This is the accepted manuscript. Please refer to the final paper via https://doi.org/10.1016/j.chb.2021.106963.

Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning

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Abstract

Despite increasing scientific interest in explaining how gamification supports positive affect and motivation, behavior change and learning, there is still a lack of an overview of the current theoretical understanding of the psychological mechanisms of gamification. Previous research has adopted several different angles and remains fragmented. Taking both an observational and explanatory perspective, we examined the theoretical foundations used in research on gamification, serious games and game-based learning through a systematic literature review and then discussed the commonalities of their core assumptions. The overview shows that scientists have used a variety of 118 different theories. Most of them share explicitly formulated or conceptual connections. From their interrelations, we derived basic principles that help explain how gamification works: Gamification can illustrate goals and their relevance, nudge users through guided paths, give users immediate feedback, reinforce good performance and simplify content to manageable tasks. Gamification mechanics can allow users to pursue individual goals and choose between different progress paths, while the system can adapt complexity to the user's abilities. Social gamification elements may enable social comparison and connect users to support each other and work towards a common goal.

1. Introduction

Games are a crucial aspect of human culture and society and promote motivation and engagement (Bozkurt & Durak, 2018). This is why the mechanics of gaming are increasingly transferred to generally game-free contexts, such as primary and secondary school education (e.g. Ioannou, 2019; Rachels & Rockinson-Szapkiw, 2018; Zainuddin, 2018), adult and higher education (e.g. Barata et al., 2017; Huang & Hew, 2018; Huang et al., 2019) healthcare and fitness (e. g. Orji & Moffatt, 2018; Sardi et al., 2017), the workplace (e.g. Passalacqua et al., 2020;

Perryer et al., 2016) or consumer behavior (e.g. Morganti et al., 2017; Tobon et al., 2020), to promote desired motivational, behavior and learning outcomes (Zainuddin et al., 2020).

Gamification, denoting the above-mentioned use of game elements in non-game contexts (Deterding et al., 2011), is linked to effects on affect and motivation (e.g. Albertazzi et al., 2019; Ding et al., 2017; Hamari et al., 2014; Koivisto & Hamari, 2019), on behavior, e.g., academic achievement and engagement (e.g. (Barata et al., 2017; Huang et al., 2019; Koivisto & Hamari, 2019; Putz et al., 2020; Zainuddin, 2018) and on (cognitive) learning (e.g. Connolly et al., 2012; Vlachopoulos & Makri, 2017). However, results are sometimes ambiguous (Hamari et al., 2014; Sailer & Homner, 2020), for instance concerning the effect of gamification on intrinsic or extrinsic motivation (e.g. Biles et al., 2014; Hanus & Fox, 2015; Mekler et al., 2017) or enjoyment (Koivisto & Hamari, 2019). Gamification is thus not effective per se (Sailer et al., 2017). Rather, the design of effective gamified interventions, which also include serious games and game-based learning, requires theoretical knowledge of hitherto unexplored cognitive, emotional and motivational mechanisms through which gamification achieves its impact (Cheng et al., 2015; Koivisto & Hamari, 2019; Sailer & Homner, 2020) to successfully decide on appropriate structures, mechanics and principles (Dichev & Dicheva, 2017). Scientific studies increasingly investigate the use of different theoretical foundations such as motivation, behavior, or learning theories to explain the effect of certain gamification elements or design gamification (Nacke & Deterding, 2017). However, existing reviews on gamification, serious games and game-based learning, in which the scope is naturally determined by the application context and the focus of the review in terms of content, so far do not reflect the entire diverging theoretical landscape. Albeit only a synthesis of the fragmented considerations from different disciplines leads to the depiction of the current state of theory in research and the identification of theoretical commonalities and basic principles that help explain how gamification works.

The gap of a comprehensive overview and analysis of theoretical foundations in gamification research requires a systematic investigation of the theories used to explain, design and evaluate gamification to guide future theoretical and empirical research. Consequently, this meta-review – a review of reviews in contrast to the analysis of primary research studies (Gough et al., 2017) – is the first to explicitly focus on the theoretical basis of gamification and aims to *identify the theoretical foundations* used in primary studies mentioned in reviews on gamification, serious games and game-based learning both in general and in specific domains. In addition, it aims to *compare and interlink the identified theoretical foundations* to create an overview of the theoretical research landscape, *discuss the common principles of how gamification works* and open up avenues for further theory development. Thus, starting from an observational perspective, the theories presented and their popularity in gamification research are reviewed, followed by a shift to an explanatory perspective, through which the relationships and commonalities of the identified theoretical foundations are analyzed. This ultimately leads to the derivation of basic theoretical principles from the underlying foundations that help explain the effects of gamification and support successful gamification design.

2. Background and Previous Research

2.1 Game, Gamification, Serious Games and Game-based Learning

A *game* refers to a structured play with rules, goals and challenges for the purpose of entertainment (Cheng et al., 2015). The term *gamification* first emerged in 2008 and gained increasing relevance since the 2010s (Deterding et al., 2011; Seaborn & Fels, 2015). In contrast to games, gamification is characterized by its serious purpose. Definitions of gamification vary and usually focus either on game elements and mechanics or the process of gaming and gameful experiences in serious contexts. Deterding et al. (2011, p. 11) define gamification as the "use of game elements in non-game contexts". Game elements are, for example, levels, points, badges, leader boards, avatars, quests, social graphs, or certificates (Zainuddin et al., 2020). Kapp et al., (2014, p. 54) highlight the usage of "game-based mechanics, aesthetics, and game-thinking to engage people, motivate action, promote learning, and solve problems". Zichermann and Cunningham (2011, p. xiv) denote gamification as "the process of game-thinking and game mechanics to engage and solve problems". Synthesizing these different perspectives, Seaborn and Fels (2015) state a possible standard definition, namely gamification as "the intentional use of game elements for a gameful experience of non-game tasks and contexts" (Seaborn & Fels, 2015, p. 17). Gamification mechanics, such as rewards and loyalty programs in marketing and grades in schools, were already used long before the emergence of the gamification research area at the beginning of the decade. More recently, the concept has been transferred and adapted to different contexts, such as education in general, the workplace and health, perhaps due to cheaper technology, tracking of personal data, the game studies movement and the general prevalence of video games as a medium (Seaborn & Fels, 2015).

Gamification is closely related to two other concepts: serious games and game-based learning. *Game-based learning* refers to the achievement of defined learning outcomes through game content and play and enhancing learning by involving problem-solving spaces and challenges that provide learners, who are also players, with a sense of achievement (Qian & Clark, 2016). Game-based learning intends to educate. It relies on a fully-fledged game, commonly named *serious game*. Beyond education, serious games (Abt, 1970) are games intended for a variety of serious purposes, for example in industry, training, or stimulation (Alsawaier, 2018; Connolly et al., 2012). Even though serious games and game-based learning differ from gamification because they are full-featured games (Deterding et al., 2011), while gamification as a broader concept only utilizes components of games and applies them to the real environment, all concepts share the idea of using positive gameful experiences for the sake of a serious purpose, for example, education or behavior change, rather than focusing on entertainment.

2.2 Effects and Outcomes of Gamification, Serious Games and Game-based Learning

When investigating the outcomes of gamification, serious games or game-based learning, scholars typically distinguish between behavioral outcomes, (cognitive) learning outcomes, and either affective outcomes (Carenys & Moya, 2016; Lamb et al., 2018), motivational outcomes (Sailer & Homner, 2020) or both (Connolly et al., 2012; Ekici, 2021). Motivational outcomes are sometimes also classified as a subcategory of affective outcomes (Dichev

& Dicheva, 2017; Vlachopoulos & Makri, 2017), similar to the distinction in Bloom's taxonomy of educational objectives (Bloom, 1956).

Affective and motivational outcomes. One of the reasons why gamification, serious games and game-based learning have become so popular is that gaming is considered as motivating (Bai et al., 2020). Motivation explains the "why" of human behavior: it describes all internal processes giving behavior its energy and direction (Reeve, 1996). Motivation is a hypothetical construct that manifests in behavior and can lead to positive cognitive outcomes such as improved learning and achievement (e.g. Keller, 2008). In the educational context, high-quality motivation, for example intrinsic motivation, is connected to better outcomes than low-quality motivation, e.g., motivation through extrinsic rewards (e.g. Deci & Ryan, 1985; Ryan & Deci, 2020). Previous research largely supports a positive relationship between the use of serious games (Connolly et al., 2012; Kordaki & Gousiou, 2017; Vlachopoulos & Makri, 2017) or gamification (Dichev & Dicheva, 2017; Ekici, 2021; Koivisto & Hamari, 2019; Sailer & Homner, 2020) and motivational outcomes. However, some studies report contradictory results (e.g. Hamari et al., 2014; Hanus & Fox, 2015; Mekler et al., 2017; Sailer & Homner, 2020; Zimmerling et al., 2019). Beyond motivation, affect as a psychophysiological construct includes the dimensions of valence, an evaluation of the subjectively experienced state, and arousal, a measure of activation that can be considered as a proxy for motivation (Harmon-Jones et al., 2013). Further affective outcomes of gamification, serious games and game-based learning that can be attributed to the valence dimension include satisfaction (Boyle et al., 2016; Vlachopoulos & Makri, 2017) and positive attitudes towards the game (Vlachopoulos & Makri, 2017) or the gamified subject (Ekici, 2021), enjoyment (Ab Jalil et al., 2020; Koivisto & Hamari, 2019; Kordaki & Gousiou, 2017), immersion (Connolly et al., 2012) and flow (Koivisto & Hamari, 2019; Lamb et al., 2018).

Behavioral outcomes. In diverse contexts like education (Connolly et al., 2012; Jarnac de Freitas & Mira da Silva, 2020; Kordaki & Gousiou, 2017; Sailer & Homner, 2020; Vlachopoulos & Makri, 2017), employee training (Obaid et al., 2020), software development (Alhammad & Moreno, 2020), innovation (Patrício et al., 2018) or energy conservation (Johnson et al., 2017), motivating effects of gamification, serious games and game-based learning are consistently accompanied by positive behavioral outcomes. These include engagement and participation (Dichev & Dicheva, 2017; Ekici, 2021; Jarnac de Freitas & Mira da Silva, 2020), social collaboration and teamwork (Kordaki & Gousiou, 2017; Vlachopoulos & Makri, 2017) and measurable performance improvements in academic and work tasks (Bai et al., 2020; Koivisto & Hamari, 2019; Liu et al., 2018; McKeown et al., 2016). Because of these positive effects, gamification is increasingly adopted in various use cases to promote behavioral change, for example towards engagement in pro-environmental behavior (e.g. Du et al., 2020; Ro et al., 2017), physical activity (e.g. Dadaczynski et al., 2017; Lier & Breuer, 2019) or knowledge transfer (e.g. Holzer et al., 2020; Mizuyama et al., 2019).

(Cognitive) learning outcomes. In addition, gamification, serious games and game-based learning contribute to a variety of learning outcomes (Behnamnia et al., 2020; Sailer & Homner, 2020; van Gaalen et al., 2021), most of which are cognitive in nature. Cognition can be understood as a set of processes and mechanisms by which an individual understands the world through reasoning and problem-solving (Lamb et al., 2018; Zimmerman &

Croker, 2014). Studies report on significant improvements in critical thinking (Qian & Clark, 2016), creative thinking (Behnamnia et al., 2020; Qian & Clark, 2016), knowledge acquisition and content understanding (Connolly et al., 2012; Vlachopoulos & Makri, 2017) and perceptual skills (Connolly et al., 2012; Lamb et al., 2018; Vlachopoulos & Makri, 2017). However, certain mixed results on learning outcomes suggest that only the combination with affective and motivational outcomes leads to cognitive learning outcomes that result in successful academic performance improvement (Bai et al., 2020; Qian & Clark, 2016).

2.3 Theoretical Foundations of Gamification, Serious Games and Game-based Learning

As presented, considerable research efforts have already been made to investigate *whether* gamification leads to noticeable benefits, such as an increase in cognitive learning outcomes or work task performance, but there is still a lack of understanding regarding *how* gamification leads to these outcomes (Nacke & Deterding, 2017). Using conceptual propositions as a basis, such as the foundations of game-based learning in which Plass, Homer and Kinzer argue that various affective, motivational, cognitive and sociocultural foundations, e.g. situated learning theory (Brown et al., 1989; Lave & Wenger, 1991), achievement goal theory (Elliot & McGregor, 2001), social cognitive theory (Bandura, 1986) and activity theory (Vygotsky, 1978) provide the basis for the successful design of game-based learning (Plass et al., 2015), scientific studies have recently begun to employ theoretical foundations to design, explain and evaluate their gamified interventions. However, existing reviews do not fully display the diversity of the theories applied in different contexts. For example, Seaborn and Fels (2015) note the use of self-determination theory (Ryan & Deci, 2000b), situational relevance theory (Wilson, 1973) and the transtheoretical model of behavior change (Prochaska & Velicer, 1997) as prevalent foundations in primary gamification studies, whereas in contrast, Martí-Parreño et al. (2016) mention cognitive load theory (Sweller, 1988), the ARCS motivational model (Keller, 1987) and the technology acceptance model (Davis, 1989) as important theoretical foundations in gamification research. Dichev and Dicheva (2017), on the other hand, review gamification in the educational context and emphasize Lander's theory of gamified learning (Landers, 2014) as an important theoretical treatise in scientific studies, which includes self-determination theory, goal-setting theory (Locke, 1968; Locke & Latham, 2002) and behavior reinforcement theory (Skinner, 1957). Thus, regarding the theoretical foundations of gamification, serious games and game-based learning, these results illustrate the controversy and lack of an overview of the theories that are used as a basis for scientific research on gamification in different contexts, and about their implications for explaining the way gamification achieves the observed positive results.

In addition, there is a scarcity of research to explain certain mixed and conflicting results regarding the effects of game elements on motivational and affective, behavioral, and learning outcomes (e.g. Hamari et al., 2014; Mekler et al., 2017; Sailer & Homner, 2020; Zimmerling et al., 2019). For example, some studies display ambiguous results regarding effects on the focus group (e.g. Hanghøj et al., 2018) or the influence of specific gamification mechanics (e.g. Facey-Shaw et al., 2020). Accordingly, gamification does not seem to be a "silver-bullet type of solution" for achieving positive outcomes (Koivisto & Hamari, 2019, p. 201), and is not effective per se (Sailer et al., 2017). It is all the more important to understand the factors contributing to successful

gamification, because in spite of the increasing adoption of theoretical foundations in research, they remain unresolved (Sailer & Homner, 2020). Insufficient knowledge about the psychological mechanisms through which gamification, serious games and game-based learning produce their effects (Cheng et al., 2015; Koivisto & Hamari, 2019; Sailer & Homner, 2020) hampers the selection of appropriate gamification structures, mechanics and principles to obtain the desired outcomes (Dichev & Dicheva, 2017). Although more recently, advances in explaining the impacts of certain gamification elements and designing gamification through the use of different theories have been made (Nacke & Deterding, 2017), further research synthesizing the principle assumptions of the theoretical foundations in use is crucial to understand how gamification, serious games and game-based learning can be designed in diverse contexts (Dichev & Dicheva, 2017; Sailer & Homner, 2020).

Therefore, this paper aims at answering the questions which theories have so far been used as foundations in research on gamification, serious games and game-based learning, how they relate to each other through core assumptions, and which basic principles can be derived that help explain how gamification achieves its effects.

3. Systematic Review Method

Systematic reviews give a methodical, replicable, and transparent overview over the complex field of literature to topics such as gamification. They provide an overall impression of the extent, nature and quality of evidence regarding the research question in focus. Thereby, they help to draw robust and broad implications for theory and future research (Siddaway et al., 2019). Meta-reviews, also called umbrella reviews, are reviews of existing reviews (Gough et al., 2017) and represent an appropriate methodological choice when there are already a large number of systematic reviews addressing the same or a very similar research question, with a concomitant increase in discordant findings (Paré et al., 2015). As explained, this is the case for existing reviews on theoretical foundations in gamification, serious games, and game-based learning. Specifically, the goal of a meta-review is to assemble the results of qualitative studies on a topic to locate core concepts or theories that provide new or stronger explanations for a particular phenomenon (Thorne et al., 2004) and to compile the available evidence on a specific research focus into a summary (Paré et al., 2015). Hence, we identified the method of a systematic meta-review as appropriate to answer the following primary research question by synthesizing the results of existing systematic literature reviews:

What are theoretical foundations used in research on gamification, serious games and game-based learning?

The review is conducted according to the ROSES Reporting standards for Systematic Evidence Syntheses, which advances the widely recognized PRISMA standard for meta-analyses from medical research (Moher et al., 2009), which focuses merely on quantitative data syntheses, into a new standard for narrative, qualitative and mixed methods syntheses (Haddaway et al., 2018).

Search strategy. For the identification of relevant literature, nine scientific databases were searched, namely the Web of Science Core Collection, EBSCO Host (APA PsychArticles, APA PsychInfo, Business Source Premier), Wiley Online, EmeraldInsight, ScienceDirect, JSTOR, SagePub, IEEE Explore and Taylor & Francis. The following search string was employed to gather review studies on gamification, serious games or game-based learning either in

general or related to specific outcomes, i.e. affect, motivation, behavior or learning: *(("Gamification" OR "Serious Gaming" OR "Serious Games" OR "Game-based learning") AND ((motivation* AND "theories") OR (behavior* AND "theories") OR (learning* AND "theories") OR (affect* AND "theories") OR "theoretical foundations" OR "theoretical perspectives" OR "theoretical frameworks" OR "theoretical approaches" OR (systematic* AND "review") OR "meta-analysis")) OR "Gamification theories".* The pluralistic version of *"theory"*, *"perspective"*, *"framework"* and *"approach"* has been used to exclude articles that mention only a single theoretical basis of their own work (e.g., a review of outcomes in game-based learning from a self-determination theory perspective) and to focus on review studies that systematically analyze theoretical underpinnings of multiple papers, since the main goal is to provide a comprehensive overview of the use of different theoretical foundations in scientific research. The search string was employed for title, abstract, and author keyword search, considering all articles published up to April 2021.

Screening strategy and inclusion criteria. According to the ROSES standard (Haddaway et al., 2018), the screening was carried out in three steps: Title screening, abstract screening, and full-text screening. To ensure research quality, only peer-reviewed journal articles and peer-reviewed conference papers were included in the final sample, while book chapters, not peer-reviewed journal articles and other grey literature were excluded. The reasons why conference papers were considered are that they account for a significant proportion of citations in computer science and research on human-computer interaction (Michels & Fu, 2014) and that the identification of articles from conference proceedings is generally recognized as good practice in systematic reviews (Scherer & Saldanha, 2019). Only English articles were included. Furthermore, the studies were included if they consisted of a systematic review or if they were a mixed-method study that contained a systematic review of scientific literature on gamification, serious gaming, or game-based learning, in which the theoretical foundations used in the reviewed sample were examined. Accordingly, empirical studies only referring to their own approach, reviews focusing on practical gamified applications such as smartphone apps or games, reviews on video games, and reviews only mentioning theories in their introduction or background but not examining the theoretical foundations of their sample studies or completely disregarding the theoretical perspective, were excluded during the screening process. The inclusion and exclusion criteria for the article screening are summarized in Table 1.

Table 1
Inclusion and exclusion criteria for the review on theoretical foundations in gamification research.

Criterion	Included	Excluded
Language	English	Other languages, e. g. Spanish, German, Russian, Korean, Chinese, Japanese
Publication type	Peer-reviewed journals, peer-reviewed conference papers	Book chapters, magazine articles, reports, theses, other grey literature
Type of study	Systematic literature review, mixed methods study containing a systematic literature review	Empirical studies, reviews of practical gamified applications or software
Study topic	Gamification, serious games, game-based learning	Video games
Study content	Examination of theoretical foundations used in the review sample	Theoretical foundations only mentioned in the introduction or background or not mentioned at all

Critical appraisal strategy. For the critical appraisal of the reviewed studies, the following criteria were checked for each individual study:

1. Did the authors formulate at least one clear research question or research goal?
2. Did the authors describe their method for the systematic review?
    a. search string(s)
    b. search results
    c. inclusion and exclusion criteria
    d. number of included studies
3. Did the authors answer their research question(s)/goal(s) properly?

Secondly, the publications were checked for their CORE journal rank, their Scientific Journal Ranking (SJR) and their Journal Impact Factor (JIF) to critically appraise the quality of the entire review sample.

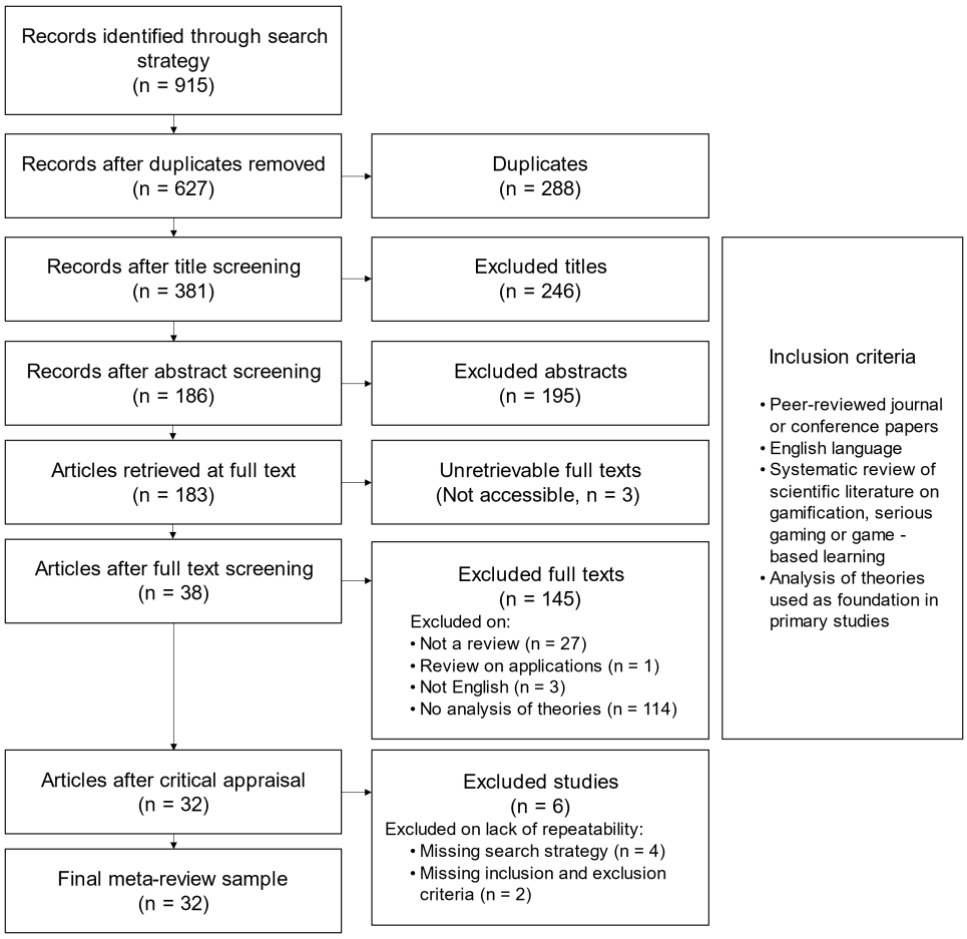

Fig. 1. **Selection process:** Flow diagram for the selection of studies in the systematic review on theoretical foundations in gamification research (2- column).

Fig. 1 illustrates the result of the search strategy and the screening process. By applying the search string to the scientific databases, 973 records were identified, of which 915 remained through filtering for peer-reviewed articles and conference papers. After the duplicate removal, 627 records remained for screening. Of this sample, 246 records were excluded after the title screening, 195 records after the abstract screening and three full texts

could not be retrieved so that 183 articles were considered for the full-text screening. During the full-text screening, 145 articles were excluded because they did not meet the specified inclusion criteria. This resulted in 38 articles remaining for critical appraisal, of which six articles were discarded due to lack of repeatability, as they either did not describe their literature search strategy (four studies) or lacked a definition of the inclusion and exclusion criteria (two studies). Every screening step was checked for consistency by the second author with at least 20% of the respectively remaining sample, i.e., 125 for title screening, 76 for abstract screening, and 36 for full-text screening according to the inclusion criteria, and 19 of 38 remaining full texts were double-checked for critical appraisal. The intercoder agreement rate was 95,2% for titles, 88,1% for abstracts, 94,6% for full-texts and 89,5% for critical appraisal. Disagreements between the two coders were resolved through discussion and detailed further review of the disputed reviews. For reasons of reproducibility, the entire list of excluded full texts is attached in Appendix A. In summary, 32 reviews remained for data extraction and synthesis.

Data extraction strategy. Metadata such as title, year of publication, authors, publication type (journal or conference proceedings) and publication name of the articles were extracted with Mendeley Reference Manager and manually checked upon import. In addition, qualitative data extraction involved inductively encoding the application context of the review, the theoretical foundations mentioned in the review using abbreviations (the full coding list of abbreviations is attached in Appendix B) and summing up the number of studies applying a particular theoretical foundation, provided that the total number was given by the analyzed review. Although five of the reviews did not note the number of studies employing a particular theory, the popularity of different theoretical foundations could be assessed based on the available data, so that the missing data was not explicitly obtained from the review authors. Furthermore, a coding scheme for the classification of the identified theoretical foundations was developed based on the three main outcomes of gamification, i.e. affect and motivation, behavior and learning (attached in Appendix C), inspired by the distinction of previous reviews, the categorization of Plass et al. (2015) and Bloom's taxonomy (Bloom, 1956). 20% of the reviews were double-coded by the second author, with an intercoder agreement rate of 85% and Cohen's kappa $\kappa = 0.84775$ for the coding of the theoretical foundations and an intercoder agreement rate of 100%, $\kappa = 1$ for the classification of the identified theoretical foundations. Any disagreements between the two coders were resolved through discussion and detailed joint review of the coded theoretical foundations in question.

4. Results

We first narratively report on the quality of the reviewed sample, the years of publication, the topics, and the application contexts of the reviewed articles, followed by the qualitative analysis of theoretical foundations mentioned in research on gamification, serious games and game-based learning.

4.1 Sample quality, topics, and application contexts

In critical appraisal of the sample's quality, it can be stated that all the reviews included were published in peer-reviewed journals, most of which are ranked highly in the Scientific Journal Ranking (SJR) and Journal Impact Factor (JIF). 18 of 32 reviews were published in the first quartile of their respective research area, mostly human-

computer interaction, computer science, pedagogy, and psychology (see Table 2 for the comprehensive overview).

Table 2
Journals and their ranking for the critical appraisal of the review sample.

Included reviews	Journal	CORE	JIF 2018	SJR H-Index	SJR Quartile
(Boyle et al., 2016; Kordaki & Gousiou, 2017)	Computers and Education	-	7.85	164	Q1
(Zainuddin et al., 2020)	Educational Research Review	-	7.19	57	Q1
(Qian & Clark, 2016)	Computers in Human Behavior	-	5.88	155	Q1
(Tobon et al., 2020)	Decision Support Systems	-	5.42	138	Q1
(Martí-Parreño et al., 2016; Wu et al., 2012)	Journal of Computer Assisted Learning	-	3.90	86	Q1
(Chan et al., 2019)	PeerJ Computer Science	-	3.67	18	Q1
(Chau et al., 2018)	International Journal of Medical Informatics	A	3.59	99	Q1
(Abraham et al., 2020; Thomas et al., 2020)	JMIR Serious Games	-	3.526	-	-
(DeSmet et al., 2014)	Preventive Medicine	-	3.47	164	Q1
(Klock et al., 2020; Seaborn & Fels, 2015)	International Journal of Human-Computer Studies	A	3.16	116	Q1
(Dichev & Dicheva, 2017)	International Journal of Educational Technology in Higher Education	-	2.99	22	Q1
(van Gaalen et al., 2021)	Advances in Health Sciences Education	-	2.75	60	Q1
(Li & Tsai, 2013)	Journal of Science Education and Technology	-	2.58	56	Q1
(Mora et al., 2017)	Journal of Computing in Higher Education	-	2.46	31	Q1
(Gao et al., 2020)	Education Technology Research and Development	-	2.30	84	Q1
(Holtz et al., 2018)	Games for Health Journal	-	2.22	26	Q2
(Behnamnia et al., 2020)	Thinking Skills and Creativity	-	2.07	36	Q1
(Orji & Moffatt, 2018)	Health Informatics Journal	C	1.90	37	Q2
(Hallinger & Wang, 2020a)	Simulation and Gaming	-	1.71	57	Q2
(Bozkurt & Durak, 2018)	International Journal of Game-Based Learning	-	1.43	15	Q2
(Carenys & Moya, 2016)	Accounting Education	-	1.38	35	Q2
(Kalogiannakis et al., 2021)	Education Sciences	-	1.19	7	Q3
(Jarnac de Freitas & Mira da Silva, 2020)	Open Learning	-	1.03	33	Q2
(Ab Jalil et al., 2020)	International Journal of Emerging Technologies in Learning	-	1.00	19	Q3
(da Silva et al., 2019)	BAR - Brazilian Administration Review	-	0.40	14	Q4
(Bakan & Bakan, 2018)	Actualidades Pedagogicas	-	-	-	-
(Gris & Bengtson, 2021)	International Journal of Serious Games	-	-	-	-
(Cheng et al., 2015)	Journal of Computers in Education	-	-	2	-

The first review explicitly mentioning theoretical foundations used in studies on serious games appeared in 2013 (Li & Tsai, 2013). Since then, the number of reviews analyzing the use of theory in empirical research demonstrates continuous scientific interest in the field of gamification, serious gaming, and game-based learning, with 12 of 32 reviews published in 2020 and 2021. Most of the reviews either focus on game-based learning or gamification in the application context of education (16 reviews). The second topic focus (8 reviews) consists of reviews on serious games, gamification and game-based learning in healthcare and fitness, followed by seven reviews on gamification, serious games and game-based learning in general, without a specific use case. In addition, one review dealt with gamification and online consumer decisions.

4.2 Theoretical foundations in research on gamification and serious games

This meta-review shows that empirical studies on gamification, serious games and game-based learning have so far used a variety of 118 different theories. Some theoretical foundations are considerably more popular than others, of which the most popular one (self-determination theory) is used in 82 different studies and the least popular ones are applied to only one study to date. Table 3 outlines all the theories mentioned in the analyzed reviews, together with the total number of primary research studies conducted based on each theory.

Table 3
Theoretical foundations mentioned in the analyzed review studies.

Theoretical foundation	Reviews mentioning theory	Sum of studies using theory
Self-determination theory	(Ab Jalil et al., 2020; Bakan & Bakan, 2018; Behnamnia et al., 2020; Bozkurt & Durak, 2018; Chan et al., 2019; Chau et al., 2018; da Silva et al., 2019; Dichev & Dicheva, 2017; Gris & Bengtson, 2021; Jarnac de Freitas & Mira da Silva, 2020; Kalogiannakis et al., 2021; Mora et al., 2017; Orji & Moffatt, 2018; Seaborn & Fels, 2015; Thomas et al., 2020; Tobon et al., 2020; Zainuddin et al., 2020)	82
Flow theory	(Ab Jalil et al., 2020; Bakan & Bakan, 2018; Behnamnia et al., 2020; Bozkurt & Durak, 2018; Cheng et al., 2015; da Silva et al., 2019; Gao et al., 2020; Gris & Bengtson, 2021; Hallinger & Wang, 2020a; Jarnac de Freitas & Mira da Silva, 2020; Kalogiannakis et al., 2021; Mora et al., 2017; Qian & Clark, 2016; Tobon et al., 2020; Zainuddin et al., 2020)	47
Experiential learning theory	(Abraham et al., 2020; Bakan & Bakan, 2018; Gao et al., 2020; Hallinger & Wang, 2020a; Li & Tsai, 2013; Qian & Clark, 2016; van Gaalen et al., 2021; Wu et al., 2012)	40
Constructivist learning theory	(Behnamnia et al., 2020; Carenys & Moya, 2016; Cheng et al., 2015; Hallinger & Wang, 2020a; Kordaki & Gousiou, 2017; Li & Tsai, 2013; Qian & Clark, 2016; Zainuddin et al., 2020)	31
Cognitive load theory	(Ab Jalil et al., 2020; Bakan & Bakan, 2018; Bozkurt & Durak, 2018; Cheng et al., 2015; Gris & Bengtson, 2021; Li & Tsai, 2013; Martí-Parreño et al., 2016; Zainuddin et al., 2020)	24
Social cognitive theory	(Abraham et al., 2020; Bozkurt & Durak, 2018; Chau et al., 2018; DeSmet et al., 2014; Gris & Bengtson, 2021; Holtz et al., 2018; Li & Tsai, 2013; Orji & Moffatt, 2018)	16
Situated learning theory	(Bakan & Bakan, 2018; Cheng et al., 2015; Gao et al., 2020; Hallinger & Wang, 2020a; Li & Tsai, 2013; Qian & Clark, 2016; Wu et al., 2012)	29
Sociocultural theory of cognitive development	(Bakan & Bakan, 2018; Cheng et al., 2015; Gao et al., 2020; Kordaki & Gousiou, 2017; Li & Tsai, 2013; Wu et al., 2012; Zainuddin et al., 2020)	23
Technology acceptance model	(Boyle et al., 2016; Bozkurt & Durak, 2018; Carenys & Moya, 2016; Martí-Parreño et al., 2016; Mora et al., 2017; Orji & Moffatt, 2018; Tobon et al., 2020)	13

Theoretical foundation	Reviews mentioning theory	Sum of studies using theory
Theory of planned behavior	(Ab Jalil et al., 2020; Bozkurt & Durak, 2018; Chau et al., 2018; da Silva et al., 2019; DeSmet et al., 2014; Orji & Moffatt, 2018; Tobon et al., 2020)	10
Reinforcement theory	(Carenys & Moya, 2016; Dichev & Dicheva, 2017; Kordaki & Gousiou, 2017; Orji & Moffatt, 2018; van Gaalen et al., 2021; Zainuddin et al., 2020)	9
Social learning theory	(Abraham et al., 2020; Bozkurt & Durak, 2018; Hallinger & Wang, 2020a; Holtz et al., 2018; Orji & Moffatt, 2018; Wu et al., 2012)	8
ACRS model	(Boyle et al., 2016; Bozkurt & Durak, 2018; Carenys & Moya, 2016; Gris & Bengtson, 2021; Martí-Parreño et al., 2016)	14
Transtheoretical model of behavior change	(Bozkurt & Durak, 2018; Chau et al., 2018; Orji & Moffatt, 2018; Seaborn & Fels, 2015)	19
Activity theory	(Cheng et al., 2015; Li & Tsai, 2013; Qian & Clark, 2016; Wu et al., 2012)	14
Goal-setting theory	(Dichev & Dicheva, 2017; Kalogiannakis et al., 2021; Orji & Moffatt, 2018; Zainuddin et al., 2020)	10
Theory of reasoned action	(Bozkurt & Durak, 2018; Chau et al., 2018; Orji & Moffatt, 2018; Zainuddin et al., 2020)	6
Problem-based learning[1]	(Bakan & Bakan, 2018; Li & Tsai, 2013; Wu et al., 2012)	29
Multimedia learning theory	(Cheng et al., 2015; Kalogiannakis et al., 2021; Li & Tsai, 2013)	10
Achievement goal theory	(Ab Jalil et al., 2020; Gris & Bengtson, 2021; Klock et al., 2020)	5
Self-efficacy theory	(Bozkurt & Durak, 2018; Chan et al., 2019; Zainuddin et al., 2020)	4
Social comparison theory	(Tobon et al., 2020; van Gaalen et al., 2021; Zainuddin et al., 2020)	4
Discovery learning theory	(Bakan & Bakan, 2018; Wu et al., 2012)	16
Case-based learning[2]	(Bakan & Bakan, 2018; Wu et al., 2012)	12
Mechanics, dynamics and aesthetics framework	(Bozkurt & Durak, 2018; Mora et al., 2017)	11
Stage theory of cognitive development	(Bakan & Bakan, 2018; Wu et al., 2012)	10
Digital game-based learning[3]	(Bozkurt & Durak, 2018; Gao et al., 2020)	6
User-centered design[4]	(Mora et al., 2017; Seaborn & Fels, 2015)	4
Cognitive evaluation theory	(Bozkurt & Durak, 2018; Zainuddin et al., 2020)	4
Uses and gratifications theory	(Ab Jalil et al., 2020; Qian & Clark, 2016)	4
Gagné's instruction strategies[5]	(Thomas et al., 2020; Wu et al., 2012)	4
Fogg's behavior model	(Bozkurt & Durak, 2018; Zainuddin et al., 2020)	3
Theory of motivation, volition and performance	(Boyle et al., 2016; Carenys & Moya, 2016)	3
Situational relevance theory	(Mora et al., 2017; Seaborn & Fels, 2015)	2
Theory of multiple intelligence	(Gao et al., 2020; Li & Tsai, 2013)	2
Immersion theory	(Gao et al., 2020; Gris & Bengtson, 2021)	2
Transportation theory	(DeSmet et al., 2014; Thomas et al., 2020)	1
Lander's theory of gamified learning	(da Silva et al., 2019; Zainuddin et al., 2020)	1
Health belief model	(DeSmet et al., 2014; Orji & Moffatt, 2018)	1
Direct instruction[6]	(Wu et al., 2012)	9
Elaboration theory	(Wu et al., 2012)	7
User-centered theoretical framework for meaningful gamification	(Bozkurt & Durak, 2018)	4
Constructionism	(Qian & Clark, 2016)	4
Cognitive apprenticeship	(Wu et al., 2012)	4

Theoretical foundation	Reviews mentioning theory	Sum of studies using theory
Inquiry-based learning[7]	(Gao et al., 2020)	4
Programmed instruction[8]	(Wu et al., 2012)	3
Social conformity theory[9]	(Orji & Moffatt, 2018)	3
Information, motivation and behavior model	(Abraham et al., 2020)	3
Interest theory of learning	(Li & Tsai, 2013)	2
Theory-driven gamification design model	(Zainuddin et al., 2020)	2
Unified theory of acceptance and use of technology	(Orji & Moffatt, 2018)	2
Malone's theory	(Carenys & Moya, 2016)	2
Taxonomy of behavior change techniques	(Thomas et al., 2020)	2
Maslow's hierarchy of needs	(Bozkurt & Durak, 2018)	2
Diffusion of innovation theory	(Bozkurt & Durak, 2018)	2
Theory of organizational behavior	(Bozkurt & Durak, 2018)	2
Situational interest theory	(Chan et al., 2019)	2
Mood management theory	(Ab Jalil et al., 2020)	2
Communication theory	(Ab Jalil et al., 2020)	2
Theory of affordances	(Behnamnia et al., 2020)	2
Guilford's structure of intellect	(Behnamnia et al., 2020)	2
Model model	(Behnamnia et al., 2020)	2
Moran's theorem	(Behnamnia et al., 2020)	2
Attribution theory	(Wu et al., 2012)	2
Actor-network theory	(Wu et al., 2012)	1
Wisom, intelligence and creativity synthesized theory	(Behnamnia et al., 2020)	1
Play, affect and creativity theory	(Behnamnia et al., 2020)	1
Self-directed learning theory	(van Gaalen et al., 2021)	1
Expectancy-value theory	(Dichev & Dicheva, 2017)	1
Theory of gamified instructional design	(Dichev & Dicheva, 2017)	1
Ego depletion theory	(Orji & Moffatt, 2018)	1
Parallel process model	(Orji & Moffatt, 2018)	1
Theory of meanings of behavior	(Orji & Moffatt, 2018)	1
Knowledge, attitude, behavior model	(Orji & Moffatt, 2018)	1
Premack's principle	(Orji & Moffatt, 2018)	1
Big five personality theory	(Orji & Moffatt, 2018)	1
Sexual health model	(Orji & Moffatt, 2018)	1
Narrative centered learning[10]	(Qian & Clark, 2016)	1
Deliberate practice[11]	(van Gaalen et al., 2021)	1
Social network theory	(Chau et al., 2018)	1
Theory of interactive technology	(Chau et al., 2018)	1
Transcontextual model of motivation	(Chau et al., 2018)	1

Theoretical foundation	Reviews mentioning theory	Sum of studies using theory
Control theory	(Chau et al., 2018)	1
Information systems success model	(Zainuddin et al., 2020)	1
Presence pedagogy model	(Zainuddin et al., 2020)	1
Eisenkraft's 7E instructional model	(Zainuddin et al., 2020)	1
Felder-Silverman learning style model	(Zainuddin et al., 2020)	1
Merrill's principles of instruction design theory	(Zainuddin et al., 2020)	1
Technology-enhanced training effectiveness model	(Zainuddin et al., 2020)	1
Unified modeling language[12]	(Zainuddin et al., 2020)	1
Rational choice theory	(Zainuddin et al., 2020)	1
Mechanics, dynamics and emotions model	(Mora et al., 2017)	1
Moral design framework	(Mora et al., 2017)	1
Organismic integration theory	(Mora et al., 2017)	1
Four drives theory	(Mora et al., 2017)	1
Person-artefact-task model	(Mora et al., 2017)	1
Affect transfer theory	(Ab Jalil et al., 2020)	1
Cognitive dissonance theory	(Ab Jalil et al., 2020)	1
Middle-range theory of chronic illness	(Abraham et al., 2020)	1
Adult learning theory	(Abraham et al., 2020)	1
Murray's secondary psychological needs	(Klock et al., 2020)	1
Situative embodiment[13]	(Li & Tsai, 2013)	1
Transformational play[14]	(Li & Tsai, 2013)	1
Prediction-observation-explanation model	(Li & Tsai, 2013)	1
Enactivism	(Li & Tsai, 2013)	1
Behavioral economics[15]	(Thomas et al., 2020)	1
Dual-task training[16]	(Thomas et al., 2020)	1
Gee's game-based learning principles[17]	(Gao et al., 2020)	1
Tripartite enjoyment model	(Gris & Bengtson, 2021)	1
Universal design for learning	(Seaborn & Fels, 2015)	1
Scientific discovery as dual search model	(Qian & Clark, 2016)	1
Werbach's gamification framework	(Gao et al., 2020)	1
Embodied learning[18]	(Gao et al., 2020)	1
Taxonomy of intrinsic motivations for learning	(Gao et al., 2020)	1
Theory of realistic mathematics education	(Gao et al., 2020)	1
Theory of motivation to learn[19]	(Kalogiannakis et al., 2021)	1
Elaboration likelihood model	(DeSmet et al., 2014)	-
Taxation theory	(Zainuddin et al., 2020)	-

[1] Problem-based learning is not a theory, but a specific paradigm of instructional design related to constructivist learning. It is therefore excluded in the further analysis.

[2] Case-based learning is not a theory, but a specific paradigm of instructional design related to constructivist learning. It is therefore excluded in the further analysis.
[3] Bozkurt and Durak (2018) note digital game-based learning as a theoretical foundation, but the term describes a whole research field within gamification and serious gaming rather than a specific theory, so it is excluded in the further analysis.
[4] User-centered design is not a theory, but much more a paradigm of tailoring the design process around the user's needs and expectations. It is therefore excluded in the further analysis.
[5] Gagnés instruction strategies or principles are not a theory, but guidelines for instructional design. They are therefore excluded in the further analysis.
[6] Direct instruction is not a theory, but a specific instructional method related to behaviorism. It is therefore excluded in the further analysis.
[7] Inquiry-based learning is not a theory, but a specific paradigm of instructional design. It is therefore excluded in the further analysis.
[8] Programmed instruction is not a theory, but a specific instructional method related to behaviorism. It is therefore excluded in the further analysis.
[9] Orji and Moffatt (2018) claim that social conformity theory was used in three of the studies they analyzed, but further investigation revealed that the studies cited only used the concept of the importance of social influence and pressure in designing their interventions, rather than referring to a specific theoretical foundation, model or framework. Since subsequent searches did not reveal gamification or serious gaming studies using such a theory, it is excluded in the further analysis.
[10] Narrative-centered learning is not a theory for itself, but the realization of instruction strategies grounded in transportation theory. It is therefore excluded in the further analysis.
[11] Deliberate practice describes a paradigm of learning with purposeful repetition, but it is not a learning theory. Therefore, it is excluded in further analysis.
[12] The Unified Modeling Language (UML) is not a theoretical foundation. It was mentioned by Zainuddin et al. (2020) because it was used in the original study as the teaching content of their gamified intervention and is listed here for the sake of completeness but excluded in the further analysis.
[13] Situative embodiment is a central concept in the phenomenological school of thought, but not a specific theory. Therefore, it is excluded in further analysis.
[14] Transformational play is a form of play to promote creativity, innovation, empowerment and social connection, but it is not a theory and therefore excluded in further analysis.
[15] Behavioral economics is a specific discipline within economic science and includes a variety of different theories, such as prospect theory and nudge theory. However, Thomas et al. did not specify the theory used in the primary study, and further investigation of the primary study did not lead to the identification of a specific theory either. Therefore, behavioral economics is excluded in the further analysis.
[16] Dual-task training is not a theory, but a training method. It is therefore excluded in the further analysis.
[17] Gee's game-based learning principles are useful for the design of game-based learning, but they rather constitute recommendations than theory. Therefore, they are excluded in the further analysis.
[18] Embodied learning is not a theory, but a specific instructional method. It is therefore excluded in the further analysis.
[19] The theory of motivation to learn was mentioned as a theoretical foundation in the review of Kalogiannakis, Papadakis and Zourmpakis, but they do not mention the specific primary study using this foundation. As a detailed search could not identify such a theory, it is excluded in the further analysis.

The theoretical foundations used originate from various theoretical research streams, including cognitive psychology, social psychology, and human-computer interaction. In the following, the identified theories are described and elaborated regarding their use in research on gamification, serious games and game-based learning. For further interest in the theoretical foundations, additional explanations of the theories and their origins are provided in Appendix D.

4.2.1 Theoretical foundations with a focus on affect and motivation

The first set of foundations focusing on affect and motivation is mainly concerned with *motivation* and *valence*, while arousal was not addressed in the identified theories.

Theories focusing on motivation deal with the mechanisms and determinants of motivation formation, such as the basic psychological needs – autonomy, competence and relatedness – from self-determination theory (Ryan & Deci, 2017) or self-efficacy, which describes a person's belief that they can successfully perform the required behavior (Bandura, 1982). Studies conclude that game mechanics partially (Frost et al., 2015; van Roy & Zaman, 2019) or fully (Xi & Hamari, 2019) address the basic needs for autonomy, competence and relatedness through elements such as customization which promote feelings of autonomy (Kim et al., 2015), achievements and badges that foster feelings of competence (Peng et al., 2012) or teams and social networks that enhance feelings

of relatedness (Xi & Hamari, 2019). Gamification and serious games also increase self-efficacy, e.g., for reacting in emergencies (Chittaro & Buttussi, 2018), identifying cyber-security threads (Baral & Arachchilage, 2019) and performing learning tasks (Blasko-Drabik et al., 2013). Related to self-efficacy theory, social comparison theory emphasizes the natural urge to assess oneself in comparison with others (Festinger, 1954), which can be perceived as motivating or discouraging depending on circumstances (Buunk & Gibbons, 2007). For example, social comparisons in form of leaderboards or social status elements can have different effects in different samples (Christy & Fox, 2014).

Flow theory presents flow as a *"holistic sensation that people feel when they act with total involvement"* (Csikszentmihalyi, 1975, p. 36). Although flow is inherently valent, it is closely related to motivation: when individuals are fully engaged in an activity, they experience the activity as intrinsically rewarding and pursue it for the sake of the activity itself rather than to achieve the ultimate goal (Csikszentmihalyi, 2014). However, the impact of gamification and serious games on flow experiences has not yet been clearly established (Almeida & Buzady, 2019; Bitrián et al., 2020; Catalán et al., 2019; Chung et al., 2019).

Other theories address both motivation and valence, describing the effect of predictors such as expectations and values, as included in the ARCS model of motivation for instructional design, which states that motivation is the result of a combination of four factors – attention, relevance, confidence and satisfaction (Keller, 1987; Porter & Lawler, 1968). Satisfaction as a valent determinant of motivation depends on outcome expectations, such as goals, while confidence refers to personal belief in success, i.e., self-efficacy (Keller, 1979). Similarly, goal-setting theory (Locke, 1968) and achievement goal theory (Nicholls, 1984) emphasize the importance of goals for motivational mechanisms and the importance of satisfaction with goal achievement for commitment to further goals (Locke & Latham, 2002, 2013). While the ARCS questionnaire is often used to quantitatively evaluate the motivational effect of serious games and game-based learning on the four factors, with positive to mixed results (e. g. Calvo-Ferrer, 2018; Deif, 2017; Kaneko *et al.*, 2015; Ozdamli, 2018), possibly due to its pedagogical focus, the latter, i.e. goal-setting and achievement goal theory, are used predominantly to refine and improve gamified interventions, e.g. with leaderboards as goal-setting mechanisms (e. g. Chernbumroong et al., 2017; Landers et al., 2017; Nebel et al., 2017), and the individualization to achievement goal orientations with various game elements such as feedback, progress bars, leaderboards and badges (e. g. Roosta & Taghiyareh, 2016).

4.2.2 Theoretical foundations with a focus on behavior

Second, there are a variety of theoretical foundations that describe the determinants of *behavioral* outcomes.

Reinforcement theory, the most prominent example of radical behaviorism (Moore, 2011), considers the cognitive processes of behavior formation as a "black box" and suggests direct relationships between stimuli and outcomes (Skinner, 1953). It primarily guides the study of whether extrinsic gamification mechanics, such as rewards (Berkovsky et al., 2012; Kordaki & Gousiou, 2017) or climbing the leaderboard (Huang et al., 2019), can positively influence learning outcomes.

Other theories focusing on behavior, such as the theory of reasoned action (Ajzen & Fishbein, 1980), the theory of planned behavior (Ajzen, 1991) and the technology acceptance model (Davis et al., 1989), outline the importance of behavioral attitudes and subjective norms on behavioral intention, which then leads to actual behavior. In addition, as an extension of the theory of reasoned action, the theory of planned behavior adds perceived behavioral control as a determinant of behavioral intention (Ajzen, 1991), which is closely related to the motivational concept of self-efficacy (Ajzen, 2002), while as a second extension of the theory of reasoned action tailored to user acceptance of information systems, the theory of planned behavior adds perceived usefulness and perceived ease of use as determinants of behavioral attitude (Davis et al., 1989). All three theories serve as a basis to assess the impact of gamification on the determinants (behavioral attitude, subjective norms and perceived behavioral control) and thus on behavioral intentions, such as the intention to adopt solar energy (Rai & Beck, 2017), choose sustainable means of transport (Andersson et al., 2018), or make a purchase (Bittner & Shipper, 2014). In the case of the technology acceptance model, the framework is also used to evaluate the acceptance of gamified interventions, e.g., whether they perform well in terms of perceived usefulness and perceived ease of use, thereby generating positive attitudes and behavioral intent to use (e. g. Bourgonjon et al., 2013; Siala et al., 2019; Vanduhe et al., 2020).

Furthermore, two theories describe the process of behavior change (Prochaska & Diclemente, 1982) and the cognitive system in which human actions are influenced by rules, culture and the community, called the activity system (Engeström, 1987; Vygotsky, 1978). These theories are not used for evaluation, but for the design of gamified systems and serious games. They are either based on the stages of the transtheoretical model to promote changes towards healthy behavior (Alsaleh & Alnanih, 2020; Bahia et al., 2014) and sustainable behavior (AlSkaif et al., 2018; Andersson et al., 2018), e.g., by focusing on the provision of information in the early stages and shifting to elements of social pressure and performance tracking mechanisms in the later stages (AlSkaif et al., 2018; Andersson et al., 2018), or based on the activity system with the game as a mediating instrument (e. g. Calvo & Reio, 2018; Carron et al., 2008; Charrouf & Taha Janan, 2019; De Freitas & Oliver, 2006; Ellahi et al., 2017).

4.2.3 Theoretical foundations with a focus on learning

The third category of theoretical foundations deals with determinants and processes of *learning*. Most of these theories originate from social psychology, e.g. social learning theory (Bandura, 1971), social cognitive theory (Bandura, 2001), and the sociocultural theory of cognitive development (Vygotsky, 1978), and describe the crucial role of sociocultural influences and interactions in successful learning processes. A central concept in social learning theory and social cognitive theory, which is an extension of social learning theory, is that of *vicarious learning*, that is, learning by observing others (Bandura, 1971). This concept guides the design of game-based learning interventions, e.g. by introducing mechanisms that enable social observation processes (Jeen et al., 2007) or by designing role model game characters (Fuchslocher et al., 2011) for vicarious learning (Amresh et al., 2019; Bowen et al., 2014; Bul et al., 2015). In turn, sociocultural theory of cognitive development introduces the idea of the *Zone of Proximal Development*, i.e., the distance between the actual level of development and

the level of potential development that can be acquired through guidance, peer cooperation, or instruction (Vygotsky, 1978). Gamification and serious games based on sociocultural theory are adaptive and individualized in design to scaffold the learners within their zones of proximal development (e.g. Davis et al., 2018; Rachels & Rockinson-Szapkiw, 2018).

Constructivist learning theory (Jonassen, 1999; Piaget, 1977) addresses the general process of knowledge construction and the initialization of learning processes, incorporating motivational aspects as crucial preconditions for successful learning. On this basis, the inclusion of constructivist principles in gamified applications such as experiential learning, participation and self-reflection (e. g. Avramenko, 2012; Huebscher & Lendner, 2010; Kordaki & Gousiou, 2017) aims to improve desired learning outcomes. In this context, experiential learning theory emphasizes that knowledge is acquired through personal and environmental experiences rather than through instruction and in an iterative learning cycle (Kolb, 1984). Relatedly, situated learning theory states that conceptual knowledge cannot be abstracted from the situations in which it is learned and used (Brown et al., 1989). Hence, learning environments need to be designed in such an authentic way that students can learn by linking their prior knowledge to real-world scenarios as they participate in the learning activities (Hwang et al., 2015). Accordingly, both experiential learning theory and situated learning theory guide the design of virtual environments in serious games to resemble real-world environments and problem-solving contexts (e.g. All et al., 2017; Hou, 2015; Hou & Li, 2014) to allow for experience, observation and experimentation (e.g. Furió et al., 2013; Verkuyl et al., 2017; Wrzesien & Alcañiz Raya, 2010).

Finally, cognitive load theory (Sweller, 1988) and multimedia learning theory (Mayer, 2005) are concerned with mental processing capacity and the different mental processes involved in organizing and linking learning content to prior knowledge. Extraneous processing or extraneous cognitive load in this context represent cognitive processes that distract from active processing of learning content (Mayer, 2005; Sweller, 1988). Both theoretical bases open up scientific discussions on whether serious games, game-based learning and gamification can be designed to reduce the extraneous cognitive load or if they increase cognitive load and thus cause counterproductive effects on learning (e.g. Adams & Clark, 2014; Brom et al., 2019; Deleeuw & Mayer, 2011; Johnson & Mayer, 2010; Moreno & Mayer, 2005).

4.2.4 Other theoretical foundations

Scientists have used a variety of other theoretical foundations of secondary importance, i.e., they were only mentioned by one or two reviews, from different disciplines. Some of them aim to propose guidelines for system design, such as the mechanics, dynamics and aesthetics model (Hunicke et al., 2004), the user-centered theoretical framework for meaningful gamification (Nicholson, 2012), or Werbach's gamification framework (Werbach, 2014). They are used for gamification design in a variety of scientific studies (e. g. Angelia & Suharjito, 2019; Arnab & Clarke, 2017; Constantinescu et al., 2017; Dietrich et al., 2018; Stansbury & Earnest, 2017). In addition, the theoretical foundations originate from management research, such as theories of organizational behavior (e. g. Mayo, 1933) or the diffusion of innovations theory (Rogers, 1962), but also medicine (Sexual Health Model; Robinson, 2015) and personality (Big Five; Allport & Odbert, 1936). Table 4 illustrates the classified

theoretical foundations according to their thematic focus and popularity in research on gamification, serious games and game-based learning.

Table 4
Classified theoretical foundations in research on gamification, serious games and game-based learning.

Affect and Motivation	Behavior	Learning	Other
Prevalent theories (mentioned at least three times)			
Self-determination theory	Technology acceptance model	Experiential learning theory	
Flow theory	Theory of planned behavior	Constructivist learning theory	
ARCS model	Reinforcement theory	Cognitive load theory	
Goal-setting theory	Transtheoretical model of behavior change	Social cognitive theory	
Self-efficacy theory	Theory of reasoned action	Situated learning theory	
Social comparison theory	Activity theory	Sociocultural theory of cognitive development	
Achievement goal theory		Social learning theory	
		Multimedia learning theory	
Other theories (mentioned less than three times)			
Cognitive evaluation theory	Fogg's behavior model	Discovery learning theory	Mechanics, dynamics and aesthetics framework
Health belief model	Information, motivation and behavior model	Stage theory of cognitive development	Uses and gratifications theory
Situational relevance theory	Unified theory of acceptance and use of technology	Theory of motivation, volition and performance	Theory of multiple intelligence
Immersion theory	Model model	Elaboration theory	Theory-driven gamification design model
Transportation theory	Rational choice theory	Constructionism	User-centered theoretical framework for meaningful gamification
Organismic integration theory	Ego depletion theory	Interest theory of learning	Control theory
Four drives theory	Parallel process model	Cognitive apprenticeship	Elaboration likelihood model
Person-artefact-task model	Theory of meanings of behavior	Universal design for learning	Taxation theory
Maslow's hierarchy of needs	Knowledge, attitude, behavior model	Presence pedagogy model	Diffusion of innovation theory
Murray's secondary psychological needs	Social network theory	Eisenkraft's 7E instructional model	Theory of organizational behavior
Transcontextual model of motivation	Premack's principle	Felder-Silverman learning style model	Communication theory
Situational interest theory		Merrill's principles of instruction design theory	Theory of affordances
Attribution theory		Technology-enhanced training effectiveness model	Moran's theorem
Expectancy-value theory		Malone's theory	Guildford's structure of intellect
Affect transfer theory		Lander's theory of gamified learning	Big five personality theory
Mood management theory		Theory of gamified instructional design	Sexual health model
Cognitive dissonance theory		Adult learning theory	Information systems success model
Play, affect and creativity theory		Theory of realistic mathematics education	
Taxonomy of intrinsic motivations for learning		Prediction-observation-explanation model	
Tripartite enjoyment model			

	Scientific discovery as dual search model Self-directed learning theory	Mechanics, dynamics and emotions model Theory of interactive technology Moral design framework Middle-range theory of chronic illness Wisdom, intelligence and creativity synthesized theory Werbach's gamification framework Enactivism Actor-network theory

5. Discussion

This systematic review aimed to identify theoretical foundations in gamification, serious games, and game-based learning research. We identified 118 different theoretical foundations that are used to design and evaluate gamified interventions, and that help explain how gamification, serious games and game-based learning achieve their desired (motivational and affective, behavioral, and learning) effects. Although the overview of these theories already represents a valuable contribution to further research on the underlying mechanisms of gamification, we have also observed notable relationships that unify several of the theories presented. Moving from an observative to an explanatory level, the discussion of the commonalities between the theoretical foundations serves to identify their core assumptions to gain a more comprehensive understanding of how gamification works. Fig. 2 shows the relationships between the theoretical foundations most widely used in research on gamification, serious games and game-based learning, which are further elaborated below. Each theory is presented as a bubble scaled according to the relative popularity of the theoretical foundation as identified in the systematic review. The bubbles are color-coded according to their thematic focus (motivation and affect, behavior or learning, see also Appendix C). As shown, some theories are marked with mixed color, indicating that their thematic focus is not clearly distinguishable. Straight arrows represent explicitly mentioned inclusions of one theory into another by the developing scientists. All the above-mentioned relations are objectively derived from the results of the systematic review. In addition, dashed lines indicate relationships concerning the main assumptions of two theories that we hypothesize based on our detailed analysis.

According to goal-setting theory, goals must fulfill the criteria of both specificity and difficulty for them to be motivating (Locke, 1968). From a motivational perspective, clear goals also support the emergence of flow experiences (Csikszentmihalyi, 2014; Csikszentmihalyi & Csikszentmihalyi, 1988), which are directly related to the concept of intrinsic motivation as articulated in self-determination theory (Ryan & Deci, 2000b): when individuals are fully involved in an activity, they experience the activity as intrinsically rewarding, and pursue it for the sake of the activity itself (Csikszentmihalyi, 2014). The ARCS model posits that clear goals represent major outcome expectations that particularly drive motivation when they are perceived as relevant and achievable

(Keller, 1987). From a self-determination view, clear goals support the need for competence, while relevant goals support the need for autonomy (Ryan & Deci, 2000b). Also from a constructivist learning perspective, demonstrating and articulating the relevance of a goal is critical to supporting successful knowledge construction (Jonassen, 1999). Behavioral theories such as the theory of reasoned action (Ajzen, 1985) and the theory of planned behavior (Ajzen, 1991) add that clear and relevant goals as outcome expectations promote a positive behavioral attitude, which then leads to behavioral intention and the actual desired behavior. Gamification and serious games can be valuable tools for illustrating goals and their relevance through elements such as badges and achievements, which have been shown to work similarly to classical goal-setting mechanisms (Gutt et al., 2020) and even improve performance compared to classical goal-setting (Groening & Binnewies, 2019). The introduction of challenges, sometimes called quests (Klock et al., 2020), can also serve as a goal mechanism (Laine & Lindberg, 2020), whereby the overarching goals are playfully broken down into specific sub-goals. Similarly, a predefined level system can provide students with goals to achieve (Ding et al., 2020). Especially in game-based learning and serious games, stories or narratives can further reinforce the communication of specific learning goals (Nebel et al., 2017) and chain goals together in an exciting story (Rapp, 2017b). From this, we derive the first principle of how gamification works:

P1: Clear and relevant goals*. Gamification can transparently illustrate goals and their relevance.*

Self-determination theory includes several sub-theories such as cognitive evaluation theory, organismic integration theory and basic psychological needs theory, and distinguishes between amotivation and different types of extrinsic and intrinsic motivation (Ryan & Deci, 2000b). A specific sub-theory of self-determination theory is goal-contents theory (Ryan & Deci, 2017), which states that people have different foci in pursuing intrinsic and extrinsic aspirations or goals. This is similar to the main assumptions of achievement goal theory, which also suggests that individuals exhibit a mixture of achievement orientations in pursuit of goals (Elliot, 1999; Elliot & McGregor, 2001). Thus, to promote the relevance of a particular intervention to subjects, individuals should be given the opportunity to set goals for themselves, which supports their need for autonomy (Ryan & Deci, 2000b) and, according to goal-setting theory, promotes positive affective responses to the goal, these being an important moderator of the goal-performance relationship (Locke & Latham, 2002, 2013). Social cognitive theory adds that the opportunity to set one's own goals is essential for self-regulation in learning (Bandura, 2001). Gamification research has emphasized that leaderboards are a main element for users to strive for their own goals (Chernbumroong et al., 2017; Landers et al., 2017). Furthermore, in game-based learning, customizable learning journeys with "level bosses" that must be defeated for each milestone achieved have been shown to support users in self-goal setting and thus self-regulated learning (Chen et al., 2019). In addition, showing avatars that represent the user's future and ideal image can effectively serve as a role model for self-improvement of offline behaviors, such as a healthy lifestyle (Rapp, 2017a). Performance stats and tracking features of gamified systems may also support users in self-monitoring processes for self-defined goals, especially related to diet, exercise, or medication (Al-Ramahi et al., 2016). Thus, we derive the following principle of how gamification works:

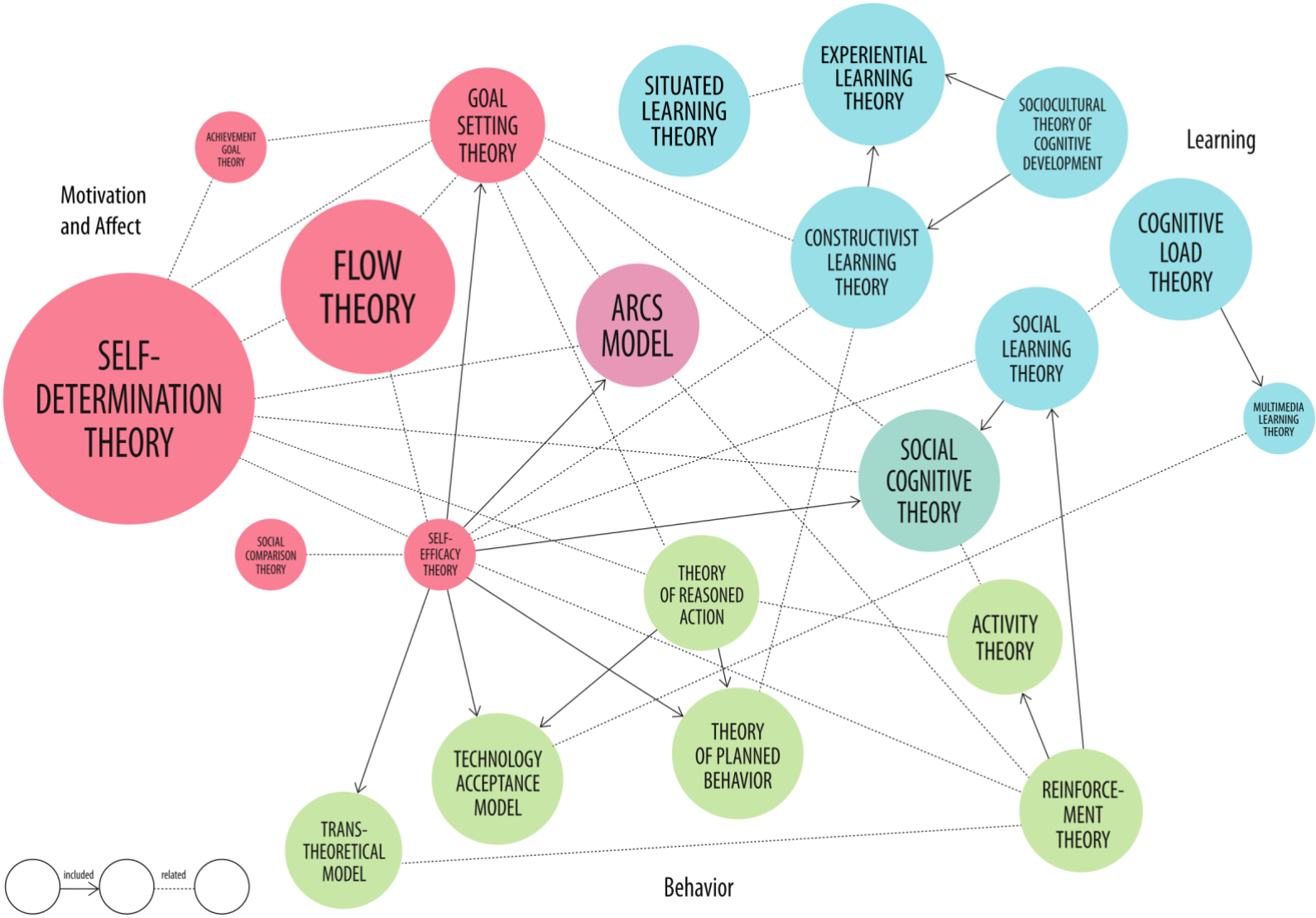

Fig. 2. Theoretical landscape: Relationships of theoretical foundations in research on gamification, serious games and game-based learning (2-column, colored)

P2: Individual goals. *Gamification can allow users to set their own goals.*

The need for competence as one of the three basic psychological needs mentioned in self-determination theory is strongly linked to the concept of self-efficacy, i.e., a person's subjective conviction that he or she can successfully perform the desired behavior (Bandura, 1982). The importance of self-efficacy for effort and persistence in activities is so central that the construct is explicitly considered in several other theories: as a moderator in goal-setting theory (Locke & Latham, 2002, 2013), as one of four factors in the ARCS model (Keller, 1987), as a mechanism in social cognitive theory (Bandura, 2001), as a determinant in the theory of planned behavior (Ajzen, 2002) and the technology acceptance model (Davis et al., 1989) and as a factor for decisional balance in the transtheoretical model of behavior change (Prochaska & Velicer, 1997). Hence, the provision of self-efficacy information through performance accomplishments, vicarious experience, and verbal persuasion (Bandura, 1978) is essential for motivation, learning and behavior change. Concerning *performance accomplishments*, all these theories state that immediate feedback on progress toward set goals is a sine qua non for perceptions of competence and self-efficacy. Furthermore, immediate feedback supports flow experiences (Csikszentmihalyi, 2014; Csikszentmihalyi & Csikszentmihalyi, 1988). Studies indicate that one of the most widely used game elements (Koivisto & Hamari, 2019), points, as well as levels and progress bars, can provide users with immediate information about their actions and progress within the system, thereby presenting immediate feedback and visible progression (Dicheva et al., 2015; Ding et al., 2020). Feedback in serious games and game-based learning can also take the form of responses from dialogues with non-player characters or instant feedback messages related to game controls and challenges performed (Laine & Lindberg, 2020). Consequently, we derive the following principle of how gamification works:

P3: Immediate feedback*. Gamification can provide users with direct feedback on their actions.*

The ARCS model of motivation is an instructional design model. It is primarily a theory of motivation based on expectations and values, the latter being a person's preference for certain outcomes driven, for example, by the three basic psychological needs of self-determination theory (Keller, 1979). However, it can also be considered part as a learning theory because it focuses on motivation in an educational context. Instructional strategies for each of its factors – attention, relevance, confidence and satisfaction – include positive reinforcements, which are also emphasized by reinforcement theory (Skinner, 1953). Reinforcements, besides immediate feedback, also represent a form of performance accomplishments to promote self-efficacy (Bandura, 1978), and continuous reinforcements are critical to maintaining behavior change from a transtheoretical model perspective (Prochaska et al., 1992). Cognitive evaluation theory as a sub-theory of self-determination theory adds that positive external stimuli must be primarily informative and not controlling in nature to achieve the desired effects (Ryan & Deci, 2017). In addition, both activity theory and social learning theory emphasize the central role of behavioral reinforcements but extend the sole significance of stimuli by a cognitive activity system (Vygotsky, 1978) and observational learning processes (Bandura, 1971). While from a self-determination perspective (Ryan & Deci, 2020), punishments or monetary incentives can be counterproductive as reinforcers, game elements such as badges and trophies (Suh et al., 2018), in-game rewards (Berkovsky et al., 2012), praise messages (Carenys & Moya, 2016; Kordaki & Gousiou, 2017) or status symbols, which are commonly used in gamification systems,

serious games and game-based learning (Klock et al., 2020; Rapp, 2017a), are more informational in nature about the performance and relevance of the user's progress and thus can represent effective forms of reinforcements. Moreover, gamified environments can also offer effective incentives in the form of additional game features, including unexpected ones (Rapp, 2017b) or virtual gifts and loot (Xu et al., 2020). Therefore, we derive the following principle of how gamification works:

P4: Positive reinforcement. *Gamification can reward users for their performance and communicate the relevance of their achievements.*

On the other hand, the importance of *vicarious experience* (Bandura, 1978), that is, observing the performance of others, is essential not only for motivation but also for social learning processes as outlined in social learning theory (Bandura, 1971). Social cognitive theory, which builds on social learning theory, integrates the role of vicarious learning by observation, self-efficacy, and self-regulation by goal-setting into what is called a self-system (Bandura, 2001). It parallels the activity system postulated in activity theory (Vygotsky, 1978), thus emphasizes the importance of both social comparisons and self-imposed goals for learning. From a different perspective, cognitive load theory states that most knowledge in long-term memory is acquired by observing others, which is expressed in the borrowing and reorganizing principle (Sweller, 2010). Vicarious experience is also central to social comparison theory, which states that people have a natural urge to evaluate their abilities in comparison with others (Festinger, 1954). In this context, the opportunity to make private comparisons and the certainty of not revealing one's inferiority to others are essential for social comparison processes to be motivating (Buunk & Gibbons, 2007). Research has demonstrated that gamification, serious games and game-based learning can represent suitable interventions to facilitate social comparisons, e.g., with elements such as leaderboards (Christy & Fox, 2014) or status symbols and rankings (Ding et al., 2020). Moreover, social comparisons can manifest in duels and contests (Klock et al., 2020) or reputation systems (Rapp, 2017a) and in-game communication (Laine & Lindberg, 2020) that enable interindividual social recognition. Social comparison and competition in gamified systems is perceived as motivating by most users (Bayuk & Altobello, 2019) and intra- and inter-team competitions have been shown to be critical mechanisms for motivation and participation in gamified systems (Morschheuser et al., 2019). Likewise, competitive game elements are pivotal mediators of team effort and performance (Dissanayake et al., 2019). As a result, we derive the following principle of how gamification works:

P5: Social comparisons*. Gamification can allow users to see their peer's performance*.

The theory of reasoned action introduces a new aspect: in addition to the behavioral attitude based on outcome expectations, behavioral intention depends on the subjective norm, i.e., normative beliefs towards peer expectations (Ajzen, 1985). Activity theory strongly supports the importance of community and cultural rules in the activity system (Engeström, 1987, 2001), and the basic psychological need of relatedness from self-determination theory expresses the crucial need for conformity and proximity with peers (Ryan & Deci, 2017). As extensions of the theory of reasoned action, the theory of planned behavior (Ajzen, 1991) and the technology acceptance model (Davis et al., 1989) also incorporate the importance of normative beliefs as determinants of behavioral intention. This suggests that social comparison mechanisms should be reinforced through the

exertion of social pressure and support for a common goal. Gamification, serious games, and game-based learning can allow users to form teams, master team challenges, collectively vote on options and connect in social networks (Klock et al., 2020). Dividing users into subgroups or teams and supporting their interdependence through shared gamified tasks may create a sense of belonging and positively foster the process of behavior change (Rapp, 2017a, 2017b). For example, game-based learning systems can require students to participate in group activities in a collaborative space (Carron et al., 2008). In addition, exchange guilds allow people to support each other with appropriate suggestions when facing difficulties (Rapp, 2017b). In this regard, communication in games and gamification that enables social support can be realized synchronously, e.g. through chats, or asynchronously, e.g. through discussion forums (Laine & Lindberg, 2020; Vanduhe et al., 2020). Furthermore, the introduction of social network features with mentoring influencers (Rapp, 2017b) or the conveyance of social norms through the presentation of average statistics (Rai & Beck, 2017) can represent suitable game elements for influencing normative beliefs towards behavior change. From this, we derive the following principle of how gamification works:

P6: Social norming. *Gamification can connect users to support each other and work towards a common goal.*

The transtheoretical model of behavior change assumes that behavioral changes occur in four distinct phases (Prochaska et al., 1992). In each phase, different psychological processes take place that must be supported to lead to the subsequent stage. Although not directly related to phases and thus not a direct theoretical link, other theoretical foundations also emphasize interindividual differences. Self-determination theory (Ryan & Deci, 2020), flow theory (Csikszentmihalyi, 1975, 2013) and self-efficacy theory (Bandura, 1982) recognize that people differ in their abilities but share similar needs for competence. Goal-setting theory (Locke & Latham, 2002, 2013) includes ability and personality as critical moderators of the goal-performance relationship. And constructivist learning theory (Jonassen, 1999) which includes both individual constructivism (Piaget, 1977) and the sociocultural theory of cognitive development (Vygotsky, 1978), emphasizes the importance of *scaffolding*, i.e. adjusting and structuring tasks to the learner's abilities to support successful learning. Thus, it is important to tailor tasks and complexity to the individual's skills, knowledge, and behavioral level. Gamification and serious games have been shown to be appropriate tools to illustrate learning potentials at a current stage (Klock et al., 2020), e.g., through knowledge maps (Borges et al., 2016) and skill trees (Barata et al., 2017). Moreover, challenges in gamification and game-based learning systems can be tailored to the learner's current skill level (Dicheva et al., 2015), e.g., by tying the difficulty of the challenge to levels (Gordon et al., 2013; Simões et al., 2013) or by using machine learning algorithms (Gordon et al., 2013). In this respect, educational games surpass traditional teaching methods (Davis et al., 2018). In terms of behavioral change, fictional avatars can be designed in serious games to go through the different behavioral phases (Bahia et al., 2014), and various gamification elements can be selected to support the different stages of behavioral change (Rapp, 2017a), e.g. statistics and messages for initial information provision in the pre-contemplation stage, followed badges and rewards to reinforce the user's effectiveness in the preparation stage and level-ups or leaderboards in the action and maintenance stage (Alsaleh & Alnanih, 2020; AlSkaif et al., 2018). Thus, we derive the following principle of how gamification works:

P7: Adaptive content. *Gamification can adapt tasks and complexity to the abilities and knowledge of the user.*

According to constructivist learning theory, in addition to adaptive content, *coaching*, i.e., supporting learning through motivational prompts, assistance, and reflection (Jonassen, 1999) plays a central role in successful knowledge construction. Sociocultural constructivism underlines that for learners to progress, it is imperative that they be guided within their *zone of proximal development* (Vygotsky, 1978). Similarly, the theory of planned behavior (Ajzen, 1991) emphasizes the importance of actions that nudge the individual to reach the next stage of behavioral change, which is referred to as *verbal persuasion* in self-efficacy theory (Bandura, 1982). Gamified systems have been shown to be effective tools for nudging (Afshar Jalili, 2019; Kwan et al., 2020). For example, gamification and serious games can provide guidance through elements such as suggestions, tips, messages and highlighting of items or elements (Klock et al., 2020), that help, suggest, or warn to follow a path (or not). In addition, role-playing can be used to guide students through different aspects of a problem (Hwang et al., 2015). Hence, we derive the following principle of how gamification works:

P8: Guided paths. *Gamification can nudge users towards the actions necessary for achieving the goals*.

Experiential learning theory, which builds on constructivist learning theory and the sociocultural theory of cognitive development (Kolb & Kolb, 2013), assumes that knowledge is acquired primarily through personal and environmental experiences rather than instruction (Kolb, 1984). Situated learning theory extends this notion, stating that conceptual knowledge cannot be abstracted from the situations in which it is learned and applied (Brown et al., 1989). Hence, learning environments need to be designed authentically so that students can learn by linking their prior knowledge to real-world scenarios as they participate in learning activities (Hwang et al., 2015). For example, through problem-based learning, case-based learning, and cognitive apprenticeship, learning can be embedded in realistic contexts and supports experimentation with multiple perspectives and ways to solve problems (Dabbagh & Dass, 2013). This is also relevant to support feelings of autonomy, one of the three basic psychological needs of self-determination theory (Ryan & Deci, 2017). Gamification can allow users to discover and choose multiple different paths and options on the way to a goal (Dicheva et al., 2015), e.g. through mechanics such as nonlinear gameplay or branching decisions (Klock et al., 2020). For example, game-based learning systems such as Duolingo provide choices between different paths of learning tasks and tests (Rachels & Rockinson-Szapkiw, 2018). Moreover, serious games can offer fictional environments in which learners can act freely and explore and try different paths and options to achieve the goal (Rapp, 2017a) and learn about specific topics (Wrzesien & Alcañiz Raya, 2010). Augmented reality games allow for similar exploration in real-world environments (Furió et al., 2013). Therefore, we derive the following principle of how gamification works:

P9: Multiple choices. *Gamification can allow users to choose between several different options to achieve a certain goal.*

Finally, the technology acceptance model emphasizes the importance of ease of use in the acceptance of information systems (Davis et al., 1989), so that users perceive self-efficacy (Bandura, 1982) in using the system. Similarly, multimedia learning theory (Mayer, 2005), based on cognitive load theory (Sweller, 1988), suggests the

importance of ease of use to minimize *extraneous cognitive processing* that distracts users from actively processing the learning content (Mayer & Johnson, 2010). Game-based learning and serious games can divide complex tasks into shorter and simple sub-tasks (Simões et al., 2013). In addition, educational simulations can support learning by abstracting real-world problems and contexts to their essential characteristics (Ranchhod et al., 2014). Studies have shown that game-based learning can successfully direct cognitive effort towards essential and generative processing when designed with, for example, self-explanation features (Johnson & Mayer, 2010) and explanatory feedback (Mayer & Johnson, 2010). Moreover, onboarding also referred to as tutorials, can provide users with relatively simple tasks to get started familiarize themselves with the system (Iosup & Epema, 2014; Kavaliova et al., 2016). Consequently, we derive the following final principle of how gamification works:

P10: Simplified user experience. *Gamification systems are usually easy to use and can simplify content.*

The discussion of relationships between the theoretical foundations used in research on gamification, serious games and game-based learning thus enables the identification of ten underlying theoretical principles that help explain how gamification can achieve its positive effects, summarized in Table 5. To enhance the overview, we distinguish three categories of principles: those that lead people to the intended results, those that enhance individual relevance, and those that enable social interaction and positive social effects on individual behavior.

Table 5
Theoretical principles that help explain the effects of gamification.

Theoretical principles	**Related theoretical foundations**
Principles that guide towards the intended behavioral outcomes	
P1: Clear and relevant goals. Gamification can transparently illustrate goals and their relevance.	Goal-setting theory, flow theory, self-determination theory, ARCS model, constructivist learning theory, theory of reasoned action, theory of planned behavior
P3: Immediate feedback. Gamification can provide users with direct feedback on their actions.	Self-determination theory, self-efficacy theory, goal-setting theory, ARCS model, social cognitive theory, theory of planned behavior, technology acceptance model, transtheoretical model of behavior change, flow theory
P4: Positive reinforcement. Gamification can reward users for their performance and communicate the relevance of their achievements.	Reinforcement theory, ARCS model, self-efficacy theory, transtheoretical model of behavior change, self-determination theory, activity theory, social learning theory
P8: Guided paths. Gamification can nudge users towards the actions necessary for achieving the goals.	Constructivist learning theory, sociocultural theory of cognitive development, theory of planned behavior, self-efficacy theory
P10: Simplified user experience. Gamification systems are usually easy to use and can simplify content.	Technology acceptance model, multimedia learning theory, cognitive load theory
Principles that foster individual relevance	
P2: Individual goals. Gamification can allow users to set their own goals.	Self-determination theory, achievement goal theory, goal-setting theory, social cognitive theory

P7: Adaptive content. Gamification can adapt tasks and complexity to the abilities and knowledge of the user.	Transtheoretical model of behavior change, self-determination theory, flow theory, self-efficacy theory, goal-setting theory, constructivist learning theory, sociocultural theory of cognitive development
P9: Multiple choices. Gamification can allow users to choose between several different options to achieve a certain goal.	Experiential learning theory, situated learning theory, self-determination theory
Principles that enable social interaction and positive social effects	
P5: Social comparisons. Gamification can allow users to see their peer's performance.	Self-efficacy theory, social cognitive theory, social learning theory, cognitive load theory, social comparison theory
P6: Social norming. Gamification can connect users to support each other and work towards a common goal.	Theory of reasoned action, activity theory, self-determination theory, theory of planned behavior, technology acceptance model

6. Implications and Further Research Suggestions

The foregoing review and discussion constitute the first to explicitly focus on the theoretical foundations used in research on gamification, serious games and game-based learning. Moving from an observational perspective to an explanatory perspective, we examined the theoretical foundations used to design and evaluate gamified interventions and explain the effects of gamification, serious games and game-based learning in our systematic meta-review. Subsequently, we highlighted the common underlying principles of the most prevalent theories identified in our review that help explain how gamification, serious games and game-based learning can achieve positive affective and motivational, (cognitive) learning and behavioral effects. Our findings provide valuable guidance for further theoretical research as well as for the practical design and use of gamification in various application contexts.

6.1 Implications for theory

This systematic meta-review has shown that the landscape of theoretical foundations that have so far been used to explain *how* gamification, serious games and game-based learning influence affect and motivation, behavior, and learning in different contexts, has acquired a fascinating variety. In conjunction with the growing interest in gamification research, this is a positive sign: While in earlier stages of gamification research, the focus has been set primarily on *whether* gamification produces positive effects (Nacke & Deterding, 2017), this review demonstrates that scientific interest has successfully broadened and expanded by investigating *how* and *why* this takes place.

Self-determination theory is an omnipresent theoretical framework in gamification research. It is by far the most used theory to this date. It was used in 82 papers, followed in popularity by flow theory, constructivist learning theory, experiential learning theory and cognitive load theory as the most common theories. In contrast, 54 of the 118 theories identified have only been used once so far. This observation may be explainable by the fact that self-determination theory depicts a macro-theory of human motivation, development, and health (Ryan & Deci, 2000b), and hence marks a broad framework by definition. Our finding that self-determination theory is also one

of the theories most often associated with other theoretical foundations (see Fig. 2 and Table 5) supports this assumption. Similarly, several of the most prevalent theories may generally be applicable in different contexts since psychological constructs such as flow or behavioral determinants from the theory of planned behavior have not been developed to explain motivation and behavior in specific contexts but rather in general terms. Other theoretical foundations, especially those that were used by only one or two papers, are more context-specific (e.g. Sexual Health Model; Robinson, 2015), which may explain their lower popularity.

It remains to be answered why some crucial theories, such as self-efficacy theory, which is a theoretical basis for much more commonly used theories (e.g. the theory of planned behavior, social cognitive theory and the technology acceptance model, as shown in Fig. 2), are not adequately investigated to explain the effects of gamification, serious games and game-based learning. Likewise, expectancy-value theory (Lawler & Porter, 1967) has only been mentioned in one of the reviews, while it provides essential insights for explaining motivational differences based on presumptions about behavioral consequences and forms the basis for the much more popular ARCS model (Keller, 1979). Why are certain theories preferred in this case? Further theoretical research should explore the possibility of making greater use of the theories that form the basis for others, in order to examine whether the observable choice of theoretical foundations is due to the actual added value of the most popular theories, or rather a result of the application context (e.g., the ARCS model for instructional design might simply be more familiar to educational researchers than the underlying expectation-value theory).

In addition, we suspect important connections and interrelations between the theories (indicated as dashed lines in Fig. 2), which are based on the main assumptions of the respective theories. Since the principles that help to explain how gamification works were derived from these relationships, further studies are invited to investigate and validate these theoretically established links.

The great variety of 118 different theoretical foundations in use also shows that there is no single theory that can explain how gamification works. Moreover, it reflects that gamification is an important and developing (research) topic in various contexts. The theoretical bases in gamification, serious games and game-based learning research address different outcomes regarding motivation and affect, behavior, and learning, and reflect attempts to explain the effects of gamification from different angles. As Keller (2008) has pointed out in the context of motivation, volition and performance, one of the future goals of gamification research should be to consider a broader variety of theoretical foundations to demonstrate empirically how gamification works, rather than choosing only one of these theories. For example, it is useful to find out how gamification motivates, but it becomes even more effective if these insights are directly linked to how gamification also transforms motivation and intention into behavior and learning outcomes. Since many theoretical foundations are at least partially interlinked, gamification research could benefit from such synergies. In this work, we tried to derive basic principles from the core assumption of several theories that help explain the effects of gamification. In future empirical research, these theoretically deducted principles should be tested, challenged, and refined, so that the "how" and "why" of gamification can be explained even more concretely and precisely.

6.2 Implications for practice

The present systematic review demonstrates that gamification, serious games and game-based learning provide a high potential for improving affect and motivation, behavior and learning outcomes in various important areas such as education, health, work, or sustainability. When there is a lack of motivation or performance or if learning behavior and outcomes display room for improvement, gamification can represent a suitable solution when it is a successful manifestation of several principles deemed important by theories on motivation and affect, behavior, and learning. Especially in contexts where motivation usually fades over time, such as education (Wigfield & Wentzel, 2007), gamification, serious games and game-based learning might be useful tools to engage learners in continuous learning, especially since it has been shown that teachers often lack preparation on how to motivate their students (Schürmann et al., 2020). Including theory on gamification, serious games and game-based learning and their impact into teacher education therefore is another crucial practical implication of this research. The same counts for practitioners in other fields: While research has already addressed the previously criticized lack of theoretical foundations in research interventions on gamification and serious games, practice should now be invited to follow up with gamification design built on these theoretical findings. This applies to all contexts in which gamification has been used in the past and will be used in the future, including, for example, health, the workplace or education.

Those who want to benefit from gamification, serious games and game-based learning, such as teachers, managers or physicians, need to develop competencies regarding the underlying theoretical foundations and their principal commonalities. For example, teachers who want to adopt gamification to motivate and engage their students and improve learning outcomes should understand the importance of (P1) clear and relevant goals as well as (P8) guided paths to connect game elements, make sure that the students get (P3) immediate feedback and are thereby (P4) positively reinforced, that the (P10) user experience is simple and supports the work on (P2) individual goals, while the system provides (P7) adaptive content and (P9) choices on the side of the students. A possibility for (P5) social comparison and (P6) social norming should also be given to achieve the best results. In light of these recommendations, it is important to note that the appropriate choice of principles still depends on the context and goals of gamification, and not every principle is necessarily appropriate in every case. For example, an intervention aimed at driving the efforts of student teams to collaboratively discover solutions to gamified problems might intentionally omit social comparisons to avoid competitive dynamics. This highlights that practitioners need to develop *gamification literacy* in the sense of an ability to engage with gamification-related issues and ideas of gamification within their application context. Teachers, managers, doctors, and all those who want to benefit from gamification need to learn how to implement it concerning their specific goals. This is particularly relevant in the educational and work context now as digital education and remote working become more widespread, for instance, due to the Covid-19 pandemic.

Conclusively, it is apparent that practitioners need to understand the underlying theories and especially the derived basic principles and how they relate to motivation and affect, behavior, and learning, so that gamification practice can benefit from a solid theoretical basis and interventions can be designed adequately and successfully to achieve the desired results.

7. Conclusion and Limitations

This systematic review has shown that scientific work on gamification, serious games and game-based learning has used a variety of theoretical foundations from different perspectives to design and evaluate gamified interventions and explain the psychological mechanisms by which gamification achieves its positive outcomes, including theories on motivation and affect, behavior and learning. Most of the theories identified in the course of this review comprise explicitly formulated or conceptual connections, which we illustrated in a graphical representation of the theoretical foundations of gamification research (Fig. 2). From their interrelationships, we derived basic theoretical principles that help explain how gamification works: Through game elements such as points, levels, badges, quests, and many more, gamification can transparently *illustrate goals* and their relevance, lead users through *guided paths* to goal-oriented activities, give users *immediate feedback* and *reinforce good performance* positively, and *simplify content* to manageable tasks. The gamification mechanics can allow users to *pursue individual goals* and *choose between several different progress paths*, while the gamified systems can *adapt tasks and complexity* to the user's abilities. Social gamification elements may enable *social comparison* and *connect users* to support each other and work towards a common goal.

However, this study is not without limitations. First, we chose an umbrella review of the scholarly literature as an appropriate methodological choice to aggregate the divergent findings of the multitude of existing reviews on theoretical foundations of gamification, serious games, and game-based learning. By opting for this methodology, we may have missed empirical or conceptual studies that develop a novel theory based on other theoretical foundations, or non-peer-reviewed research contributions to theoretical foundations, e.g., in book chapters, and therefore cannot claim that our review is fully exhaustive. Second, we based our evaluation of the popularity of various theoretical foundations both on the number of reviews in which any given theory is mentioned and on the scope of the primary research studies in which it was applied. However, five of the 32 reviews that we meta-analyzed did not provide the sum of primary studies that used a particular theory, so the total number of studies listed in our review may be biased. However, the theories mentioned in the respective reviews fit the general distribution of theories in research, so it is likely that the divergent sum of the studies does not affect our results.

Third, we have studied the conceptual links between different theoretical foundations in detail. However, we would like to emphasize that neither our theoretical landscape nor the conceptually derived principles claim to be complete and are open for further development by other scientists. We have, for example, only compared the 21 most popular theories to derive our theoretical principles that help explain how gamification works. There are at least 95 more theories used in primary studies that future research could investigate and link to the effects of gamification, serious games and game-based learning in general or other theories and different contexts in particular. The resulting implications and core assumptions for gamification, serious games and game-based learning are still to be investigated. Also, our derived principles are based primarily on a conceptual discussion, and further empirical research is needed to support their validity and investigate how well the different principles can explain the effects of gamification, serious games and game-based learning.

Finally, it should be noted that our theoretically derived principles that help explain how gamification works share parallels with several design guidelines for successful gamification (Krath & von Korflesch, 2021) that have either been derived from qualitative research (e.g. Israel et al., 2013; Morschheuser et al., 2018; Sezgin & Yüzer, 2020) or have been developed conceptually using specific theories (Liu et al., 2017; Plass et al., 2015). It would support both the validity of our theoretical findings and the validity of the design principles if the basic assumptions on the principles of gamification that lead to its positive outcome matched the guidelines for successful gamification design, and we invite further research for such a profound comparison. In this way, research can gradually gain an accepted understanding of how gamification works and how it must be realized to be successful, thereby reducing or explaining potentially ambiguous results about outcomes and advancing the effective application of gamification and serious games in various application contexts.

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Appendix

Appendix A: List of excluded full texts during the review on theoretical foundations in gamification research

Type	Authors	Title	Journal	Annotation
Journal	(Beard-Gunter et al., 2019)	TQM, games design and the implications of integration in Industry 4.0 systems	International Journal of Quality and Service Sciences	Excluded: No repeatability. Inclusion criteria not reported, final sample not reported.
Journal	(Osatuyi et al., 2018)	Systematic review of gamification research in is education: A multi-method approach	Communications of the Association for Information Systems	Excluded: No repeatability. Search strings ambiguous, Inclusion criteria not provided.
Journal	(Ahmad et al., 2015)	An analysis of educational games design frameworks from software engineering perspective	Journal of Information and Communication Technology	Excluded: No repeatability. Search strings not provided, inclusion criteria not provided
Journal	(Boyle et al., 2011)	The role of psychology in understanding the impact of computer games	Entertainment Computing	Excluded: No repeatability. Search strings not provided, no systematic review
Journal	(Marini et al., 2018)	Socio-psychological perspectives on the potential for serious games to promote transcendental values in IWRM decision-making	Water (Switzerland)	Excluded: No repeatability. Search strings not provided, results not provided
Journal	(Helf & Hlavacs, 2016)	Apps for life change: Critical review and solution directions	Entertainment Computing	Excluded: Search strategy missing
Journal	(Ahmed & Sutton, 2017)	Gamification, serious games, simulations, and immersive learning environments in knowledge management initiatives	World Journal of Science, Technology and Sustainable Development	Introduction to Special Issue
Journal	(Rapp et al., 2019)	Strengthening gamification studies: Current trends and future opportunities of gamification research	International Journal of Human Computer Studies	Introduction to Special Issue
Journal	(Wünderlich et al., 2020)	The great game of business: Advancing knowledge on gamification in business contexts	Journal of Business Research	Introduction to Special Issue
Journal	(Abdul Jabbar & Felicia, 2015)	Gameplay Engagement and Learning in Game-Based Learning: A Systematic Review	Review of Educational Research	No analysis of theories
Journal	(Akl et al., 2013)	Educational games for health professionals	Cochrane Database of Systematic Reviews	No analysis of theories
Journal	(Alahäivälä & Oinas-Kukkonen, 2016)	Understanding persuasion contexts in health gamification: A systematic analysis of gamified health behavior change support systems literature	International Journal of Medical Informatics	No analysis of theories
Journal	(Alanne, 2016)	An overview of game-based learning in building services engineering education	European Journal of Engineering Education	No analysis of theories
Conference	(Alla & Nafil, 2019)	Gamification in IoT application: A systematic mapping study	Procedia Computer Science	No analysis of theories
Journal	(Alomari et al., 2019)	The role of gamification techniques in promoting student learning: A review and synthesis	Journal of Information Technology Education: Research	No analysis of theories
Journal	(Anderson et al., 2010)	Developing serious games for cultural heritage: a state-of-the-art review	Virtual Reality	No analysis of theories
Journal	(Andersson et al., 2018)	Promoting sustainable travel behaviour through the use of smartphone applications: A review and development of a conceptual model	Travel Behaviour and Society	No analysis of theories
Journal	(Antonaci et al., 2019)	The effects of gamification in online learning environments: A systematic literature review	Informatics	No analysis of theories
Journal	(Bai et al., 2020)	Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts	Educational Research Review	No analysis of theories
Journal	(Baptista & Oliveira, 2019)	Gamification and serious games: A literature meta-analysis and integrative model	Computers in Human Behavior	No analysis of theories
Journal	(Behl et al., 2020)	Gamification in E- Commerce	Journal of Electronic Commerce in Organizations	No analysis of theories
Journal	(Bodnar et al., 2016)	Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students	Journal of Engineering Education	No analysis of theories

Type	Authors	Title	Journal	Annotation
Journal	(Bossen et al., 2020)	Effectiveness of Serious Games to Increase Physical Activity in Children with a Chronic Disease: Systematic Review with Meta-Analysis	Journal of Medical Internet Research	No analysis of theories
Journal	(Caballero-Hernández et al., 2017)	Skill assessment in learning experiences based on serious games: A Systematic Mapping Study	Computers and Education	No analysis of theories
Journal	(Calderón & Ruiz, 2015)	A systematic literature review on serious games evaluation: An application to software project management	Computers and Education	No analysis of theories
Journal	(Calderón et al., 2018)	A multivocal literature review on serious games for software process standards education	Computer Standards and Interfaces	No analysis of theories
Journal	(Coleman & Money, 2020)	Student-centred digital game–based learning: a conceptual framework and survey of the state of the art	Higher Education	No analysis of theories
Journal	(Collado-Mateo et al., 2018)	Effect of exergames on musculoskeletal pain: A systematic review and meta-analysis	Scandinavian Journal of Medicine and Science in Sports	No analysis of theories
Journal	(Connolly et al., 2012)	A systematic literature review of empirical evidence on computer games and serious games	Computers and Education	No analysis of theories
Journal	(Cordero-Brito & Mena, 2020)	Gamification and Its Application in the Social Environment: A Tool for Shaping Behaviour	Journal of Information Technology Research	No analysis of theories
Journal	(Darejeh & Salim, 2016)	Gamification Solutions to Enhance Software User Engagement—A Systematic Review	International Journal of Human-Computer Interaction	No analysis of theories
Journal	(Dehghanzadeh et al., 2019)	Using gamification to support learning English as a second language: a systematic review	Computer Assisted Language Learning	No analysis of theories
Journal	(De la Hera Conde-Pumpido, 2017)	Persuasive Gaming: Identifying the different types of persuasion through games	International Journal of Serious Games	No analysis of theories
Journal	(den Haan & van der Voort, 2018)	On evaluating social learning outcomes of serious games to collaboratively address sustainability problems: A literature review	Sustainability (Switzerland)	No analysis of theories
Journal	(Derksen et al., 2020)	Serious games for smoking prevention and cessation: A systematic review of game elements and game effects	Journal of the American Medical Informatics Association	No analysis of theories
Journal	(DeSmet et al., 2015)	A Systematic Review and Meta-analysis of Interventions for Sexual Health Promotion Involving Serious Digital Games	Games for Health Journal	No analysis of theories
Journal	(De Vette et al., 2015)	Engaging Elderly People in Telemedicine Through Gamification	JMIR Serious Games	No analysis of theories
Journal	(De Wit-Zuurendonk & Oei, 2011)	Serious gaming in women's health care	BJOG: An International Journal of Obstetrics and Gynaecology	No analysis of theories
Journal	(Dias et al., 2018)	Gamification and serious games in depression care: A systematic mapping study	Telematics and Informatics	No analysis of theories
Journal	(Dicheva et al., 2015)	Gamification in education: A systematic mapping study	Educational Technology and Society	No analysis of theories
Journal	(Drummond et al., 2017)	A systematic review of serious games in asthma education	Pediatric Allergy and Immunology	No analysis of theories
Journal	(Edwards et al., 2019)	Tools for adaptive governance for complex social-ecological systems: A review of role-playing-games as serious games at the community-policy interface	Environmental Research Letters	No analysis of theories
Journal	(Eichenberg & Schott, 2017)	Serious Games for Psychotherapy: A Systematic Review	Games for Health Journal	No analysis of theories
Journal	(Farrington, 2011)	From the research: Myths worth dispelling: Seriously, the game is up	Performance Improvement Quarterly	No analysis of theories
Journal	(Z. Feng et al., 2018)	Immersive virtual reality serious games for evacuation training and research: A systematic literature review	Computers and Education	No analysis of theories
Journal	(Fleming et al., 2014)	Serious games for the treatment or prevention of depression: A systematic review	Spanish Journal of Clinical Psychology	No analysis of theories
Journal	(Fleming et al., 2017)	Serious games and gamification for mental health: Current status and promising directions	Frontiers in Psychiatry	No analysis of theories
Journal	(Flood et al., 2018)	Adaptive and interactive climate futures: Systematic review of 'serious games' for engagement and decision-making	Environmental Research Letters	No analysis of theories
Journal	(Fox et al., 2018)	Simulations in Entrepreneurship Education: Serious Games and Learning Through Play	Entrepreneurship Education and Pedagogy	No analysis of theories
Journal	(Garcia et al., 2020)	The effects of game-based learning in the acquisition of “soft skills” on undergraduate software engineering courses: A systematic literature review	Computer Applications in Engineering Education	No analysis of theories
Journal	(Gauthier et al., 2019)	Board Games for Health: A Systematic Literature Review and Meta-Analysis	Games for Health Journal	No analysis of theories

Type	Authors	Title	Journal	Annotation
Journal	(Gentry et al., 2019)	Serious gaming and gamification education in health professions: systematic review	Journal of Medical Internet Research	No analysis of theories
Journal	(Girard et al., 2013)	Serious games as new educational tools: How effective are they? A meta-analysis of recent studies	Journal of Computer Assisted Learning	No analysis of theories
Journal	(Gorbanev et al., 2018)	A systematic review of serious games in medical education: quality of evidence and pedagogical strategy	Medical Education Online	No analysis of theories
Journal	(Graafland et al., 2012)	Systematic review of serious games for medical education and surgical skills training	British Journal of Surgery	No analysis of theories
Journal	(Hainey et al., 2016)	A systematic literature review of games-based learning empirical evidence in primary education	Computers and Education	No analysis of theories
Journal	(Hallinger & Wang, 2020b)	Analyzing the intellectual structure of research on simulation-based learning in management education, 1960-2019: A bibliometric review	The International Journal of Management Education	No analysis of theories
Journal	(Hassan & Hamari, 2020)	Gameful civic engagement: A review of the literature on gamification of e-participation	Government Information Quarterly	No analysis of theories
Journal	(Hinton et al., 2019)	Enterprise gamification systems and employment legislation: a systematic literature review	Australasian Journal of Information Systems	No analysis of theories
Journal	(Hung et al., 2018)	A scoping review of research on digital game-based language learning	Computers and Education	No analysis of theories
Journal	(Hussein et al., 2019)	Effects of Digital Game-Based Learning on Elementary Science Learning: A Systematic Review	IEEE Access	No analysis of theories
Journal	(Indriasari et al., 2020)	Gamification of student peer review in education: A systematic literature review	Education and Information Technologies	No analysis of theories
Journal	(Johnson et al., 2016)	Gamification for health and wellbeing: A systematic review of the literature	Internet Interventions	No analysis of theories
Journal	(Johnson et al., 2017)	Gamification and serious games within the domain of domestic energy consumption: A systematic review	Renewable and Sustainable Energy Reviews	No analysis of theories
Journal	(Kangas et al., 2017)	A qualitative literature review of educational games in the classroom: the teacher's pedagogical activities	Teachers and Teaching: Theory and Practice	No analysis of theories
Journal	(Kasurinen & Knutas, 2018)	Publication trends in gamification: A systematic mapping study	Computer Science Review	No analysis of theories
Journal	(Keusch & Zhang, 2017)	A Review of Issues in Gamified Surveys	Social Science Computer Review	No analysis of theories
Journal	(Kinross, 2018)	Precision gaming for health: Computer games as digital medicine	Methods	No analysis of theories
Journal	(Koh, 2020)	A Qualitative Meta-Analysis on the Use of Serious Games to Support Learners with Intellectual and Developmental Disabilities: What We Know, What We Need to Know and What We Can Do	International Journal of Disability, Development and Education	No analysis of theories
Journal	(Koivisto & Hamari, 2019)	The rise of motivational information systems: A review of gamification research	International Journal of Information Management	No analysis of theories
Journal	(Lai & Bower, 2020)	Evaluation of technology use in education: Findings from a critical analysis of systematic literature reviews	Journal of Computer Assisted Learning	No analysis of theories
Journal	(Laine & Lindberg, 2020)	Designing Engaging Games for Education: A Systematic Literature Review on Game Motivators and Design Principles	IEEE Transactions on Learning Technologies	No analysis of theories
Journal	(Lamb et al., 2018)	A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations	Computers in Human Behavior	No analysis of theories
Journal	(Lämsä et al., 2018)	Games for enhancing basic reading and maths skills: A systematic review of educational game design in supporting learning by people with learning disabilities	British Journal of Educational Technology	No analysis of theories
Journal	(Landers, 2014)	Developing a Theory of Gamified Learning: Linking Serious Games and Gamification of Learning	Simulation and Gaming	No analysis of theories
Journal	(Lau et al., 2017)	Serious Games for Mental Health: Are They Accessible, Feasible, and Effective? A Systematic Review and Meta-analysis.	Frontiers in psychiatry	No analysis of theories
Journal	(Lin et al., 2013)	Designing a web-based behavior motivation tool for healthcare compliance	Human Factors and Ergonomics In Manufacturing	No analysis of theories
Journal	(Lopes et al., 2018)	Games Used With Serious Purposes: A Systematic Review of Interventions in Patients With Cerebral Palsy.	Frontiers in psychology	No analysis of theories
Journal	(Magista et al., 2018)	A review of the applicability of gamification and game-based learning to improve household-level	International Journal of Technology	No analysis of theories

Type	Authors	Title	Journal	Annotation
		waste management practices among schoolchildren		
Journal	(Maheu-Cadotte et al., 2018)	Effectiveness of serious games and impact of design elements on engagement and educational outcomes in healthcare professionals and students: A systematic review and meta-Analysis protocol	BMJ Open	No analysis of theories
Journal	(Marlow et al., 2016)	Eliciting teamwork with game attributes: A systematic review and research agenda	Computers in Human Behavior	No analysis of theories
Journal	(Martinho et al., 2020)	A systematic review of gamification techniques applied to elderly care	Artificial Intelligence Review	No analysis of theories
Journal	(Morganti et al., 2017)	Gaming for Earth: Serious games and gamification to engage consumers in pro-environmental behaviours for energy efficiency	Energy Research and Social Science	No analysis of theories
Journal	(Morschheuser et al., 2018)	How to design gamification? A method for engineering gamified software	Information and Software Technology	No analysis of theories
Journal	(Morschheuser et al., 2017)	Gamified crowdsourcing: Conceptualization, literature review, and future agenda	International Journal of Human Computer Studies	No analysis of theories
Journal	(Obaid et al., 2020)	Gamification for Recruitment and Job Training: Model, Taxonomy, and Challenges	IEEE Access	No analysis of theories
Journal	(O'Loughlin et al., 2020)	Exergaming in Youth and Young Adults: A Narrative Overview	Games for Health Journal	No analysis of theories
Journal	(Pathak et al., 2021)	A study on Systematic review of Gamification in Education Sector	Journal of Contemporary Issues in Business and Management	No analysis of theories
Journal	(Perttula et al., 2017)	Flow experience in game based learning – a systematic literature review	International Journal of Serious Games	No analysis of theories
Journal	(Petri & von Wangenheim, 2016)	How to evaluate educational games: A systematic literature review	Journal of Universal Computer Science	No analysis of theories
Journal	(Pimentel et al., 2020)	Game-Based Learning Interventions to Foster Cross-Cultural Care Training: A Scoping Review	Games for Health Journal	No analysis of theories
Journal	(Ravyse et al., 2017)	Success factors for serious games to enhance learning: a systematic review	Virtual Reality	No analysis of theories
Journal	(Riopel et al., 2019)	Impact of serious games on science learning achievement compared with more conventional instruction: an overview and a meta-analysis	Studies in Science Education	No analysis of theories
Journal	(Rodrigues et al., 2019)	Main gamification concepts: A systematic mapping study	Heliyon	No analysis of theories
Journal	(Roth et al., 2015)	The ludic drive as innovation driver: Introduction to the gamification of innovation	Creativity and Innovation Management	No analysis of theories
Journal	(Rumeser & Emsley, 2018)	A systematic review of project management serious games: Identifying gaps, trends and directions for future research	Journal of Modern Project Management	No analysis of theories
Journal	(Sailer & Homner, 2020)	The Gamification of Learning: a Meta-analysis	Educational Psychology Review	No analysis of theories
Journal	(Santamaría et al., 2011)	Serious games as additional psychological support: A review of the literature	Journal of Cybertherapy and Rehabilitation	No analysis of theories
Journal	(Sardi et al., 2017)	A systematic review of gamification in e-Health	Journal of Biomedical Informatics	No analysis of theories
Journal	(Schmidt & De Marchi, 2017)	Usability evaluation methods for mobile serious games applied to health: a systematic review	Universal Access in the Information Society	No analysis of theories
Journal	(Sera & Wheeler, 2017)	Game on: The gamification of the pharmacy classroom	Currents in Pharmacy Teaching and Learning	No analysis of theories
Conference	(Shoukry & Göbel, 2020)	Reasons and Responses: A Multimodal Serious Games Evaluation Framework	IEEE Transactions on Emerging Topics in Computing	No analysis of theories
Journal	(Sipiyaruk et al., 2018)	A rapid review of serious games: From healthcare education to dental education	European Journal of Dental Education	No analysis of theories
Journal	(Stanitsas et al., 2019)	Facilitating sustainability transition through serious games: A systematic literature review	Journal of Cleaner Production	No analysis of theories
Journal	(Subhash & Cudney, 2018)	Gamified learning in higher education: A systematic review of the literature	Computers in Human Behavior	No analysis of theories
Journal	(Tăut et al., 2017)	Play seriously: Effectiveness of serious games and their features in motor rehabilitation. A meta-analysis	NeuroRehabilitation	No analysis of theories
Journal	(Taylor et al., 2012)	The Coaching Cycle: A Coaching-by-Gaming Approach in Serious Games	Simulation and Gaming	No analysis of theories
Journal	(Theng et al., 2015)	The Use of Videogames, Gamification, and Virtual Environments in the Self-Management of Diabetes: A Systematic Review of Evidence	Games for Health Journal	No analysis of theories
Journal	(Tsai & Fan, 2013)	Research trends in game-based learning research in online learning environments: A review of	British Journal of Educational Technology	No analysis of theories

Type	Authors	Title	Journal	Annotation
		studies published in SSCI-indexed journals from 2003 to 2012		
Journal	(Tsikinas & Xinogalos, 2019)	Studying the effects of computer serious games on people with intellectual disabilities or autism spectrum disorder: A systematic literature review	Journal of Computer Assisted Learning	No analysis of theories
Journal	(Valladares-Rodríguez et al., 2016)	Trends on the application of serious games to neuropsychological evaluation: A scoping review	Journal of Biomedical Informatics	No analysis of theories
Journal	(Wang et al., 2016)	A systematic review of serious games in training: Health care professionals	Simulation in Healthcare	No analysis of theories
Journal	(Wanick & Bui, 2019)	Gamification in Management: a systematic review and research directions	International Journal of Serious Games	No analysis of theories
Journal	(Warmelink et al., 2020)	Gamification of production and logistics operations: Status quo and future directions	Journal of Business Research	No analysis of theories
Journal	(Wouters et al., 2013)	A meta-analysis of the cognitive and motivational effects of serious games	Journal of Educational Psychology	No analysis of theories
Journal	(Xu et al., 2017)	Serious games and the gamification of tourism	Tourism Management	No analysis of theories
Journal	(Yáñez-Gómez et al., 2017)	Academic methods for usability evaluation of serious games: a systematic review	Multimedia Tools and Applications	No analysis of theories
Journal	(Yıldırım & Şen, 2019)	The effects of gamification on students' academic achievement: a meta-analysis study	Interactive Learning Environments	No analysis of theories
Journal	(Yu, 2019)	A Meta-Analysis of Use of Serious Games in Education over a Decade	International Journal of Computer Games Technology	No analysis of theories
Journal	(Zhou et al., 2020)	A Meta-analysis of Narrative Game-based Interventions for Promoting Healthy Behaviors	Journal of Health Communication	No analysis of theories
Journal	(Zou et al., 2019)	Digital game-based vocabulary learning: Where are we and where are we going?	Computer Assisted Language Learning	No analysis of theories
Journal	(Edwards et al., 2016)	Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps	BMJ open	No review on literature
Journal	(Aparicio et al., 2019)	Gamification: A key determinant of massive open online course (MOOC) success	Information and Management	Not a review
Journal	(Afyouni et al., 2017)	A therapy-driven gamification framework for hand rehabilitation	User Modeling and User-Adapted Interaction	Not a review
Journal	(Bíró, 2014)	Didactics 2.0: A Pedagogical Analysis of Gamification Theory from a Comparative Perspective with a Special View to the Components of Learning	Procedia - Social and Behavioral Sciences	Not a review
Journal	(Cardador et al., 2017)	A theory of work gamification: Something old, something new, something borrowed, something cool?	Human Resource Management Review	Not a review
Journal	(Carvalho et al., 2015)	An activity theory-based model for serious games analysis and conceptual design	Computers and Education	Not a review
Journal	(Chen, 2019)	Exploring Design Guidelines of Using User-Centered Design in Gamification Development: A Delphi Study	International Journal of Human-Computer Interaction	Not a review
Journal	(Conway, 2014)	Zombification?: Gamification, motivation, and the user	Journal of Gaming and Virtual Worlds	Not a review
Journal	(D'Aprile et al., 2015)	Social, constructivist and informal learning processes: Together on the edge for designing digital game-based learning environments	Journal of E-Learning and Knowledge Society	Not a review
Journal	(Gunter et al., 2008)	Taking educational games seriously: Using the RETAIN model to design endogenous fantasy into standalone educational games	Educational Technology Research and Development	Not a review
Journal	(Huang & Hew, 2018)	Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts	Computers and Education	Not a review
Journal	(Kam & Umar, 2018)	Fostering Authentic Learning Motivations through Gamification: a Self-Determination Theory (SDT) Approach	Journal of Engineering Science and Technology	Not a review
Journal	(Landers et al., 2019)	Defining gameful experience as a psychological state caused by gameplay: Replacing the term 'Gamefulness' with three distinct constructs	International Journal of Human Computer Studies	Not a review
Journal	(Liu et al., 2017)	Toward Meaningful Engagement : a Framework for Design and Research of Gamified Information Systems	MIS Quarterly	Not a review
Journal	(Murillo-Zamorano et al., 2020)	Gamified crowdsourcing in higher education: A theoretical framework and a case study	Thinking Skills and Creativity	Not a review
Journal	(Nacke & Deterding, 2017)	The maturing of gamification research	Computers in Human Behavior	Not a review

Type	Authors	Title	Journal	Annotation
Journal	(Perryer et al., 2016)	Enhancing workplace motivation through gamification: Transferrable lessons from pedagogy	International Journal of Management Education	Not a review
Journal	(Plass et al., 2015)	Foundations of Game-Based Learning	Educational Psychologist	Not a review
Journal	(Procci et al., 2014)	Opening Cinematics: Their Cost-Effectiveness in Serious Games	Simulation and Gaming	Not a review
Journal	(Rapp, 2017b)	Drawing inspiration from world of warcraft: Gamification design elements for behavior change technologies	Interacting with Computers	Not a review
Journal	(Rodrigues et al., 2016)	Playing seriously - How gamification and social cues influence bank customers to use gamified e-business applications	Computers in Human Behavior	Not a review
Conference	(Songer & Miyata, 2014)	A playful affordances model for gameful learning	ACM International Conference Proceeding Series	Not a review
Conference	(Suttie et al., 2012)	In pursuit of a 'serious games mechanics' : A theoretical framework to analyse relationships between 'game' and 'pedagogical aspects' of serious games	Procedia Computer Science	Not a review
Journal	(Tahir & Wang, 2020)	Codifying Game-Based Learning: Development and Application of LEAGUE Framework for Learning Games	The Electronic Journal of e-Learning	Not a review
Journal	(Turkay et al., 2014)	Toward Understanding the Potential of Games for Learning: Learning Theory, Game Design Characteristics, and Situating Video Games in Classrooms	Computers in the Schools	Not a review
Journal	(Brancato et al., 2020)	Behavioral Psychological based on Development of Serious Digital Games for Individuals with Autistic Spectrum Disorder: Systematic Review	Humanidades & Inovacao	Not english
Journal	(Christianini et al., 2016)	Gamified Systems Development focused on Edutertainment and Player: an Analysis of Bartle and Marczewski Archetypes	Revista Ibero-Americana de Estudos em Educação	Not english
Journal	(Contreras, 2020)	Gamification in Educational Contexts: Analysis of Its Application in a Distance Public Accounting Program	Revista Universidad Empressa	Not english
Journal	(Kankanamge et al., 2020)	How can gamification be incorporated into disaster emergency planning? A systematic review of the literature	International Journal of Disaster Resilience in the Built Environment	Unaccessible
Journal	(Kleiman et al., 2020)	A Systematic Literature Review on the Use of Games for Attitude Change: Searching for Factors Influencing Civil Servants' Attitudes	International Journal of Electronic Government Research	Unaccessible
Journal	(Noorbehbahani et al., 2019)	A systematic mapping study on gamification applied to e-marketing	Journal of Research in Interactive Marketing	Unaccessible

Appendix B: List of theoretical foundations and coded abbreviations used for the systematic review on theoretical foundations in gamification research

Abbreviation	Name	Abbreviation	Name
TPB	Theory of planned behavior	UDL	Universal design for learning
RT	Reinforcement theory	PPM	Presence pedagogy model
TRA	Theory of reasoned action	7E	Eisenkraft's 7E instructional model
TTM	Transtheoretical model of behavior change	FSLS	Felder-Silverman learning style model
FBM	Fogg's behavior model	MPID	Merrill's principles of instruction design theory
RCT	Rational choice theory	TETEM	Technology-enhanced training effectiveness model
EDT	Ego depletion theory	SOLT	Social learning theory
PPROM	Parallel process model	MT	Malone's theory
TMB	Theory of meanings of behavior	SDT	Self-determination theory
KABM	Knowledge, attitude, behavior model	FT	Flow theory
SNETT	Social network theory	SE	Self-efficacy theory
AT	Activity theory	GS	Goal-setting theory
SCONT	Social conformity theory	CET	Cognitive evaluation theory
TAM	Technology acceptance model	OIT	Organismic integration theory
MDA	Mechanics, dynamics and aesthetics framework	FDT	Four drives theory
ISSM	Information systems success model	PAT	Person-artefact-task model
MDE	Mechanics, dynamics and emotions model	MHN	Maslow's hierarchy of needs
TIT	Theory of interactive technology	GOT	Achievement goal theory
MDF	Moral design framework	SCOMT	Social comparison theory
UTAUT	Unified theory of acceptance and use of technology	MSPN	Murray's secondary psychological needs
MGF	User-centered theoretical framework for meaningful gamification	TCMM	Transcontextual model of motivation
SCOGT	Social cognitive theory	HBM	Health belief model
ARCS	ACRS model	SR	Situational relevance theory
LGL	Lander's theory of gamified learning	CONTT	Control theory
CLT	Cognitive load theory	ELM	Elaboration likelihood model
SLT	Situated learning theory	TT	Taxation theory
CONLT	Constructivist learning theory	DIT	Diffusion of innovation theory
SCTCD	Sociocultural theory of cognitive development	TOB	Theory of organisational behavior
MVP	Theory of motivation, volition and performance	BIG5	Big five personality theory

Abbreviation	Name	Abbreviation	Name
MML	Multimedia learning theory	TRANST	Transportation theory
SHM	Sexual health model	UML	Unified modeling language
TDGDM	Theory-driven gamification design model	SI	Situational interest theory
EV	Expectancy-value theory	TGID	Theory of gamified instructional design
DGBL	Digital game-based learning	PP	Premack's principle
UCD	User-centered design	ELT	Experiential learning theory
STCD	Stage theory of cognitive development	CBL	Case-based learning
DLT	Discovery learning theory	PBL	Problem-based learning
UGT	Uses and gratifications theory	TMI	Theory of multiple intelligence
IM	Immersion theory	MMT	Mood management theory
ATT	Affect transfer theory	CT	Communication theory
TRME	Theory of realistic mathematics education	IMB	Information, motivation and behavior model
MRT	Middle-range theory of chronic illness	ALT	Adult learning theory
WICS	Wisdom, intelligence and creativity synthesized theory	PACT	Play, affect and creativity theory
TA	Theory of affordances	MM	Model model
MOT	Moran's theorem	GT	Guilford's structure of intellect
GGBL	Gee's game-based learning principles	IBL	Inquiry-based learning
WGF	Werbach's gamification framework	CDT	Cognitive dissonance theory
IML	Taxonomy of intrinsic motivations for learning	EMLT	Embodied learning
TML	Theory of motivation to learn	TEM	Tripartite enjoyment model
TP	Transformational play	SEM	Situative embodiment
EN	Enactivism	POE	Prediction-observation-explanation model
ITL	Interest theory of learning	CONSTR	Constructionism
SDDSM	Scientific discovery as dual search model	NCL	Narrative centered learning
GIS	Gagné's instruction strategies	BE	Behavioral economics
DTT	Dual-task training	SDL	Self-directed learning theory
BCT	Taxonomy of behavior change techniques	ATR	Attribution theory
DPT	Deliberate practice	TCONL	Theory of conditions for learning
ELAB	Elaboration theory	CA	Cognitive apprenticeship
ANT	Actor-network theory	DI	Direct instruction
PI	Programmed instruction		

Appendix C: Coding scheme for the categorization of theoretical foundations used in research on gamification, serious games and game-based learning

Category	Description	Initial exemplary theories
Affect and motivation	Theoretical foundations related to the determinants or processes of motivation, valence (e.g. satisfaction, enjoyment, immersion, attitude) or arousal	Self-determination theory, flow theory
Behavior	Theoretical foundations related to the determinants of behavior or processes of behavior change	Theory of planned behavior, transtheoretical model of behavior change
Learning	Theoretical foundations related to cognitive processes and influence factors of learning (e.g. reasoning, problem-solving, creative thinking, knowledge acquisition)	Social learning theory, situated learning theory

Appendix D: Detailed explanation of theoretical foundations, their origins, and their use in research on gamification and serious games

Theoretical foundation	Origin and core statements	Use in research on gamification
Theoretical foundations related to affect and motivation		
Self-determination theory (SDT)	SDT has evolved over several decades as an organismic, dialectic meta-theory of human motivation (Ryan & Deci, 2020). It does not only describe motivation in quantity but also in quality, as it differentiates between amotivation and different types of extrinsic and intrinsic motivation (Ryan & Deci, 2000b). These types of motivation are aligned on a continuum of relative autonomy, from fully controlled external regulation of behavior over introjected, identified, and integrated regulation to intrinsic regulation as the prototype of self-regulated behavior (Ryan & Deci, 2020). More autonomous forms of behavior regulation are connected to well-being and personal development. Moreover, motivation can become more autonomous through the process of integration, as described in Organismic Integration Theory, a sub-theory of SDT (Ryan & Deci, 2000a, Ryan & Deci, 2020). According to SDT, three basic psychological needs – the need for *competence*, the need for *autonomy,* and the need for *relatedness* –form the basis of human motivation (Ryan & Deci, 2000b).	Applications of SDT usually relate to the basic psychological needs. They aim either deriving implications for game design (e.g. Barata *et al.*, 2017; Sailer *et al.*, 2017; Wee & Choong, 2019) or at measuring whether an intervention increases the perceived competence, relatedness and autonomy (e.g. Frost, Matta & MacIvor, 2015; van Roy & Zaman, 2019; Xi & Hamari, 2019).
Flow theory	Flow is a *"holistic sensation that people feel when they act with total involvement"* (Csikszentmihalyi, 1975, p. 36). This mental state is characterized by intense concentration, merging of action and awareness, loss of self-consciousness and a distortion of temporal experience (Csikszentmihalyi, 1990, 2014). The concept of flow is directly related to intrinsic motivation: when individuals are fully involved in an activity, they experience the activity as intrinsically rewarding, and pursue it for the sake of the activity itself rather than to achieve the ultimate goal (Csikszentmihalyi, 2014). To achieve flow, the opportunities for action must be balanced with the abilities of the actor (Csikszentmihalyi, 1975, 2013). Additionally, clear objectives and immediate feedback support flow (Csikszentmihalyi, 2014; Csikszentmihalyi & Csikszentmihalyi, 1988).	Flow is measured to evaluate gamified interventions and to draw implications for the relationship between flow and behavioral outcomes (e. g. Bachen *et al.*, 2016; Almeida & Buzady, 2019; Catalán, Martínez & Wallace, 2019; Chung, Shen & Qiu, 2019; Bitrián, Buil & Catalán, 2020).
ARCS model	Keller's ARCS model is a motivational model for instructional design based primarily on expectancy-value theory as presented by Porter & Lawler (1967), which describes motivation as the result of a function of value – a person's preference for certain outcomes, e.g. based on psychological needs – and expectancy – a subjective probability of success (Keller, 1979). These two factors are expanded to four: *attention* and *relevance* refer to the value category, and *confidence* and *satisfaction* belong to the expectancy side (Keller, 1987). Satisfaction is related with outcome expectations, such as goals, whereas confidence refers to the personal belief in success, i.e. self-efficacy (Bandura, 1982). Keller postulates different teaching strategies for each of these four factors (Keller 1987).	The ARCS model is used pertinently for evaluating serious games in education (e. g. Kaneko *et al.*, 2015; Deif, 2017; Calvo-Ferrer, 2018; Ozdamli, 2018), but it has also been applied to health-related serious games, for instance (Alamri et al., 2014).

Theoretical foundation	Origin and core statements	Use in research on gamification
Goal-setting theory	The core of goal-setting theory arose from the observation that difficult goals produce a higher level of performance than easy goals, and that specific difficult goals produce a higher level of performance than ambiguous difficult goals (Locke, 1968). They do so through three motivational mechanisms of behavior (the *direction, effort* and *persistence* of behavior) and through influencing *task-relevant knowledge* (Locke & Latham, 2002, 2013). Furthermore, there are six moderators which influence the relationship between goals and performance*: goal commitment*, *feedback*, *task complexity, situational constraints, personality, affect* and *ability*. The concept of self-efficacy (Bandura, 1982) is explicitly described as an enabler of goal commitment (Locke & Latham, 2002, 2013).	Scientists investigate if goals in game-based learning enhance performance (Nebel et al., 2017) and put forward the hypothesis that e.g. leaderboards provide goals and immediate feedback, so that performance improves (Chernbumroong et al., 2017; Landers et al., 2017).
Self-efficacy theory	Self-efficacy is a person's conviction that he or she can successfully execute the behavior which is required to achieve the outcomes (Bandura, 1982). Self-efficacy does not necessarily depend on the objective level of ability and is highly context-dependent, so it can vary considerably depending on circumstances (Bandura, 1997). However, perceived self-efficacy has a direct influence on people's choice of activities. It determines how much effort people will expend and how long they will persist if obstacles occur (Bandura, 1978), which is why self-efficacy is highly relevant for motivation. Self-efficacy theory states that perceived self-efficacy can be influenced by four main sources of efficacy information: one's own *performance accomplishments*, *vicarious experience* (seeing others perform well), *verbal persuasion* and *emotional arousal* (Bandura, 1978).	Gamification studies examine whether game mechanics strengthen the transparency of performance in order increase self-efficacy (Y. Feng et al., 2018), e.g. for reacting in emergencies (Chittaro & Buttussi, 2018), identifying cyber-security threads (Baral & Arachchilage, 2019) and performing in learning tasks (Blasko-Drabik et al., 2013).
Social comparison theory	The theory of social comparison processes states that people have a natural drive to evaluate their opinions and abilities (Festinger, 1954). Social comparisons allow people to check their own version of reality and serve as a basis for self-evaluation (Wedell & Parducci, 2000). While Festinger (1954) assumes an unidirectional drive for upward comparisons in abilities, later research led to the suggestion that people foremost try to achieve a positive self-evaluation (Goethals & Darley, 1987). Ultimately, the direction of social comparison processes and their outcome can have a lasting effect on self-esteem (Goethals, 1986). Empirical research has shown that several factors influence whether an upward comparison is perceived as motivating or discouraging, such as the possibility to make private comparisons, the perceived risk of exposing one's own inferiority to others, and the personal motive of self-improvement (Buunk & Gibbons, 2007).	Researchers investigate whether social comparisons, in form of leaderboards or elements of social status, have a positive or negative impact on motivation and performance (e.g. Christy & Fox, 2014; Bayuk & Altobello, 2019).
Achievement goal theory	Nicholls (1984) first described that there are two types of achievement motivations in the pursuit of goals: ego involvement – or *mastery goal orientation* - and task involvement – or *performance goal orientation*. These orientations interact, meaning that each individual exhibits a mixture of these orientations with varying intensity (Pintrich, 2000). Elliot and others added the dimension of avoidance, resulting in an achievement goal matrix with four goal orientations (Elliot, 1999; Elliot & McGregor, 2001): the *mastery-approach orientation*, where the individual focuses on increasing competence, the *mastery-avoidance orientation*, where the individual works to avoid failure, the *performance-approach orientation*, where the individual seeks to demonstrate ability and self-esteem relative to others and the *performance-avoidance* orientation, where the individual strives to avoid being perceived as incompetent relative to peers (Wolters, 2004).	Scholars are considering achievement goal theory to investigate whether motivational effects of gamified elements differ according to the participants' goal orientation (Auvinen et al., 2015; Hakulinen & Auvinen, 2014) and if gamified interventions can be individualized to fit the user's goal orientation towards a particular task (Roosta & Taghiyareh, 2016).

Theoretical foundation	Origin and core statements	Use in research on gamification
Theoretical foundations related to behavior		
Theory of reasoned action (TRA)	The theory of reasoned action, formulated by Ajzen and Fishbein, postulates that the actual behavior of an individual depends on its behavioral intention, which is again determined by two influence factors: the *behavioral attitude* and the *subjective norm* (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). Generally speaking, people intend to perform a behavior when they evaluate it positively and when they think that others expect them to perform it (Ajzen, 1985). The behavioral attitude is based on *behavioral beliefs* towards the outcome of the behavior in question (positive or negative), while the subjective norm depends on *normative beliefs* towards the expectations of important peers (Ajzen, 1985).	TRA constitutes the ground theory for the technology acceptance model (TAM), so most studies use both frameworks together to evaluate the acceptance and actual usage of gamified systems (e.g. Bourgonjon *et al.*, 2013; Aydin, 2015, 2018; Cheon, Chung & Lee, 2015).
Theory of planned behavior (TPB)	The theory of planned behavior (TPB) is a further development of the TRA. It differs from the original TRA in terms of *perceived behavioral control*, which is added as determinant for behavioral intention (Ajzen, 1991). While the objective control over the behavior is not always measurable, people tend to have a subjective belief towards their capability to perform a certain behavior (Ajzen, 1991, 2008). This *control belief* is closely related to Bandura's concept of self-efficacy (Bandura, 1982): both are concerned with the perceived ability to perform a behavior (Ajzen, 2002).	The TPB is used as a theoretical model to evaluate whether gamification influences the determinants and the intention itself, such as the intention to adopt solar energy (Rai & Beck, 2017), to choose sustainable means of transport (Andersson et al., 2018) or to purchase (Bittner & Shipper, 2014).
Technology acceptance model (TAM)	The TAM is an adaption of the TRA tailored to the user acceptance of information systems. In particular, TAM postulates that behavioral attitude, which in turn influences the behavioral intention to use the system, depends on two behavioral beliefs: *perceived usefulness* and *perceived ease of use* (Davis et al., 1989). The importance of perceived usefulness is underpinned by the principal assumptions from expectancy theory (Vroom, 1964). On the other hand, self-efficacy theory (Bandura, 1982) and research on the diffusion of innovations (Tornatzky & Klein, 1982) support the importance of ease of use for the acceptance of technology. Finally, cost-benefit paradigms from behavioral decision theory (Payne, 1982) as well as the channel disposition model (Swanson, 1974) and research on the evaluation of information reports (Larcker & Lessig, 1980) also suggest the dualistic importance of both factors.	TAM is applied to measure the perceived usefulness and the perceived ease of use and their influence on attitude, behavioral intent and behavioral outcomes (e. g. Bourgonjon *et al.*, 2013; Siala, Kutsch & Jagger, 2019; Vanduhe, Nat & Hasan, 2020)
Reinforcement theory	Reinforcement theory is the most prominent example of radical behaviorism, a philosophy of science that treats behavior as an observable subject, apart from internal psychological processes (Moore, 2011). It concentrates on the stimuli presented and distinguishes between reinforcement and punishment: positive reinforcement presents or adds positive stimuli, such as rewards, while negative reinforcement removes discomforting stimuli, such as pain. Conversely, positive punishment adds negative reinforcers, and negative punishment removes positive reinforcers (Skinner, 1953).	Reinforcement theory leads to examining whether learning can be manipulated by praise mechanisms (Carenys & Moya, 2016), such as rewards (Berkovsky et al., 2012; Kordaki & Gousiou, 2017) or climbing the leaderboard (Huang et al., 2019) – while punishments are usually left out.

Theoretical foundation	Origin and core statements	Use in research on gamification
Transtheoretical model of behavior change (TTM)	TTM aims to describe the phases in which changes in human behavior occur. In the *precontemplation stage*, the individual is not yet aware of the situation and gets in contact with a behavior change through consciousness raising, dramatic belief and environmental reevaluation. In the *contemplation stage*, self-reevaluation processes asses one's own positioning towards the problem, followed by the *preparation stage*, where self-liberation leads to the commitment to action. In the *action* and *maintenance stage*, continuous reinforcement management, helping relationships, counterconditioning and stimulus control support the actual change in behavior (Prochaska et al., 1992). The decisional balance towards change in behavior depends on two decisive factors: one's own *self-efficacy*, as described by Bandura (1982), and *temptation*, which describes the intensity of the urge to engage in a certain behavior under difficult situational circumstances (Prochaska & Velicer, 1997).	Scholars aim at designing interventions based on the TTM stages to promote health behavior change (Alsaleh & Alnanih, 2020; Bahia et al., 2014) as well as changes towards sustainable behavior (AlSkaif et al., 2018; Andersson et al., 2018).
Activity theory	In 1978, Vygotsky postulated that human behavior is not a form of a direct relation between stimulus and response, as assumed in reinforcement theory (Skinner 1953), but that rather a complex psychological act takes place, thereby defining the basic triangle of the human activity system (Vygotsky, 1978). Later, Leontyev suggested that individual actions are inevitably linked to collective activities (Leontyev, 1981). This aspect, among others, was added by Engeström to the activity triad to form a structure of human activity (Engeström, 1987). The system consists of a *subject* (the individual itself) acting towards an *object* (or goal), mediated by *tools and signs* and influenced by an activity system of *rules and culture*, the *community* (other individuals) and the *division of labor* in that community (Engeström, 1987, 2001). Furthermore, different systems interact in an activity system network (Engeström, 2001).	Research uses the activity triangle to design and evaluate serious games, with the game as the mediating instrument in the activity system (e. g. De Freitas & Oliver, 2006; Carron, Marty & Heraud, 2008; Ellahi, Zaka & Sultan, 2017; Calvo & Reio, 2018; Charrouf & Taha Janan, 2019).
Theoretical foundations related to learning		
Social learning theory	Although agreeing with the behaviorist mechanisms such as operant conditioning (Skinner, 1953), social learning theory questions the sole significance of reinforcement processes for learning and adds that people often learn from their environment by processes of *observational learning* (Bandura, 1971). Through observation, individuals *model* activities and outcomes they witness from others, which causes learning by its informative function – so behavior can be learned before it is performed (Bandura, 1971). There are four interrelated moderating processes that influence behavioral modeling: *attention*, *retention* (imaginable and verbal), *reproduction* and *motivation or reinforcement* (Bandura, 1971).	The application of social learning theory guides the design of gamified interventions, e. g. by introducing mechanisms that enable social observation processes (Jeen et al., 2007) and by designing role model game characters (Fuchslocher et al., 2011).

Theoretical foundation	Origin and core statements	Use in research on gamification
Social cognitive theory	Drawing on social learning theory (Bandura, 1971), social cognitive theory focuses on the interaction between social and cognitive factors as determinants of behavior (Middleton et al., 2019). Human functioning is explained as a form of *reciprocal determinism*: cognitive, biological, and emotional factors, behavior patterns, and environmental events represent interacting determinants of behavior (Bandura, 2001). The second principal assumption of social cognitive theory is that people are not only reactors but *agents* in a network of sociocultural influences. Through *intentionality*, *forethought*, *self-regulation* and *self-reflectiveness* (which refers to the theory of self-efficacy, see Bandura, 1982), sociocultural factors are embedded in psychological processes (Bandura, 2001). Thirdly, cognitive capabilities play an essential role in this self-system: humans are able to cognitively *symbolize* events and their outcomes before they happen, they learn *vicariously* through observation and they *self-regulate* by goal setting (Locke & Latham, 1990) and anticipating the consequences of prospective actions (Bandura, 2001).	Usage in gamification research focuses on game-based learning processes and guides the implementation of mechanisms for vicarious learning and the building of self-efficacy (Amresh et al., 2019; Bowen et al., 2014; Bul et al., 2015) as well as the evaluation of the intervention based on outcome expectations (All et al., 2017).
Constructivist learning theory	Constructivism has a long history in education and philosophy (Duffy & Cunningham, 1996), and can be roughly divided in two streams: the individual cognitive constructivism, derived from Piaget (1977), and the sociocultural constructivism, based on the sociocultural ideas of cognitive development by Vygotsky (1978). Constructivist learning theories, however, share some essential commonalities: they regard learning as an *active process of constructing* rather than acquiring knowledge, and instruction as a *process of supporting that construction* rather than communicating knowledge (Duffy & Cunningham, 1996). Jonassen postulates three instructional activities to support learning: *modeling* – through demonstration and articulation of the reasoning –, *coaching* – through motivational prompts, help and reflection –and *scaffolding* – through adjusting and restructuring of tasks (Jonassen, 1999).	Game-based learning includes constructivist principles, such as experiential learning and participation (Kordaki & Gousiou, 2017), and researchers aim at designing gamification in such way that self-reflection is encouraged (e. g. Huebscher & Lendner, 2010; Avramenko, 2012).
Sociocultural theory of cognitive development	The sociocultural theory of cognitive development represents a theory of sociocultural constructivism. In the same work in which Vygotsky articulated the human activity system triangle (Vygotsky, 1978), he emphasized the role of social interaction on two levels: first, on the social dimension (*interpsychological*) and second, on the psychological dimension (*intrapersonal*) (Vygotsky, 1978). Tools such as language, art or writing assist the development of cognitive functions to move from the social dimension to the psychological plane (Wang et al., 2011), so that external functions are internalized to become inner functions (Vygotsky, 1978). A particular concept of the sociocultural theory is the *Zone of Proximal Development*, i.e., the distance between the actual level of development and the level of potential development that can be acquired through guidance, peer cooperation, or instruction (Vygotsky, 1978). Instruction and instructional tools should therefore aim at creating new, higher levels of development rather than to train existing skills (Fielding, 1989).	Interventions based on sociocultural theory are designed to scaffold the learner within his or her zone of proximal development by being adaptive and personalized to foster the learner's development (e.g. Davis et al., 2018; Rachels & Rockinson-Szapkiw, 2018)
Cognitive load theory	Sweller hypothesized that learning and problem solving occasionally contradict each other due to two related mechanisms: *selective attention* and cognitive processing capability, or *cognitive load*. Since conventional problem solving by means-end analysis may require a high level of cognitive effort, it may not simultaneously contribute to schema acquisition (Sweller, 1988). While *intrinsic cognitive load* results from the interactivity and complexity of the learning material itself, *extraneous cognitive load* arises from the instructional process. To reduce this extraneous cognitive load, five basic principles of human cognition must be considered (Sweller, 2010): the *information store principle*, the *borrowing and reorganizing principle*, the *randomness as genesis principle,* the *narrow limits of change principle* and the *environment organizing and linking principle*. The reduction of extraneous load allows an increase in working memory resources devoted to intrinsic cognitive load and enhances learning.	The central discussion about applying cognitive load theory in game-based learning concerns whether games can be designed in such a way that they reduce extraneous cognitive load or if they increase cognitive load and thus prevent participants from learning (e. g. Deleeuw & Mayer, 2011; Adams & Clark, 2014; Brom *et al.*, 2019).

Theoretical foundation	Origin and core statements	Use in research on gamification
Situated learning theory	Situated learning theory suggests that learning is usually unintentional and embedded in activities, contexts and culture (Brown et al., 1989; Lave & Wenger, 1991). Thus, conceptual knowledge cannot be abstracted from the situations in which it is learned and used (Brown et al., 1989). Hence, learning environments need to be designed in such an authentic way that students can learn by linking their prior knowledge to real-world scenarios as they participate in the learning activities (Hwang et al., 2015). There are several related pedagogical models rooted in this idea of situated cognition, for example cognitive apprenticeship, problem-based learning, learning-by-design and case-based learning, among others. They all share common principles of embedding learning in complex, realistic, and relevant contexts, integrating social negotiation as an integral part of learning, supporting multiple perspectives and multiple modes of representation, encouraging ownership in learning and promoting self-awareness of the knowledge construction process (Dabbagh & Dass, 2013).	Educational games and game-based learning environments are considered as effective situated learning environments in which students can acquire problem-solving abilities through playing the game (Hwang et al., 2012, 2015). Thus, situated learning theory and its principles are applied to guide the design of game-based learning as situated problem-solving context (e.g. All et al., 2017; Hou, 2015; Hou & Li, 2014).
Experiential learning theory	The theory of experiential learning builds on several other theories of learning, e.g. constructivist learning and social constructivism (Kolb & Kolb, 2013), and emphasizes the meaning-making process of the individual's direct experience in the absence of a teacher (Wu et al., 2012). The core assumption of experiential learning theory is that knowledge is acquired through personal and environmental experiences rather than instruction (Kolb, 1984). The learning process is portrayed as an idealized learning cycle where the student iteratively learns through a sequence of c*oncrete experience*, *reflective observation*, *abstract conceptualization* and *active experimentation* (Kolb & Kolb, 2013). Furthermore, these four steps in the learning cycle can be diverted into nine different learning styles that each involve one or multiple sequences: Initiating, Experiencing, Imagining, Reflecting, Analyzing, Thinking, Deciding, Acting and Balancing (Kolb & Kolb, 2013).	Experiential learning theory is often used in research on game-based learning to guide the design of educational games (e.g. Furió et al., 2013; Verkuyl et al., 2017; Wrzesien & Alcañiz Raya, 2010) , but it has also been applied to evaluate the learning outcomes of game-based learning (Koivisto et al., 2017; Ranchhod et al., 2014).
Multimedia learning theory	Multimedia learning theory, also referred to as cognitive theory of multimedia learning, draws on dual coding theory (Paivio, 1986), Baddeley's working memory theory (Baddeley, 1992), Wittrock's generative theory (Wittrock, 1989) and cognitive load theory (Sweller, 1988) and states that a learner possesses a visual information processing system and a verbal information processing system (Mayer, 2005). Beside this *dual channel* principle, multimedia learning theory suggests that learners have a *limited capacity* for processing in each channel and that learning occurs through *active processing*, which means that learners attend to relevant information, mentally organize it to form a coherent representation (essential processing) and relate it to prior knowledge (generative processing) (Mayer & Johnson, 2010).	Multimedia learning theory guides game-based learning design in such way that extraneous processing, thus cognitive processing that distracts from active processing of the learning content, is aimed to be reduced through choosing suitable game features (Johnson & Mayer, 2010; Mayer & Johnson, 2010; Moreno & Mayer, 2005).