg, Germany: Springer-Verlag, 2012, pp. 208–221, doi: 10.1007/978-3-642-33263-0_17.

[86] T. Laine and H. J. Suk, "Designing mobile augmented reality exergames," *Games Culture*, vol. 11, no. 5, pp. 548–580, Jul. 2016, doi: 10.1177/1555412015572006.

[87] F. Groh, "Gamification: State of the art definition and utilization," in *Proc. 4th Sem. Res. Trends Media Informat.*, Ulm, Germany, Feb. 14, 2012, pp. 39–46.

[88] K. Starks, "Cognitive behavioral game design: A unified model for designing serious games," *Frontiers Psychol.*, vol. 5, pp. 1–10, Feb. 2014, doi: 10.3389/fpsyg.2014.00028.

[89] L. Shaw, B. Wunsche, C. Lutteroth, S. Marks, and R. Callies, "Challenges in virtual reality exergame design," in *Proc. 16th Australas. User Interface Conf.*, Jan. 27–30, 2015, pp. 61–68.

[90] D. Pinelle and N. Wong, "Heuristic evaluation for games: Usability principles for video game design," in *Proc. 26th Annu. Conf. Human Factors Comput. Syst.*, Florence, Italy, Apr. 2008, pp. 1453–1462, doi: 10.1145/1357054.1357282.

[91] A. S. Miller, J. A. Cafazzo, and E. Seto, "A game plan: Gamification design principles in mHealth applications for chronic disease management," *Health Informat. J.*, vol. 22, no. 2, pp. 184–193, Jun. 2016, doi: 10.1177/1460458214537511.

[92] H. Zhang, Z. Shen, J. Lin, Y. Chen, and Y. Miao, "Familiarity design in exercise games for elderly," *Int. J. Inf. Technol.*, vol. 22, no. 2, pp. 1–19, Nov. 2016.

[93] J. Nielsen and R. L. Mack, Eds., *Usability Inspection Methods*. New York, NY, USA: Wiley, 1994.

[94] A. Rapp, "Designing interactive systems through a game lens: An ethnographic approach," *Comput. Human Behav.*, vol. 71, pp. 455–468, Jun. 2017, doi: 10.1016/j.chb.2015.02.048.

[95] M. Bond and R. Beale, "What makes a good game? Using reviews to inform design," in *Proc. 23rd Brit. HCI Group Annu. Conf. People Comput.: Celebrating People Technol.*, Cambridge, U.K., Sep. 2009, pp. 418–422, doi: 10.1145/1671011.1671065.

[96] J. H. Hardy, A. M. Ness, and J. Mecca, "Outside the box: Epistemic curiosity as a predictor of creative problem solving and creative performance," *Pers. Individual Differences*, vol. 104, pp. 230–237, Jan. 2017, doi: 10.1016/j.paid.2016.08.004.

[97] W. Westera, R. Nadolski, H. Hummel, and I. Wopereis, "Serious games for higher education: A framework for reducing design complexity," *J. Comput. Assisted Learn.*, vol. 24, no. 5, pp. 420–432, Sep. 2008, doi: 10.1111/j.1365-2729.2008.00279.x.

[98] M. F. Story, "Maximizing usability: The principles of universal design," *Assistive Technol.*, vol. 10, no. 1, pp. 4–12, Jun. 1998, doi: 10.1080/10400435.1998.10131955.

[99] B. Morschheuser, L. Hassan, K. Werder, and J. Hamari, "How to design gamification? A method for engineering gamified software," *Inf. Softw. Technol.*, vol. 95, pp. 219–237, Mar. 2018, doi: 10.1016/j.infsof.2017.10.015.

[100] M. Resnick, "Edutainment? No thanks. I prefer playful learning," *Associazone Civita Rep. Edutainment*, vol. 14, pp. 1–4, 2004.

[101] Y. Y. R. Lee, H. Samad, and Y. M. Goh, "Perceived importance of authentic learning factors in designing construction safety simulation game-based assignment: Random forest approach," *J. Construction Eng. Manage.*, vol. 146, no. 3, Mar. 2020, p. 04020002, doi: 10.1061/(ASCE)CO.1943-7862.0001779.

[102] A. H. Maslow and R. Frager, *Motivation and Personality*, 3rd ed. New York, NY, USA: Harper & Row, 1987.

[103] D. Lordly, "Once upon a time... storytelling to enhance teaching and learning," *Can. J. Dietetic Pract. Res.*, vol. 68, no. 1, pp. 30–35, Apr. 2007, doi: 10.3148/68.1.2007.30.

[104] M. Alterio, *Learning Through Storytelling in Higher Education: Using Reflection & Experience to Improve Learning*. London, U.K.: Kogan Page, 2003, doi: 10.4324/9780203416655.

[105] D. Bormann and T. Greitemeyer, "Immersed in virtual worlds and minds: Effects of in-game storytelling on immersion, need satisfaction, and affective theory of mind," *Social Psychol. Pers. Sci.*, vol. 6, no. 6, pp. 646–652, Aug. 2015, doi: 10.1177/1948550615578177.

[106] G. Kaufman, M. Flanagan, and M. Seidman, "Creating stealth game interventions for attitude and behavior change: An 'embedded design' model," *Trans. Digit. Games Res. Assoc.*, vol. 2, no. 3, pp. 173–193, Dec. 2016, doi: 10.26503/todigra.v2i3.57.

[107] A. Amory, "Game object model version II: A theoretical framework for educational game development," *Educ. Technol. Res. Develop.*, vol. 55, no. 1, pp. 51–77, Feb. 2007, doi: 10.1007/s11423-006-9001-x.

[108] K. Mitgutsch and N. Alvarado, "Purposeful by design? A serious game design assessment framework," in *Proc. 13th Int. Conf. Digit. Games*, 2012, pp. 121–128, doi: 10.1145/2282338.2282364.

[109] M. Habgood, "The effective integration of digital games and learning content," Doctoral dissertation, Learn. Sci. Res. Inst., Univ. Nottingham, Nottingham, U.K., 2007.

[110] I. Rodriguez, A. Puig, S. Grau, and M. Escayola, "Designing a math game for children using a participatory design experience," in *Proc. 8th Int. Conf. Adv. Human-Oriented Pers. Mech., Technol., Serv.*, Barcelona, Spain, Nov. 15–20, 2015, pp. 28–35.

[111] K. Werbach and D. Hunter, *For the Win: How Game Thinking Can Revolutionize Your Business*. Philadelphia, PA, USA: Wharton Digit. Press, 2012.

[112] F. S. da Conceicao, A. P. da Silva, A. Q. d. O. Filho, and R. C. S. Filho, "Toward a gamification model to improve it service management quality on service desk," in *Proc. IEEE 9th Int. Conf. Qual. Inf. Commun. Technol.*, Guimaraes, Portugal, Sep. 2014, pp. 255–260.

[113] F. Bellotti, R. Berta, A. De Gloria, A. D'ursi, and V. Fiore, "A serious game model for cultural heritage," *J. Comput. Cultural Heritage*, vol. 5, no. 4, pp. 1–27, Dec. 2012, doi: 10.1145/2399180.2399185.

[114] E. Herranz and R. Colomo-Palacios, "Gamification as a disruptive factor in software process improvement initiatives," *J. Universal Comput. Sci.*, vol. 20, no. 6, pp. 885–906, Jun. 2014, doi: 10.3217/jucs-020-06-0885.

[115] I. Chow and L. Huang, "A software gamification model for cross-cultural software development teams," in *Proc. Int. Conf. Manage. Eng., Softw. Eng. Serv. Sci.*, Wuhan, China, Jan. 2017, pp. 1–8, doi: 10.1145/3034950.3034955.

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