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Dehghanzadeh, Hojjat; Farrokhnia, Mohammadreza; Dehghanzadeh, Hossein; Taghipour, Kiumars; Noroozi, Omid

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REVIEW

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Using gamification to support learning in K-12 education: A systematic literature review

Hojjat Dehghanzadeh[1] | **Mohammadreza Farrokhnia**[2] | **Hossein Dehghanzadeh**[3] | **Kiumars Taghipour**[3] | **Omid Noroozi**[2]

[1]Educational Sciences Department, Faculty of Literature and Humanities, Urmia University, Urmia, Iran

[2]Education and Learning Sciences Group, Wageningen University and Research, Wageningen, The Netherlands

[3]Faculty of Educational Science and Psychology, University of Tabriz, Tabriz, Iran

Correspondence
Hossein Dehghanzadeh, Faculty of Educational Science and Psychology, University of Tabriz, 5166616471 Tabriz, Iran.
Email: dehghanzadeh@tabrizu.ac.ir

Abstract

Using gamification to support learning in K-12 education has received much attention from scholars in recent years. However, there is still a lack of comprehensive understanding of how gamification should be used to effectively enhance the learning experiences of K-12 students. The purpose of this review was to synthesize research findings on the use of gamification in K-12 education and to propose an evidence-informed framework. This framework will guide teachers and scholars in developing gamified learning environments that are effective in improving K-12 students' learning. In this regard, 54 empirical studies (out of 907 peer-reviewed articles), dating from 2008 through 2021, were reviewed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline. The findings were systematically categorized into four essential dimensions of learning environments inspired by Biggs' 3P teaching and learning model, ie, 'individual factors', 'environmental factors', 'learning process' and 'learning outcome'. The review yielded rich findings concerning each dimension, providing K-12 teachers and scholars with a comprehensive overview of research findings on using gamification for educational purposes. Meanwhile, the findings indicated the lack of empirical studies regarding constructively aligned gamified courses, in which the different dimensions of the adopted framework are implemented and evaluated coherently. The paper concludes by presenting several suggestions and directions for future research to address this shortcoming.

KEYWORDS

gamification, K-12 education, learning outcomes, systematic review

Practitioner notes

What is already known about this topic

- Gamification has demonstrated the potential to enhance learning outcomes in K-12 education.
- There are instances where the findings suggest neutral or negative effects of gamification on students' learning outcomes.
- There is a lack of a comprehensive overview of empirical findings concerning the effectiveness of gamification in K-12 education.

What this paper adds

- The study highlights the potential of gamification in enhancing cognitive, affective and behavioural learning outcomes in K-12 education, mainly by increasing motivation, engagement and competitiveness.
- The study provides a comprehensive overview of empirical studies on using gamification in K-12 education.
- The study proposes an evidence-informed framework that can serve as a blueprint for developing constructively aligned gamified learning environments for K-12 education.

Implications for practice and/or policy

- The study presents several up-to-date and empirically rooted calls for future research on using gamification in K-12 education.
- The study makes evidence-based recommendations for the effective integration of gamification in K-12 education.

INTRODUCTION

Learning through gamification has recently attracted attention from teachers, practitioners and researchers in various subjects and educational levels (Dahalan et al., 2023; Kaya & Ercag, 2023; Oliveira et al., 2023; Saleem et al., 2021). Gamification is defined as the use of game elements such as badges, points and/or leaderboards in none game contexts (Brigham, 2015; Majuri et al., 2018) for creating game-like experiences (Thomas & Baral, 2023). In gamification, game elements (and not a whole game) are used to engage learners with the content and help them progress towards a goal. For example, when somebody logs into a computer application correctly, she/he receives a badge. Receiving a badge is an element of a game, but in this case, such action is not related to other game activities, such as moving to a new level (see Kapp, 2012).

Although various terms such as serious games and educational games are similar to gamification, their applications are different. 'Serious games' is a broad term representing any game-based initiative whose primary purpose is more than just pure entertainment (Dahalan et al., 2023). The term serious games can also be attributed to the use of digital games for different purposes, including educational ones (Dehghanzadeh et al., 2019). An 'educational game' is a form of video game specifically designed for educational purposes (Lamb et al., 2018). Thus, both serious games and educational games can be used to develop the players' skills and knowledge through gameplay (Stege et al., 2011). However, the educational content of serious games can be represented implicitly in the gameplay, and it

can be assigned to the game by the context they are used (Breuer & Bente, 2010), whereas in educational games, such content is presented explicitly in the gameplay (Ke, 2016).

The term 'gamification' was used for the first time in 2008 but only obtained popularity in 2010 (Deterding et al., 2011), primarily for use in marketing and work environments (Zichermann & Cunningham, 2011). Later, its application has been extended to education at different levels, from early childhood (Kayimbaşioğlu et al., 2016), elementary (Rachels & Rockinson-Szapkiw, 2018) and secondary education (Khan et al., 2017) to higher education (Sanchez et al., 2020) and workplace learning (Grünewald et al., 2019). Gamification has the potential to enhance students' engagement (Huang et al., 2019; Panmei & Waluyo, 2023; Noroozi, McAlister, & Mulder, 2016), motivation (Chapman & Rich, 2018; Kaya & Ercag, 2023), satisfaction (Oliveira et al., 2023; Xi & Hamari, 2019), achievement (Su & Cheng, 2015) and higher-order thinking skills (Bourke, 2019; Noroozi et al., 2020).

Despite these potentials, the research findings are still inconclusive regarding the positive effect of gamification on students' learning outcomes (Sailer & Homner, 2020). In a longitudinal study on the impact of gamification on learning outcomes, Hanus and Fox (2015) reported that students in the gamified course showed less motivation and obtained lower final examination scores than students in the non-gamified class. In the same vein, some scholars reported that in comparison with traditional classes, gamified learning environments did not yield a positive effect on students' knowledge acquisition (Kwon & Özpolat, 2021), performance in written assignments (Domínguez et al., 2013), engagement (Buisman & van Eekelen, 2014) and interest (Berkling & Thomas, 2013). These contradictory findings can be related to the fact that gamification is context-dependent (Toda et al., 2018). Moreover, according to Nicholson (2015), any given approach to gamification would not benefit every learner in the same way. Employing game elements in an educational context without considering the interplay between design, context and user characteristics (van Roy & Zaman, 2017) and a proper instructional design (Toda et al., 2018) would not ensure the desired learning outcomes.

So far, several scholars have conducted systematic literature review research on using gamification in educational contexts (eg, De Sousa Borges et al., 2014; Majuri et al., 2018; Nah et al., 2014; Subhash & Cudney, 2018; Surendeleg et al., 2014). However, most review studies included all educational levels (and not exclusively on K-12 education) and with different objectives. For instance, Caponetto et al. (2014) conducted a systematic review study to shed light on the emergence and consolidation of gamification in education in general, reporting findings on target populations, type of research (theoretical vs. experimental), kind of educational content delivered and the tools deployed. Kalogiannakis et al.'s (2021) review study was focused on identifying key gamification features in science education and elements of success and theoretical gaps in pedagogy and contribute to gamification in science education at all educational levels. Zainuddin et al. (2020) conducted a review study to evaluate and synthesize state-of-the-art literature on gamification in educational domains at different levels, touching on methodological approaches, theoretical models, common platforms and apps, game mechanics and its inherent learning outcomes. Only Lindberg et al. (2019) conducted a study exclusively in the K-12 context but with a different methodology, scope and purpose. They reviewed the guidelines on programming education in K-12 in seven countries by collecting curricula and other relevant official data from governmental and non-profit educational websites.

Despite the invaluable contributions of previous review studies to the field, they have failed to provide an overview of research on the use of gamification in K-12 education, determining the individual and environmental characteristics that would affect the outcome of this teaching approach in K-12 education, how gamification should be integrated into a learning environment to support students' learning and the effect of gamified learning environments on K-12 students' learning outcomes in different subject matters. In this regard, the main

objective of the current review is to systematically identify, critically analyse and discuss scientific research on using gamification in K-12 education, providing future educators with an evidence-informed framework that enable them to effectively utilize gamification in their classes. Besides, this review study also aims to highlight the research gaps, providing directions for future research in the field.

In line with Farrokhnia et al. (2020) and inspired by Biggs's (2003) 3P model, individual characteristics, learning environment prerequisites, learning processes and learning outcomes were adopted as the main categorical descriptions in this review study. This structure allows us to categorize available research findings into sections relevant to educators and K-12 education researchers, highlighting both the main findings and main avenues for further research of the four components. Based on the four components mentioned above, the following research questions are formulated to be answered in this study:

RQ1. What is the latest state of the art concerning the use of gamification in K-12 education?
RQ2. What individual characteristics affect students' learning in gamified environments in K-12 education?
RQ3. What environmental prerequisites are considered when developing gamified environments in K-12 education?
RQ4. What research findings are available regarding the learning processes involved when using gamification in k-12 education?
RQ5. What research findings are available regarding the relationship between gamification and learning outcomes in K-12 education?

METHOD

This review study is guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al., 2009) while adopting a narrative analysis approach (see Van Dinther et al., 2011) to identify current trends and practical implications of gamification in K-12 education. PRISMA offers researchers a structured and transparent approach to conducting and reporting systematic reviews, which contributes to the generation of high-quality and reliable review outcomes (Page et al., 2021). The PRISMA statement comprises four phases: *identification*, *screening, eligibility* and *analysis* processes necessary for developing the review protocol.

Identification phase

This review study used a systematic search strategy based on two sets of keywords that overlap in the research questions: one set refers to gamification and one set to the study context. In the first step, synonyms or related keywords for each set using Merriam-Webster's Online Thesaurus. In the second step, the overlapped sets were combined with the Boolean operator “AND” and the related asterisks marked keywords within each set with “OR” to arrive at the final search string: gamif* AND “pre-elementary” OR “pre-elementary” OR “elementary school” OR “elementary class*” OR “elementary student*” OR “primary school” OR “primary education” OR “primary student” OR “middle school” OR “lower secondary” OR “secondary school” OR “secondary education” OR “high school” OR “K-12”. The search keywords could appear in an article's title, keywords and/or abstract. The literature search was conducted on the following databases: Scopus, Web of Science (WoS), ScienceDirect, Wiley online library, ERIC, IEEE Xplore,

ProQuest, ACM Digital Library and APA Psych INFO to find related studies. In total three sets of inclusion criteria were used in this study (see Table 1). As the first set of inclusion criteria, the search parameters were set to focus on peer-reviewed scientific journal articles. Moreover, the search was limited to English-language articles from 2008, as gamification was primarily applied in an educational context from 2008 onwards. The initial search resulted in 1971 articles. However, after restricting the search to the specified time span (ie, 2008–21), peer-review journals and the English language, only 907 articles remained. Among the findings, 320 articles appeared to be duplicated.

Screening phase

In the next step, the second inclusion criteria were employed for screening the abstracts and collecting relevant studies. During this step, the first author reviewed titles, abstracts and the full text of the articles when required and excluded a number of unrelated studies that did not satisfy the inclusion criteria ($n = 430$). The articles were excluded from further analysis because they: (1) did not report empirical findings (eg, meta-analysis, review or conceptual studies); (2) were not published in peer-reviewed journals (eg, books, book chapters, dissertations, thesis, conference proceedings and reports); (3) focused on using educational games, video games and serious games rather than gamification; (4) off-topics (eg, studies that were focused on either gamification or an instructional subject in K-12 education and not both).

Eligibility phase

In this phase, the first author first thoroughly read the remaining 157 full texts to find the most relevant articles. After applying the third set of inclusion criteria, 96 articles

TABLE 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Identification phase	
• Peer-reviewed articles • English articles • Publication date from 2008 to 2021	• Not peer-reviewed • Articles in languages other than English • Publication date before 2008
Screening phase	
• Empirical studies (used qualitative and/or quantitative methods) • Peer-reviewed journals[a] • Used gamification	• Not empirical (eg, meta-analysis, review or conceptual studies) • Not peer-reviewed (eg, books, book chapters, dissertations, thesis, conference proceedings and reports) • Used instructional, video or serious games, etc. • Off-topic (ie, not relevant to the topic under study)
Eligibility phase	
• Conducted in the K-12 context • Conducted with K-12 students • Used gamification[b] • Conducted within formal classrooms • With instructional purposes	• Conducted in other contexts (eg, higher education) • Conducted with other stakeholders (eg, teachers) • Used instructional, video or serious games, etc. • Outside formal classrooms (eg, extra-curricular courses for students in need) • With non-instructional purposes (eg, weight loss)

[a]Although the search parameters were set to include only peer-reviewed articles, non-peer-reviewed articles still were found and thus were removed during the screening phase.

[b]While some scholars mentioned gamification in the abstract, further examination of the full texts revealed that they used games (instead of gamification) for educational purposes.

were excluded again since they: (1) were conducted in the higher education context; (2) recruited K-12 teachers instead of students, (3) used games and not gamification, (4) were not within the formal K-12 classrooms (such as studies in extra-curricular classes for students with dyslexia) and (5) with non-instructional purposes (eg, to increase fruit intake). In the next step, the quality of the remaining articles was assessed using Theelen et al.'s (2019) criteria. For the quality appraisal, the retrieved articles were evaluated based on each criterion separately and scored between 0 (ie, no elaboration) and 3 (ie, extensive elaboration). Seven articles were excluded for further analysis after quality appraisal (with a mean score below 2), which resulted in 54 articles deemed eligible for content analysis. The steps followed in selecting relevant articles are depicted in an adapted PRISMA flow diagram shown in Figure 1.

Analysis phase

For the content analysis of the selected articles, a coding scheme was inductively developed in a group discussion consisting of all authors (with relevant backgrounds such as educational technology, learning sciences, educational psychology and educational research) based on the research questions. In the next step, the first author used an iterative process of testing the initial codes, identifying new codes and applying the revised codes until reaching a saturation point (ie, no new codes were generated). During this process, other authors were asked to check independently whether the coding worked with regard to the coded phrases. Moreover, to establish coding reliability, the first and second authors randomly picked six articles (=11%) and blind-coded them. Cohen's Kappa statistic was used to examine the inter-rater reliability concerning the coding quality. According to Cohen (1960), there was high agreement between reviewers' coding ($\kappa = 0.81$, $p < 0.001$), which confirms the reliability of the final coding scheme. After discussing the discrepancies and finalizing the coding scheme, the first author coded all identified articles to synthesize their findings.

RESULTS

The latest state of the art concerning the use of gamification for K-12 education

Table 2 presents an overview of the selected articles concerning authors, the publication year, article source, educational level, methodology, data collection method, subject matter, learning environment, instructional supports, gamification element(s) and main findings.

The findings showed that the popularity of gamification in K-12 education is increasing. The use of gamification in K-12 education has gained attention since 2014 but has grown rapidly afterwards, showing that the use of gamification for K-12 education has become a new area of research in recent years. Most gamified learning environments were utilized in secondary education with 29 frequencies accompanied by primary education with 25 articles. Most publications contained quantitative data analysis ($n = 32$), while 20 articles contained both qualitative and quantitative analysis, ie, mixed methods, and only two articles used qualitative data analysis. For example, Azar and Tan (2020) used a web-based questionnaire to measure the effectiveness of their gamified environment in learning English skills by students. Ioannou (2019), on the contrary, used qualitative methods to measure the outcomes, including logfile data—tracking information video (audio recording) interviews and observation notes as a new qualitative method for gathering data in gamified learning environments (see Figure 2).

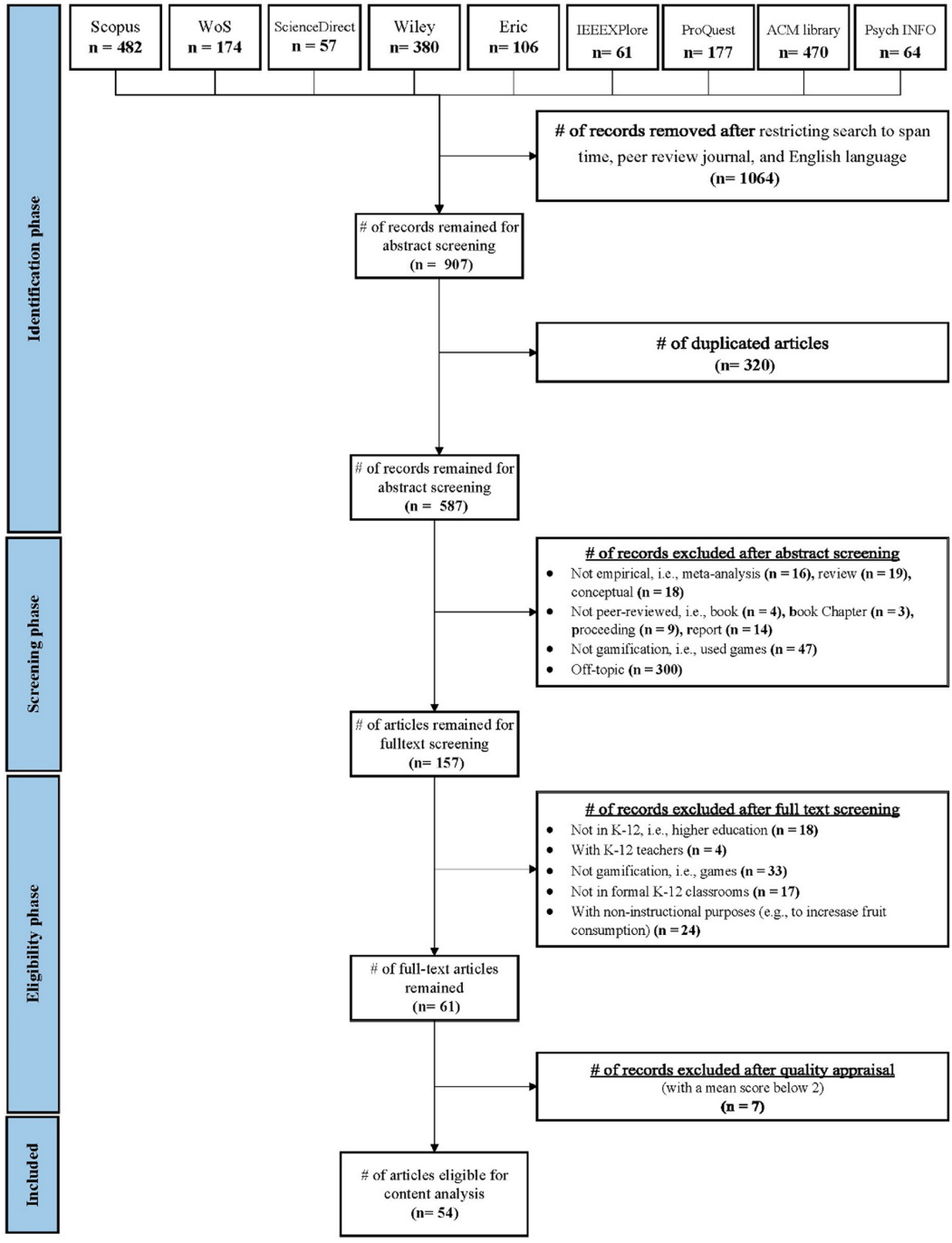

FIGURE 1 Adapted PRISMA flow diagram.

In the reviewed studies, the duration of the study design was quite varied, from 15 minutes for each session (eg, Jagušt et al., 2018) to 1 year as a longitudinal study (eg, González et al., 2016) with a varied number of participants ranging from 11 (eg, Barcomb & Cardoso, 2020) to 990 (eg, Arias Aranda et al., 2016). Gamified learning environments for K-12 education were mostly used for teaching language ($n = 19$), followed by mathematics

TABLE 2 Quantitative description of the use of gamification in K-12 education.

Authors/year	Journal	Educational level	Research method	Data collection	Subject matter
Arias Aranda et al. (2016)	Revista de Educación	High school	Quantitative	Questionnaire	Business and economics
Attali and Arieli-Attali (2015)	Computers & Education	High school	Quantitative	Questionnaire	Mathematics
Azar and Tan (2020)	Universal Journal of Educational Research	High school	Quantitative	Questionnaire	Language
Barcomb and Cardoso (2020)	CALICO	High school	Mixed method	Questionnaire, interview	Language
Çakıroğlu and Güler (2021)	e-Learning and Digital Media	High school	Mixed method	Questionnaire and interview	Mathematics
Castañeda et al. (2018)	Interactive Technology and Smart Education	Elementary	Quantitative	Questionnaire	Language
Chen and Chiu (2016)	Computers & Education	Elementary	Quantitative	Questionnaire	Mathematics
Chen et al. (2020)	Computers & Education	Elementary	Mixed method	Questionnaire and interview	Reading comprehension
Cheng et al. (2020)	Educational Computing Research	High school	Quantitative	Questionnaire	Physics
Chu and Fowler (2020)	Game-Based Learning	High school	Quantitative	Questionnaire	Language, art, mathematic
Duarte and Cruz (2018)	Revista Lusófona de Educação	Elementary	Qualitative	Observation, reactions	Language
Fan et al. (2015)	Eurasia Journal of Mathematics, Science & Technology Education	High school	Mixed method	Questionnaire and interview	Biology
Gafni et al. (2017)	Information Technology Education: Research	High school	Quantitative	Questionnaire	Language
Garcia-Sanjuan et al. (2018)	Computers & Education	Elementary	Mixed method	Questionnaire and observation	Language, science, history, geography
Gómez-García et al. (2020)	Nutrients	Elementary	Quantitative	Questionnaire	Science
González et al. (2016)	Computers in Human Behaviour	Elementary	Quantitative	Questionnaire	Health

Learning environment	Instructional support	Gamification element	Main finding
Praxis MMT	Modelling feedback	Point, leaderboard	The gamified simulation affected the entrepreneurship attitude orientation of students positively
CBAL MATH	Advice	Point	The game element had no positive impact on the accuracy of responses, although the response speed increased
ICT Techs Application	Modelling feedback	Goal, reward	Using gamified ICT techs had positive effects on language learning skills
Moodle	Advice, modality, interactivity	Point, badge, competition	The participants benefited from the proposed gamified system for L2 pronunciation learning, and it was enjoyable, anxiety-reducing and pedagogically useful
Mathematic course	Collaboration feedback	Badge, leaderboard real gift	The literacy skills among students and their performance improved by using gamification elements
Leap Motion Controller	Advice, modality feedback	Points, level	The students gained a positive impact in terms of educational performance and learning. In addition, students showed great empathy with the gamified AR tool
Multitouch screen	Narrative elements, contextualization, collaboration	Competition, score, leaderboard	The intergroup competition was effective for the learning, engagement and achievement of learners and enhanced their cognitive processes
WCRAS	Narrative elements, collaboration feedback	Level, leaderboard	Although the experimental group performed better than the control group in constructing more annotations in almost all forms of reading annotations and social interaction, the difference between the two groups in reading comprehension output was not identified
–	Modality, interactivity, personalization, collaboration, advice	Challenge, goal, story	The gamified environment enhanced the flow and science process skills of students
–	Modelling feedback	Score	Gamified learning has put learners extra effort into understanding and applying their knowledge and skills
Kwesukasukela	Collaboration, interactivity, reflection	Collaboration, story, point, competition, leaderboard	The game elements improved the whole reading process (pre-reading/reading/postreading) and the development of pupils' critical thinking skills and creativity
MMBCLS	Advice, feedback	Point, level	Students had greater learning achievement in the experimental group than the students in the control group
Duolingo	Feedback, advice	Competition, point, level, progress bar, goal, performance graph, badge	The features of gamification had positive effects on the learning process and enhanced willingness to continue using the application
Quizbot	Narrative elements, collaboration	Constraint, relationship, progress bar, emotion	Quizbot was essentially fun and easy to use and could effectively support collaboration between learners
Moodle	Personalization, interactivity, choice	Badge, challenge, mission, level	Increasing the motivation of students, as well as their autonomy and self-regulation when facing the contents of the gamified environment
TANGO	Advice, interactivity, feedback	Point, badge, leaderboard, time counter, challenge	Using game elements was a significant positive intervention for learning healthy habits and experiences

TABLE 2 (Continued)

Authors/year	Journal	Educational level	Research method	Data collection	Subject matter
Halloluwa et al. (2018)	Personal and Ubiquitous Computing	Elementary	Mixed method	Questionnaire, observation, interview	Mathematics
Haruna et al. (2018)	Environmental Research and Public Health	High school	Mixed method	Questionnaire interview	Health
Haruna et al. (2019)	Information and Learning Sciences	High school	Mixed method	Questionnaire, interview	Science
Hashim et al. (2019)	Arab World English Journal	High school	Quantitative	Questionnaire	Language
Homer et al. (2018)	Educational Technology & Society	Elementary	Mixed method	Questionnaire, observation, interview	Language
Hubalovsky et al. (2019)	Computers in Human Behaviour	Elementary	Quantitative	Questionnaire	Mathematics
Hulse et al. (2019)	Educational Technology Research and Development	Elementary	Quantitative	Questionnaire	Mathematics
Hursen and Bas (2019)	iJET	Elementary	Mixed method	Questionnaire, interview	Science
Ioannou (2019)	Educational Technology Research and Development	Elementary	Qualitative	Logfile data—tracking, information video/audio recordings, discussion, interview observation, notes	Socio-emotion
Jagušt et al. (2018)	Computers & Education	Elementary	Mixed method	Learner-generated usage logs, focus group, interviews	Mathematics
Jo et al. (2018)	Computer Applications in Engineering Education	High school	Mixed method	Questionnaire, interview	Engineering
Jones et al. (2019)	Simulation & Gaming	High school	Quantitative	Questionnaire	Biology
Khan et al. (2017)	Education and Information Technologies	High school	Mixed method	Questionnaire, observation, focused group discussion	Science
Kickmeier-Rust et al. (2014)	Game-Based Learning	Elementary	Mixed method	Questionnaire, focus group discussion, observation	Mathematics

Learning environment	Instructional support	Gamification element	Main finding
Sellam Gannan	Narrative elements, feedback	Progress bar, narration, reward	The gamified environment had positive effects on students' learning performance in mathematics
Moodle	Narrative elements, advice, interactivity	Storyline, point, badge, leaderboard, choice	The use of a gamified learning environment had significant positive effects on the experimental group's motivation, attitude, knowledge and engagement
My Future Begins Today	Modelling, interactivity, feedback	Avatar, point, time counter, score	Gamified learning was more effective in learning than traditional approaches
Kahoot	Interactivity, modality	Challenge, score	The gamified learning was effective in teaching grammar to ESL learners
ClassDojo	Advice	Badge, point	Using the digital badges and points was more effective on task activities and improved performance than the classroom group of non-digital badges and points
Moodle	Advice	Level, reward	Using the game elements in the educational course enabled students to achieve the course's educational objectives more successfully
FH2T:E	Feedback, advice	Goal, level, prize, bonus, star	The gamified environment positively affected students' performance in the math lesson, and they solved more problems and engaged more with them
ClassDojo	Collaboration, advice	Point, teamwork, leaderboard	The gamified application positively affected students' learning motivation for science. Additionally, the research results also showed that students and parents have positive opinions on using gamification in science education
Face-to-face instruction	Interactivity, collaboration, modality	Point, competition, challenge, collaboration, story	Using game elements promoted communication and collaboration of learners in a real classroom
The Math Widget	Collaboration, narrative elements	Competition, collaboration, narration, adaption	Gamified activities significantly increased student performance levels in math learning
Online instruction	Modelling	Point	The use of the game elements in online learning was effective in the participation in the promotion, academic achievement and student's attitude towards the course
Kahoot	Feedback, advice	Point, leaderboard, badge, time counter	The gamified assessment tool increased—the engagement and enjoyment of students in learning the topic of 'Transcription and Translation' in Biology
–	Interactivity, feedback, advice	Point, challenge, goal, progress bar, level	The students had better performance after using and learning from the gamified application rather than the control group
Sonic Divider	Feedback, advice	Point, score	The individualized and constructive feedback had significant motivational and learning effects

(Continued)

TABLE 2 (Continued)

Authors/year	Journal	Educational level	Research method	Data collection	Subject matter
Korkmaz and Özturk (2020)	Participatory Educational Research	High school	Quantitative	Questionnaire	Social Studies
Lam et al. (2018)	Language Learning & Technology	High school	Mixed method	Written essays, student's online postings, interviews	Argumentative writing
Leftheriotis et al. (2017)	Smart Learning Environments	High school	Mixed method	Questionnaire, observation	History and ecology
Li and Chu (2021)	British Journal of Educational Technology	Elementary	Mixed method	Questionnaire, interview	Language
Lo and Hew (2020)	Interactive Learning Environments	High school	Mixed method	Questionnaire, interview	Mathematics
Monterrat et al. (2017)	Simulation & Gaming	High school	Quantitative	Questionnaire	Language
Mukhtar et al. (2019)	Scientific & technology research	Elementary	Quantitative	Questionnaire	Language
Nand et al. (2019)	Smart Learning Environments	Elementary	Quantitative	Questionnaire	Mathematics
Otero-Agra et al. (2019)	Emergency Medicine	High school	Quantitative	Questionnaire	Health
Pitura and Chmielarz (2017)	Teaching English with Technology	High school	Quantitative	Questionnaire	Biology
Pozo Sánchez et al. (2020)	Multimodal Technologies and Interaction	High school	Quantitative	Questionnaire	Language
Prasetyoajt and Napitupulu (2018)	Theoretical and Applied Information Technology	High school	Quantitative	Questionnaire	Mathematics
Purgina et al. (2020)	Educational Computing Research	Elementary	Mixed method	Questionnaire, interview	Language
Puritat (2019)	iJEP	High school	Quantitative	Questionnaire	Management
Rachels and Rockinson-Szapkiw (2018)	Computer Assisted Language Learning	Elementary	Quantitative	Questionnaire	Language

Learning environment	Instructional support	Gamification element	Main finding
Face-to-face education	Interactivity, collaboration	Competition, point	Social studies education reinforced by gamification contributes significantly more to students' attitudes stoward social studies courses, cooperative learning skills and academic achievement than the traditional method
Face-to-face and online instruction	Modelling, advice	Point, leaderboard, competition	Using game mechanics in the digital environment increased students' online contribution and writing performance
GAID	Collaboration, advice	Time counter, competition, collaboration, score	The integration of gamification elements into conventional informal learning practices significantly improved the acquisition of knowledge, satisfaction, enjoyment and participation by the students
Reading battle	Reflection, interactivity, feedback	Point, badge, leaderboard	The gamified e-learning platform can help increase their reading motivation and improve their reading abilities
Moodle	Personalization, interactivity, feedback	Point, badge, progress bar, level, competition, leaderboard	Flipped learning with gamification improved students' cognitive engagement more than the other two approaches
Voltaire	Narrative elements	Leaderboard, sharing feature	The gamified learning environment improved the motivation of students, but the process of adaptation did not increase learners' engagement
QLETZ	Interactivity, feedback	Level, leaderboard, competition	The gamified platform was more effective in students' vocabulary acquisition
JQuizShow	Advice, interactivity, feedback	Challenge, point	The FEG (gamified platform) was more effective in increasing children's learning and engagement
GAM	Feedback	Competition	The gamification-based system improved the quality of cardiopulmonary resuscitation and the correct rate in learners
–	Narrative elements, collaboration, interactivity	Storyline, rule, challenge, cooperation	The gamified environment was effective in increasing students' educational, emotional and motivational dimensions
PeerWise	Modelling, interactivity, feedback	Level, score system, badge, leaderboard	The complement of gamification in flipped learning has led to improvements in various academic indicators such as learning, motivation, Problem-solving, interaction with teachers and interactions with students
–	Advice, interactivity	Point, level, challenge, leaderboard	The gamified e-learning did not improve student motivation in terms of behavioural, emotional and cognitive, and learning achievement
WordBricks	Interactivity, advice, feedback	Character, visual clues	The Irish WordBricks had a positive effect on Irish Grammar learning. Also, the learners reported that they enjoyed working with the application, found it easy to use and would like to use it as a part of their homework
Face-to-Face instruction	Advice	Badge, leaderboard	The leaderboards in the experimental group improved the performance of learners
Duolingo	Advice, feedback interactivity	Challenge, progress bar, level, point, goal, leaderboard	Duolingo had positive effects on learning achievement and academic self-efficacy

(Continued)

TABLE 2 (Continued)

Authors/year	Journal	Educational level	Research method	Data collection	Subject matter
Reed et al. (2020)	Special Education Technology	High school	Mixed method	Observation, questionnaire, focus group discussion	Language
Reyes et al. (2020)	Social Robotics	High school	Quantitative	Questionnaire	Mathematics
Saman et al. (2019)	Asian Journal of University Education	Elementary	Mixed method	Questionnaire, interview	Language
Su and Cheng (2015)	Computer Assisted Learning	Elementary	Quantitative	Questionnaire	Science
Sun and Hsieh (2018)	Educational Technology & Society	High school	Quantitative	Questionnaire	Language
Sun-Lin and Chiou (2019)	Educational Technology & Society	Elementary	Quantitative	Questionnaire	Mathematics
Tsai (2018)	Educational Computing Research	High school	Quantitative	Questionnaire	Science
Wang et al. (2019)	Technology and Chinese Language Teaching	High school	Quantitative	Questionnaire	Language
Yung et al. (2020)	Indonesian Journal of Electrical Engineering and Computer Science	Elementary	Quantitative	Questionnaire	Mathematics

($n = 14$) and science ($n = 7$) (see Figure 3). Different digital learning environments (eg, Moodle, ClassDojo, Duolingo, Kahoot, WordBricks, MGLS, I-Sign, PeerWise, QLETZ, Voltaire and GAID) have been employed to gamify educational subjects, which implies that various subject matters can simply be gamified with digital technologies.

The individual characteristics that affect students' learning in gamified environments

Although no study has been found to explicitly investigate the effect of students' characteristics on their learning in gamified learning environments, in some studies, scholars controlled the effect of some individual factors when comparing the effect of gamified and non-gamified

Learning environment	Instructional support	Gamification element	Main finding
Gamified reading assessment-computer-based tests	Modality, feedback	Avatar, progress, rule, level, challenge, reward	Students became immersed in the gamified reading assessment and were motivated by tasks that were challenging but not frustratingly difficult
gamified NAO robotic platform	Modelling, advice, feedback	Alert, tracking, visual gesture	The gamified robotic platform ensures better academic performance for students. Also, they stated that this tool promotes social activities in the classroom
I-Sign	Modality, feedback	Point, level, time counter, challenge, randomized quiz	The application meets learners' expectations of its capability in terms of effectiveness, efficiency and user satisfaction. Multimedia applications with simple gamification can help in delivering lessons effectively and efficiently for children with hearing loss
MGLS	Advice, pedagogical agent	Leaderboard, badge, mission	The gamified mobile app improved student learning, motivation and engagement of students in science lessons
IRS	Narrative elements, personalization, interactivity	Time counter, challenge, fantasy, curiosity, control	Using gamified applications increased the experimental group's engagement, intrinsic motivation and learning. But, in extrinsic motivation, they were not significantly different
–	Modelling	Progress, challenge, level	The gamified group performed significantly better than the control group in academic achievement. Also, it had a positive impact on their attitude towards learning
Gamified computer-simulated science inquiry environment	Modelling, interactivity, advice, feedback	Point, story, challenge, progress bar, score, level, character, reward, choice	Students' electricity knowledge was significantly increased through gamified activity and most students had positive perceptions regarding the environment
Chinese Skill	Interactivity, feedback	Points, level, challenge, reward	The gamified platform had a significant effect on Speed Mandarin on students' belief in their ability to speak Chinese, but showed no significant effects on reading, listening or vocabulary acquisition. Also, no significant effects were found on students' confidence in their abilities to use various learning strategies or on their motivation to learn Chinese
1 Slash 100%	Modelling, feedback	Competition, reward, level, progress, point, rule	The gamified application increases students' mastery of decimals, fractions and percentages

conditions on the targeted learning outcomes. The full list of individual factors controlled in the reviewed articles is provided in Table 3.

Students' gender was the most controlled factor in the reviewed articles. However, the findings related to the effect of gender on learning outcomes in gamified learning environments were inconclusive. Hulse et al. (2019) reported no differences between the gamified and non-gamified conditions in posttest performance when only condition, gender and pre-test performance were used to anticipate posttest performance. Jagušt et al.'s (2018) findings indicated that girls generally perform better than boys across gamified environments in math learning, but the difference was not statistically significant. On the contrary, Khan et al. (2017) showed that gamified application has consistently improved the body language of girls in contrast to boys. Also, Kickmeier-Rust et al.'s (2014) findings indicated that girls generally had a lower error performance than boys in gamified conditions. Also,

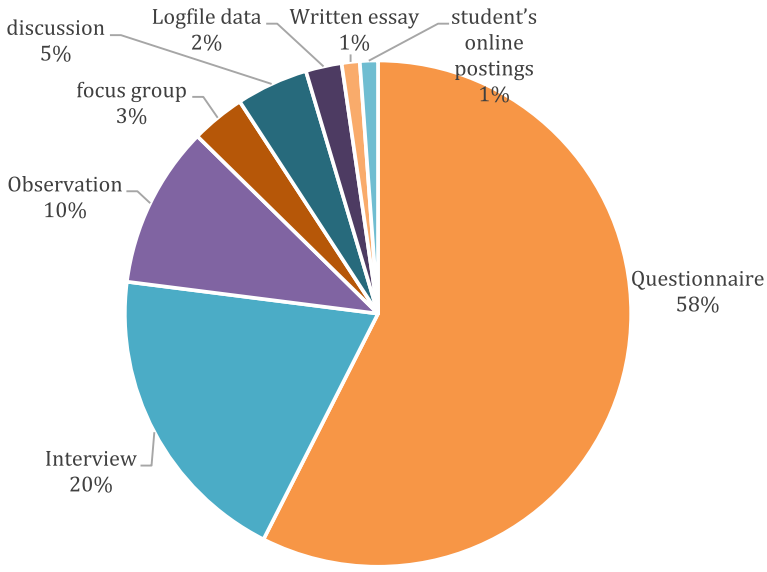

FIGURE 2 Data collection approaches used in the reviewed articles.

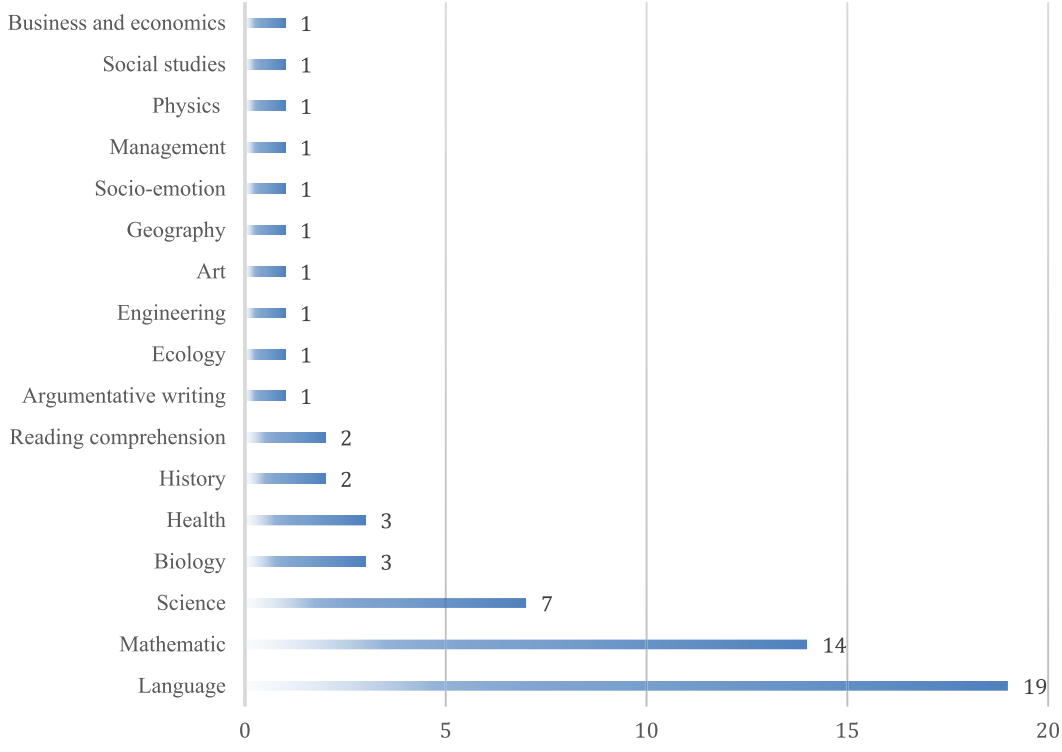

FIGURE 3 Distribution of subject matters in the reviewed articles.

their findings indicated that girls were much less attracted by competition elements (eg, by comparing high scores) than boys; however, they were more attentive to feedback coming from the tool.

TABLE 3 Individual factors that affect learning outcomes in the gamified learning environments.

Factors	Citation
Gender	Attali and Arieli-Attali (2015), Cheng et al. (2020), Gafni et al. (2017), Jagušt et al. (2018), Khan et al. (2017), Kickmeier-Rust et al. (2014), Su and Cheng (2015)
Prior knowledge	Chen et al. (2020), Halloluwa et al. (2018), Homer et al. (2018), Hulse et al. (2019)
Learning styles	Chu and Fowler (2020), Oliveira and Cruz (2018), Jones et al. (2019), Monterrat et al. (2017)
Affective dispositions	Chu and Fowler (2020)
Voluntariness	Gafni et al. (2017)
Motivation	Hursen and Bas (2019)
Social and cultural factors	Khan et al. (2017)
Subject matter interest	Su and Cheng (2015)

Prior knowledge was another common individual factor that researchers have investigated as a moderating variable when learning through gamification. Hulse et al. (2019) found that students with higher prior knowledge of mathematics could solve more mathematics problems in the gamified condition. Chen et al. (2020) showed that prior knowledge could affect students' overall reading comprehension performance in the gamified condition. Students with higher prior knowledge had a better understanding of reading than those without prior knowledge.

Students' learning styles were another common trait controlled in the reviewed articles. Monterrat et al.'s (2017) findings indicated that ignoring students' learning preferences and profiles in designing gamified settings could negatively impact their motivation. Jones et al. (2019) reported that learning styles could affect the performance of students' learning of science in gamified learning environments.

The environmental prerequisites for developing gamified environments in K-12 education

The review of selected studies revealed two environmental prerequisites that scholars considered when designing gamified environments in K-12 education: game elements and instructional support. In addition, the findings revealed several (mostly technical) challenges scholars faced when using gamification in K-12 education and thus should be considered before developing gamified environments in this context.

The content analysis of 54 articles revealed that scholars used various *game elements* to gamify learning environments. The most frequently used game elements, respectively, were 'point', 'level' and 'leaderboard'. Table 4 presents an overview of the game elements used for gamifying different subject matters in the reviewed articles.

Several studies used 'point' for gamifying learning environments. For example, Lam et al. (2018) designed a points-based system to motivate students to contribute their viewpoints and support them with evidence. In their study, students could be awarded one point if they contributed ideas relevant to the topic using the correct message labels. Tsai (2018) used points to give feedback and reward students. Their students could earn points by clicking the electrical appliances and obtaining useful information while interacting with the virtual characters. In the next step, they could earn points when collecting useful information. Thus, the points in their study not only served as a reward for students to motivate them to participate in the designed inquiry activities seriously but also served as a status indicator

TABLE 4 Game elements used facilitate K-12 education in gamified learning environments.

Game elements	Frequency (*N*)	Game elements	Frequency (*N*)	Game elements	Frequency (*N*)
Point	28	Rule	3	Emotion	1
Level	19	Avatar	2	Fantasy	1
Leaderboard	19	Choice	2	Prize	1
Challenge	16	Character	2	Randomized quiz	1
Badge	13	Mission	2	Relationship	1
Competition	13	Narration	2	Real gift	1
Progress bar	10	Adaption	1	Sharing features	1
Score	8	Alert	1	Star	1
Reward	7	Performance graph	1	Teamwork	1
Goal	6	Constraint	1	Tracking	1
Story	6	Control	1	Visual clues	1
Time counter	6	Cooperation	1	Visual gesture	1
Collaboration	4	Curiosity	1	–	–

for determining whether or not students were allowed to report each task result. Homer et al. (2018) used points in their gamified learning environments to better engage students with learning.

'Level' was the next most used game element in the reviewed publications. 'Level' was primarily used to unlock new challenges after meeting certain requirements (eg, Sun-Lin & Chiou, 2019). Halloluwa et al. (2018) designed learning activities on three levels. Students could receive a reward for doing the tasks designed at each level, and the next level would be unlocked if students could successfully finish the tasks. The levels were designed from simple to difficult to avoid demotivating students.

The third most used game element was the 'leaderboard'. Haruna et al. (2019) used a leaderboard as a game mechanic for increasing competition among students in teaching sexual health content to students. In their study, each topic was represented by one quiz containing 10 relevant questions. Students were asked to answer the questions and were awarded points for correct answers and lost points for incorrect answers. The students could obtain higher scores and be placed at the top of the leaderboard based on their earned points. Lam et al. (2018) designed a leaderboard as a high-score table that could show the ranking of students according to the total points they earned. They showed that using the 'leaderboard' as a game element could increase students' motivation for learning. In the same vein, Çakıroğlu and Güler (2021) found that the leaderboard could keep the students' external motivation fresh for achieving their goals.

In addition to game elements, the current study's findings indicated that scholars used several *instructional supports* to improve the effect of gamified learning environments on the targeted learning outcomes (see Table 5).

Based on the reviewed articles, 'feedback' as instructional support has been used in various forms in gamified learning environments. For example, Garcia-Sanjuan et al. (2018) used audio and video feedback to improve students' learning, motivation and enjoyment when using a multi-tablet gamified quiz system. In Halloluwa et al.'s (2018) study, feedback was used in the form of visualization of students' progression in real time. Moreover, if students could complete an activity successfully, a congratulatory pop-up

TABLE 5 Instructional support used in gamified learning environments for K-12 education.

Type	Frequency (*N*)	Description
Feedback	29	Information is given whether an answer or action is correct or not. The feedback can be corrective (correct or not) or explanatory (why correct or not)
Advice	25	Tips and suggestions created by the system to focus attention
Interactivity	24	The system/teacher is responsive to the player's actions
Collaboration	12	A discussion that often seeks to explain implicit knowledge
Modelling	9	Explaining how a task/problem is solved
Narrative elements	8	A storyline that can help players to organize educational material
Modality	8	The use of the audio channel to limit the visual search
Personalization	4	Adapting context to player's personal interest
Reflection	2	Stimulation to think about answers and/or explain these answers
Choice	1	Control over the irrelevant dimension of learning tasks
Contextualization	1	Delivering learning in a meaningful context

would be shown to them as feedback. Students could also receive encouraging feedback from the system to try again in case of failure. Cheng et al. (2020) used feedback as an instructional support in their gamified science inquiry activity and showed that well-designed feedback could provide students with a joyful experience. In their study, students could receive various feedback in the form of a real prize, a gift and a star for each task they performed correctly.

The second most common instructional support in the reviewed article was advice. Barcomb and Cardoso (2020) used 'advice' in the form of a meta-linguistic clue to visually draw the learner's attention to the relevant articulators in teaching pronunciation (eg, the positioning of the tongue tip against the alveolar ridge to produce /l/). In Khan et al.'s (2017) study, 'advice' was used in the form of an attractive animation to encourage users to achieve learning outcomes. Leftheriotis et al. (2017) designed a gamified system that could give users more information during the learning process using both visual materials (pictures or videos) and additional information in the text.

'Interactivity' was the third most frequently used instructional support. In Haruna et al.'s (2018) study, students were needed to perform various activities such as attempting quizzes and completing exercises related to sexual education. Their gamified learning environments could provide different interactivity-related supports by asking students to answer the questions for each topic or move to the next topic and by requiring them to score at least 6 out of 10 points; otherwise, the game would have started from the beginning. Tsai (2018) developed an environment where students could interact with different characters to go forward to reach a targeted goal.

The in-depth review of selected articles revealed several technology- and education-related *challenges* scholars faced when using gamification in the K-12 context. Being costly (Chu & Fowler, 2020), insufficient devices (Castañeda et al., 2018; Chen & Chiu, 2016; Rachels & Rockinson-Szapkiw, 2018) and not having proper ICT equipment and stable Internet connection (Gafni et al., 2017; Haruna et al., 2019) were the most mentioned technology-related challenges. In addition, some scholars referred to the difficulties in training teachers to work with virtual learning environments (Azar & Tan, 2020), dealing with teachers who were reluctant to use new technological devices (Oliveira & Cruz, 2018) and sustaining gameplay engagement and student performance throughout lessons for a longer period (Jagušt et al., 2018) as the most education-related challenges.

The research findings available regarding learning processes involved when using gamification in K-12 education

No study has been found to explore the role of using game elements in stimulating specific learning processes. However, some scholars related their positive outcomes to various learning processes stimulated due to their gamified learning environments (see Table 6).

Motivating students to learn was the most mentioned stimulated learning process in the reviewed articles. Jones et al. (2019) argued that gamified learning could inspire students to be motivated about the learning material even when there is a sense of heightened anxiety regarding the material and the class. Sun-Lin and Chiou (2019) posited that gamified comparison tasks in their study could motivate students to compare examples to gain effective algebra word problem-solving techniques, encouraging them to solve challenging practice problems by giving game rewards and level-up settings.

The study of Azar and Tan (2020) showed that learning through gamified virtual reality could effectively engage students in the language learning process. They related the positive effect of their gamified environment on students' language learning to the real-life learning experiences it provided, thus creating a feeling of involvement among them. Similarly, Chen and Chiu's findings (2016) indicated that the students under the intergroup competition condition had significantly higher involvement during the multitouch gaming activity than those under the non-competition condition.

TABLE 6 Learning processes involved when using gamification in K-12 education.

Learning process	Citation
Becoming motivated	Azar and Tan (2020), Çakıroğlu and Güler (2021), Castañeda et al. (2018), Chen and Chiu (2016), Gafni et al. (2017), Gómez-García et al. (2020), González et al. (2016), Haruna et al. (2018), Hashim et al. (2019), Hursen and Bas (2019), Jones et al. (2019), Kickmeier-Rust et al. (2014), Lam et al. (2018), Li and Chu (2021), Monterrat et al. (2017), Pitura and Chmielarz (2017), Pozo Sánchez et al. (2020), Prasetyoajt and Napitupulu (2018), Reed et al. (2020), Sun and Hsieh (2018), Sun-Lin and Chiou (2019)
Feeling of involvement	Azar and Tan (2020), Çakıroğlu and Güler (2021), Castañeda et al. (2018), Chen and Chiu (2016), Cheng et al. (2020), Duarte and Cruz (2018), Garcia-Sanjuan et al. (2018), Hulse et al. (2019), Khan et al. (2017), Lam et al. (2018), Leftheriotis et al. (2017), Lo and Hew (2020), Nand et al. (2019), Puritat (2019), Su and Cheng (2015)
Sense of competition	Azar and Tan (2020), Chen and Chiu (2016), Gafni et al. (2017), Homer et al. (2018), Jagušt et al. (2018), Jo et al. (2018), Lam et al. (2018), Reed et al. (2020)
Willingness to go ahead	Chen et al. (2020), Chu and Fowler (2020), Gafni et al. (2017), Hashim et al. (2019), Hursen and Bas (2019), Reed et al. (2020)
Having fun	Garcia-Sanjuan et al. (2018), Jo et al. (2018), Jones et al. (2019), Saman et al. (2019)
State of flow	Cheng et al. (2020), Chu and Fowler (2020), Garcia-Sanjuan et al. (2018)
Sense of progress	Barcomb and Cardoso (2020), Homer et al. (2018)
Attracting attention	Sun-Lin and Chiou (2019), Sun and Hsieh (2018)
Sense of achievement	Li and Chu (2021), Sun-Lin and Chiou (2019)
Sense of reputation	Chen et al. (2020)
Deep thinking	Khan et al. (2017)
Anxiety-reducing	Barcomb and Cardoso (2020)

Homer et al. (2018) study stated that using badges and progress bars could give students a sense of competition and stimulates them to go further. The progress bars show students where they are in their learning and how far they are from reaching the goals, and thus, it motivates them to move towards completion and stimulates their sense of competition.

The research findings available regarding the relationship between gamification and learning outcomes in K-12 education

Many scholars in the reviewed articles reported the positive effect of using gamification in K-12 education on various cognitive, affective and behavioural learning outcomes (see Table 7).

Several studies investigated the effect of gamified learning environment on various cognitive learning outcomes, reporting a positive impact on students' statistical literacy (eg, Çakıroğlu & Güler, 2021), Algebra problem solving (eg, Sun-Lin & Chiou, 2019), learning languages such as English (eg, Homer et al., 2018) and conceptual learning of science (eg, Khan et al., 2017; Su & Cheng, 2015), physics (eg, Cheng et al., 2020) and biology (eg, Fan et al., 2015; Pitura & Chmielarz, 2017). In addition, some scholars reported the positive effect of using game elements on K-12 students' perception of learning (eg, Haruna et al., 2018; Ioannou, 2019) and positive emotions towards physical activity (eg, González et al., 2016), opinions about science learning (eg, Hursen & Bas, 2019) and their self-efficacy (eg, Rachels & Rockinson-Szapkiw, 2018). Some reviewed articles also reported the positive effect of gamification on students' behaviours, such as improving their healthy lifestyle and physical activity (eg, González et al., 2016) and higher quality cardiopulmonary resuscitation performance (eg, Otero-Agra et al., 2019).

Despite all the reported positive outcomes, the current study's findings also revealed some neutral results concerning the effect of gamification on different learning outcomes. Chen et al. (2020) reported that gamification mechanisms adopted in their study only promoted students' reading activity in competing for the number of annotations and interactions but did not facilitate reading comprehension performance. Their students stated that they would concentrate more on the article's content when using a learning environment without gamification mechanisms because they would not have to care about the task levels. Although Sun-Lin and Chiou (2019) reported the positive effect of gamification on sixth graders' performance of algebra problem-solving and attitude towards algebra learning, they did not find any significant effects on students' confidence in solving algebra problems. Homer et al. (2018) reported no significant difference in reading posttest scores between the experimental and control groups for elementary school students in Grades 1 and 2 but only for Grades 3 and 4. They asserted that a combination of young age and circumstances of these classes might have a part to play in achieving this natural finding. Despite their positive result regarding the effect of gamification on students' belief in their ability to speak Chinese, Wang et al. (2019) reported no significant effects on their high school students' reading, listening or vocabulary acquisition. Çakıroğlu and Güler (2021) showed that while the gamification implementation accurately increased the motivation and engagement of medium and high-level achievers, low performers remained distant. Prasetyoajt and Napitupulu's (2018) reported that e-learning gamification does not have a positive effect or improvement on student motivation in terms of behavioural, emotional and cognitive and their learning achievement. They related their findings to the absence of a teacher in self-paced e-learning, which will make the students feel difficult and confused to understand the lesson.

TABLE 7 Investigated learning outcomes and their references in K- 12 education.

Category	Subcategory	Citation
Cognitive	Learning mathematics (eg, mathematics concepts and problem-solving)	Attali and Arieli-Attali (2015), Çakıroğlu and Güler (2021), Chen and Chiu (2016), Chu and Fowler (2020), Halloluwa et al. (2018), Hubalovsky et al. (2019), Hulse et al. (2019), Jagušt et al. (2018), Kickmeier-Rust et al. (2014), Nand et al. (2019), Reyes et al. (2020), Sun-Lin and Chiou (2019), Yung et al. (2020)
	Learning language skills (eg, grammar and vocabulary, reading and writing)	Saman et al. (2019), Barcomb and Cardoso (2020), Castañeda et al. (2018), Chu and Fowler (2020), Duarte and Cruz (2018), Hashim et al. (2019), Homer et al. (2018), Li and Chu (2021), Mukhtar et al. (2019), Purgina et al. (2020), Rachels and Rockinson-Szapkiw (2018), Reed et al. (2020)
	Conceptual understanding of sciences (eg, Physics and Biology)	Cheng et al. (2020), Fan et al. (2015), Haruna et al. (2018), Hursen and Bas (2019), Jones et al. (2019), Khan et al. (2017), Pitura and Chmielarz (2017), Su and Cheng (2015), Tsai (2018)
	Improving health knowledge	Haruna et al. (2019), Otero-Agra et al. (2019)
	Learning History and Ecology	Leftheriotis et al. (2017)
	Improving reading comprehension skills	Chen et al. (2020)
	Improving social skills (eg, communication, collaboration)	Ioannou (2019)
	Improving argumentative writing	Lam et al. (2018)
	Improving management skills	Puritat (2019)
	Improving creativity	Duarte and Cruz (2018)
Affective	Positive perception and emotions	González et al. (2016), Haruna et al. (2018), Ioannou (2019), Khan et al. (2017), Leftheriotis et al. (2017), Pitura and Chmielarz (2017), Su and Cheng (2015), Tsai (2018), Sun-Lin and Chiou (2019)
	Increasing self-efficacy	Rachels and Rockinson-Szapkiw (2018), Wang et al. (2019)
	Positive opinions on science learning	Hursen and Bas (2019)
Behavioural	–	González et al. (2016), Haruna et al. (2019), Otero-Agra et al. (2019)

DISCUSSIONS AND AVENUES FOR FUTURE RESEARCH

The primary purpose of this study was to inform educators and scholars about the latest state of the art on using gamification in K-12 education and present an overview of scientific investigation in this research field. As such, a systematic search was performed with related keywords in various databases, resulting in 54 articles that focused exclusively on using gamification for K-12 education from 2008 onwards. The findings revealed a growing number of studies since 2014, highlighting the popularity of this teaching approach for K-12

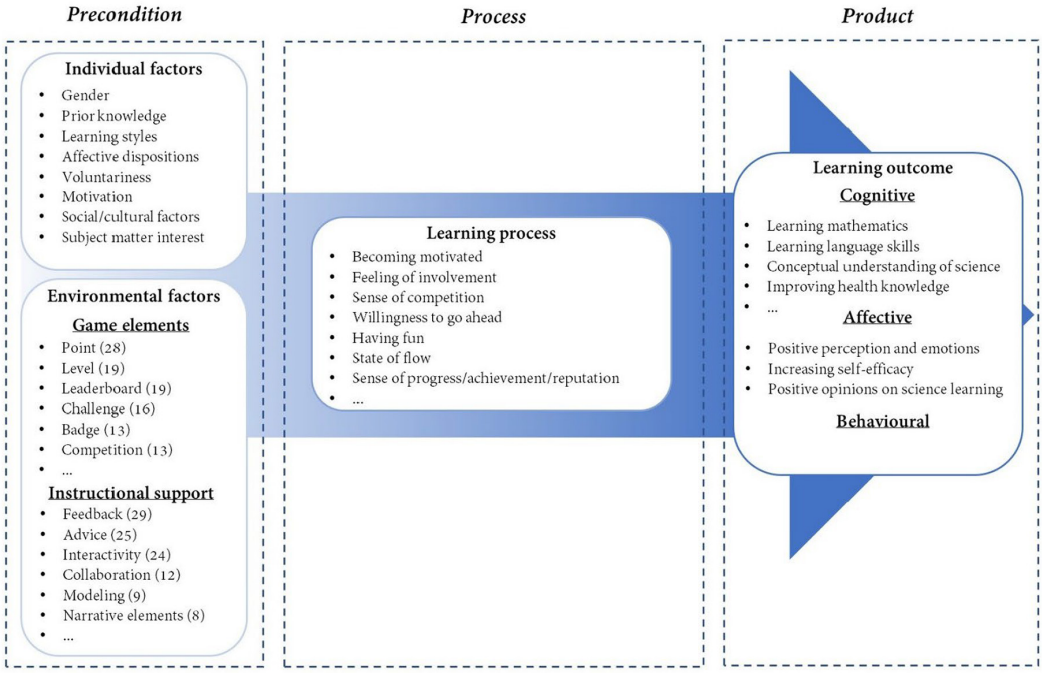

FIGURE 4 Evidence-informed framework for designing efficacious gamified learning environments for K-12 education.

education in recent years. This finding aligns with previous studies reporting a growing interest in using gamification for educational purposes (eg, Dehghanzadeh et al., 2019; Huang et al., 2019; Pozo Sánchez et al., 2020; Tsay et al., 2018). Inspired by Biggs's (2003) 3P model, the findings of reviewed articles were then categorized into four educational dimensions essential for designing any learning environment, providing future scholars with an evidence-informed framework for designing efficacious gamified learning environments for K-12 education (see Figure 4).

Preconditions

According to Biggs (2003), several presage factors provide the context in which a learning experience is conducted, influencing its planning and outcomes. Similarly, the current study's findings indicated that a successful implementation of gamification in K-12 education requires careful consideration of different individual and environmental factors.

Individual factors

Previous research findings indicate that the successful implementation of gamification in educational contexts requires an adaptive (and not one-fits-all) approach (Rodríguez et al., 2022), wherein the gamified environments are adapted to the user's traits, such as personality type (Buckley & Doyle, 2017), gender (Denden et al., 2021), learning styles (Buckley & Doyle, 2017) and age (Palmquist & Jedel, 2021). The in-depth review of the selected articles also revealed that some scholars related their findings to individual factors, such as gender, prior knowledge and learning style, arguing that their results could be

different for learners with different characteristics. However, no empirical study was found to investigate the effect of K-12 students' traits and individual differences on their learning in a gamified environment. This shortcoming is also highlighted by Bai et al. (2020) in their meta-analysis review on the effect of gamification on K-12 and higher education students' learning outcomes, as they could not find any study that explicitly explored the effect of students' traits. This is problematic as individual differences significantly influence students' gamification experiences (Buckley & Doyle, 2017; Lavoué et al., 2019; Smiderle et al., 2020) and how they interact with and perceive different game elements (Denden et al., 2021; Pakinee & Puritat, 2021). Therefore, as Bai et al. (2020) also suggested, further studies are still needed to examine what K-12 students' individual characteristics can affect the gamified environments' learning outcomes and how students with different characteristics should be best supported to achieve the targeted learning outcomes successfully.

Moreover, there is an ongoing debate among scholars over whether or not gamified learning environments can help K-12 students. In their meta-analysis review on the effects of gamification on behavioural change in education, Kim and Castelli (2021) reported that gamified intervention effects were the most significant for older adults compared with those for K-12 and college students, arguing that their finding warrants further investigation to understand the effects of a gamification strategy in education by age groups. Similarly, Huang et al.'s (2020) meta-analysis showed that the effect size of studies using gamification for undergraduates nearly doubles that of K-12 students. Based on this finding, Huang et al. (2020) posed two important questions that still need to be answered in future studies: 'What supports do K-12 students need to be successful in gamified learning environments? Are K-12 students developmentally ready for the facets of gamified learning?' (p. 1896).

Environmental factors

Game elements

The most frequently utilized elements for gamifying educational courses in K-12 education were 'point'. According to Hosseini et al. (2019), points can increase the external motivations of players and encourage competition and involvement in learning activities among learners. 'Level' was the next most used game element in the reviewed article. 'Level' is usually incorporated in gamified environments as a progress bar and corresponding points necessary to reach the next level. Progression to the next level mirrored the leaderboard as another game element, albeit without the option for social comparison. According to scholars, the level could give students a sense of progression in the game (Goehle, 2013), maximizing their social and collaborative experience during lectures (Subhash & Cudney, 2018). 'Leaderboard' was another used game element in the reviewed studies to improve various learning outcomes in K–12 education. According to Landers et al. (2017), leaderboards can increase the flow states in the learning process and encourage learners to compete with other players to achieve the desired purpose. Moreover, they asserted that leaderboards and narrative elements provide opportunities for learners to participate actively in learning environments. The current study's findings partially align with Subhash and Cudney's (2018) literature reviews on gamification in higher education, showing that points, badges and leaderboards were the most frequently used game elements when using gamification games for higher education.

Despite using various game elements by scholars in the reviewed articles, no clear trend was found showing what game elements can be more effective in achieving a specific learning outcome. This can be due to a frequently mentioned shortcoming of research on using gamification in educational contexts. As pointed out by several scholars (eg, Krath et al., 2021; Landers, 2014; Landers et al., 2015; Mekler et al., 2017), most of the gamification research suffers from a lack of theoretical framework and is based on the premise that

using the most common game elements such as points, levels and leaderboards can always improve learning as they can further engage students with learning materials. However, the effect of incorporating game elements in education is likely to vary with regard to different learning outcomes, depending upon the specific game elements used and the contexts in which they are used (Landers, 2014). Thus, there is a crucial need for theory-driven empirical studies to compare the effect of a different set of game elements on various learning outcomes, especially in K-12 education.

Furthermore, despite the crucial role of students' differences in how they perceive game elements (Denden et al., 2021; Kim & Castelli, 2021), no study was found to consider individual differences when using different elements. The current study's findings showed that female students were much less attracted by competition elements (eg, by comparing high scores) than boys (Kickmeier-Rust et al., 2014). According to Çakıroğlu and Güler (2021), the influence of using game elements such as leaderboards and badges on low-achiever students was not positive. Also, concerning age, scholars in previous studies related their findings to the fact that compared with younger adults, older users are more easily influenced by game elements that stimulate social comparison, such as leaderboards (Kim & Castelli, 2021). These findings highlight the importance of further investigations to understand what game elements could better help K-12 students based on their individual differences, helping designers and educators personalize their gamified courses.

Instructional support

The findings indicated that external instructional supports and guidance play an essential role in facilitating K-12 students' learning process through gamification. This finding is in keeping with Wouters and Van Oostendorp (2013), arguing that proper instructional supports could enhance learning within game-based learning environments because they aid learners in preventing inefficient use of cognitive activity, assisting them in choosing pertinent information. Several scholars also argued that without instructional support in gamified learning environments, students are more likely to learn to play the game (ie, in-game performance) rather than learn domain-specific knowledge and skills (Ke, 2009; Leutner, 1993). Thus, in line with previous scholars, external supports are necessary to enhance learning outcomes within gamified learning environments (Hwang et al., 2012; Lee & Chen, 2009).

Feedback in the form of video/audio alerts, visualization of students' progression and a real prize or a star was the most used instructional support in the reviewed articles. Scholars posited that immediate task-level feedback, for instance, provided by points in gamified environments, has a high potential to scaffold learning process performance (Sailer & Sailer, 2021) and encourage students to keep trying, raising their level of engagement with the task (Simões et al., 2013). According to Carless (2006), feedback is integral to learning and involves communication about a gap between actual performance and desired outcomes. A synthesis of over 500 meta-analyses identified feedback as one of the most critical factors in improving student achievement (Hattie & Timperley, 2007; Noroozi, Biemans, & Mulder, 2016; Noroozi et al., 2023). In addition, many studies have shown that feedback has positive effects on learners' motivation (Burgers et al., 2015), achievement (Carter, 2009; Foley et al., 2019) and performance in the learning process (Gielen & De Wever, 2015; Latifi et al., 2021; Van der Kleij et al., 2015).

Advice was the second most used instructional support in the reviewed studies that primarily emphasized students' interests, learning styles, differences in cognitive level and other aspects to provide the most appropriate learning resources for each student. Research suggests that learning characteristics vary for each learner and that students prefer to use different resources in distinct ways (Kelly & Tangney, 2006). Besides, students' preferences and background knowledge also influence students' learning outcomes within any learning environment (Fuadi et al., 2021). Therefore, an ideal learning environment should adapt its

design to the students' needs (Mensah et al., 2021). In this regard, Wouters et al. (2013) referred to advice as critical instructional support used in gamified learning environments to adapt the design to students' needs and differences. They defined it as 'system-generated hints and suggestions to support the learner to continue in the game' (p. 415). For instance, in one of the reviewed studies, the system could give users more information during the learning process concerning the artefact with both visual materials (pictures or videos) and additional information in the text (see Leftheriotis et al., 2017).

Interactivity was another frequently used instructional support in the reviewed articles. The term interactivity is used to describe a variety of learning activities, including interactions between students (ie, student–student interaction), interactions with the tutor (ie, teacher–student interaction) and interactions with the teaching material itself (ie, student–content interaction) (Moore, 1989). According to Wouters et al. (2013), interactivity is regular instructional support in gamified learning environments that allows learners to make choices when solving a specific problem or performing a task. For example, in Haruna et al.'s (2018) study, students were needed to perform various activities such as attempting quizzes and completing exercises related to sexual education. Their gamified environment could provide different interactivity-related supports by asking students to answer the questions for each topic or move to the next topic and by requiring them to score at least 6 out of 10 points; otherwise, the game would have started from the beginning.

Scholars in the reviewed studies incorporated several instructional supports to facilitate and improve K-12 education through gamification. However, no study was found to explore which instructional supports can be utilized exclusively to enhance specific learning outcomes. Moreover, previous studies showed that individual differences also affect learners' perception of the provided instructional support. For instance, Denden et al.'s (2021) findings indicated that females are more likely to find feedback useful than males. Therefore, a critical path for upcoming research is to address these issues and explore how each instructional support at a micro level can contribute to the benefits of using gamification in K-12 education.

Learning process

The learning process is the second element of Biggs' (2003) 3P model, referring to how students approach learning (ie, surface vs. deep learning) as a result of individual and environmental presage factors. While the surface approach to learning requires a minimum effort only to meet course requirements, deep learning implies a high engagement with the subject matter (Farrokhnia et al., 2019; Kanashiro et al., 2020). In this regard, some scholars in the reviewed articles associated their positive findings with different internal processes stimulated in the gamified environment (eg, becoming motivated, feeling of involvement and the sense of competition), arguing that these processes would increase students' engagement with learning materials (Azar & Tan, 2020) and encourage them to complete the learning tasks successfully (Sun-Lin & Chiou, 2019). These findings align with previous studies showing that gamification can improve learning outcomes (Huang & Hew, 2018; Romero-Rodriguez et al., 2019) by enabling students to be more involved in their learning and ownership of the course's completion (Gonzalez et al., 2017). Additionally, previous scholars posited that gamification could help motivate students to achieve their learning goals (Bicen & Kocakoyun, 2018; Loos & Crosby, 2017).

However, no study was found to determine how the game elements were selected to trigger these internal processes. In most studies, various game elements were used with only some vague intention of increased engagement without a theoretical model linking the used elements with the outcomes. This shortcoming significantly limits the generalizability of the

research findings and provides misleading recommendations to future gamification practitioners, as also highlighted by previous scholars (eg, Landers, 2014; Landers et al., 2015). In this regard, future empirical studies should benefit from the existing learning and motivational theories of gamification (see Krath et al., 2021) for designing theory-driven gamified learning environments. For instance, based on Landers's (2014) theory of gamified learning, game elements can be divided into two categories, the ones that trigger *moderating* processes to strengthen the relationship between instructional design quality and outcomes and those that influence the targeted behaviour or attitude directly by triggering *mediating* processes. This theory provides several promising directions for future empirical research. For instance, while some studies explored the role of the mediational process in gamified environments in achieving the targeted behaviours (eg, Landers & Landers, 2014), the moderation process remains untested, and as suggested by Landers et al. (2015), it should be a high priority for future studies in the field. Moreover, there is a need for future empirical studies to compare the effect of using game elements that trigger moderating processes with those that stimulate mediating processes on different learning outcomes.

Inspired by Ryan and Deci's (2000) self-determination theory, many scholars related the effect of gamification on learning to the role that game elements play in stimulating individuals' extrinsic and intrinsic motivations (eg, Botte et al., 2020; Kim et al., 2020; van Roy & Zaman, 2017). Extrinsic motivation is defined as doing something due to a separable outcome, such as pressure or 'extrinsic rewards' in the form of money or praise (Mekler et al., 2017). In contrast, intrinsic motivation refers to doing an activity for its inherent satisfaction and enjoyment rather than for some separable consequence (Oudeyer et al., 2016). Similarly, extrinsic motivation in gamified environments refers to behaviour driven by external rewards such as points, badges, leaderboards and medals. In comparison, intrinsic motivators are those game elements such as challenge, narration, collaboration, cooperation, curiosity and storytelling (Malone & Lepper, 1987) that could affect learners' innate psychological needs for competence and autonomy (Mekler et al., 2017). Although scholars in the reviewed studies investigated the impact of multiple game elements on learning outcomes, it was difficult to determine how and to what extent the used elements contribute to students' motivation and behaviour. In this regard, future empirical studies are needed to isolate the effect of different game elements on learners' intrinsic and/or extrinsic motivation in various contexts, especially K-12. Moreover, as Landers et al. (2015) highlighted, there is still an open call for future empirical studies to investigate the aspects of gamification that are intrinsically motivating and identify moderators that need to be considered when looking at these relationships. In this regard, Ryan's (1982) well-known intrinsic motivation inventory can be used to measure the effects on learners' intrinsic motivation. Moreover, Bedwell et al.'s (2012) taxonomy of game elements in educational settings can be used to establish which elements trigger students' intrinsic motivation.

Learning outcome

Most reviewed articles reported a positive effect of employing game elements in K-12 education on various cognitive, affective and behavioural learning outcomes. This finding aligns well with Sailer and Homner's (2020) meta-analysis, indicating that gamification can positively affect cognitive, motivational and behavioural learning outcomes, especially in a school setting. These positive effects could be due to the various learning opportunities it provides for students through incorporating different game elements (Filippou et al., 2018), increasing their memory capacity (Fotaris et al., 2016) and improving attention and motivating students to increase their efforts to comprehend concepts and content (Alabbasi, 2018).

The current study's findings also revealed neutral results reported in some reviewed articles showing that using game elements in educational contexts does not always end with a favourable outcome. Scholars in reviewed articles related these neutral results to different reasons, such as the complexity of learning tasks (ie, the tasks were very easy or complex) (Homer et al., 2018; Sun-Lin & Chiou, 2019), the lack of proper instructional support from the teacher (Prasetyoajt & Napitupulu, 2018), the appropriateness of some game elements for low-motivated students who exert less effort during the learning process (Attali & Arieli-Attali, 2015) and the distraction that game elements could cause students when engaging with the learning task (Chen et al., 2020). These reasons suggest that the successful implementation of gamification in any educational context demands careful consideration of several essential factors, such as the targeted learning outcomes (Landers, 2014), the required instructional support (Wouters & Van Oostendorp, 2013) and students' differences (Lavoué et al., 2019; Smiderle et al., 2020) and needs (Mensah et al., 2021). However, as in previous review studies (eg, Bai et al., 2020; Sailer & Homner, 2020), the current study failed to identify a set of evidence-informed factors that are crucial to be considered when implementing gamification, especially in the K-12 context.

The study's findings also showed that all researchers used traditional approaches such as questionnaires, interviews and various learning tests to collect data and evaluate the effect of gamification on different learning outcomes. Thus, the gamification affordances for providing researchers with valuable data were largely neglected in the reviewed studies. Gamified learning environments can provide researchers with immediate and useful data and feedback such as game scores, final assessments or time spent engaged in gamification activities, which significantly can improve and support their findings (Delacruz, 2010). In gamified learning environments, learners produce different information about their learning progress and needs, and these environments allow teachers and researchers to gather these user-specific data through a 'non-invasive form' of assessment (Kelly, 2005; McClarty et al., 2012). Shute (2011) referred to this non-invasive form of assessment as 'stealth assessment', defined as an evidence-based process by which assessment can be integrated directly with learning environments. Moreover, with the emergence of new digital tools into gamified learning environments, researchers are provided with other assessment methods such as eye-tracking, motion-tracking or mouse-tracking that could give researchers high accuracy and detailed records of students' movements, tendencies, way of thinking and general learning progress (Guzsvinecz & Szucs, 2019). As a result of using these data-collecting approaches, researchers do not have to monitor the whole procedure continuously, and students can be relieved from the anxiety they are being assessed (Kingsley & Grabner-Hagen, 2015; Sánchez-Rivas et al., 2019). In this regard, another important research line for future studies is to explore the potential of gamified learning environments in gathering valuable data during the learning process and improving the validity and reliability of research findings.

Last but not least, based on this review study's findings, all the reviewed studies had a short-term format indicating that there is still insufficient high-quality evidence to support the long-term benefits of gamification in educational contexts. Thus, in keeping with Dichev and Dicheva (2017), future longitudinal studies are necessary to measure the sustainability of gamified learning environments' effects on K-12 students' learning outcomes over time.

CONCLUSION

Guided by Biggs' 3P model, a systematic review of high-quality empirical studies on gamification in K-12 education was conducted to thematically map their findings. The study has serval contributions to the literature. First, it offers a comprehensive overview of the current

state of research on the use of gamification in K-12 education. The findings highlight the potential of gamification as an effective strategy for promoting cognitive, affective and behavioural learning outcomes in K-12 education, primarily by stimulating students' motivation and raising their level of engagement. Second, the study proposes an evidence-informed framework based on the synthesis of available empirical findings. The framework can serve as a blueprint for teachers in designing gamified environments effective for K-12 education, by considering three essential dimensions, namely preconditions (individual and environmental factors), learning processes, and outcomes and their interrelationships. Based on the framework, if teachers, for instance, plan to use gamification to enhance students' meaningful learning of science, they need to consider individual differences among students (eg, such as their learning style), which may moderate the effect of gamification on their science learning. Furthermore, driven by relevant learning theories, they need to carefully choose suitable game elements and provide instructional supports that can effectively engage students in learning processes that can lead to desirable learning outcomes. Thirdly, this study identifies three main ways of moving forward for future scholars: (1) it provides an up-to-date and empirically rooted call for research on using gamification in K-12 education, (2) it uses Biggs' 3P model to offer several research gaps and intriguing and under-emphasized areas for developing constructively aligned gamified learning environment, and (3) it provides critical insights into the reasons for the neutral results in reviewed literature that can be further teased out through future empirical studies.

This study also comes with its own limitations. Firstly, only peer-reviewed publications were included in this review, which means that there is a possibility of missing relevant work on using gamification in K-12 education, including non-peer-reviewed studies. Nevertheless, using a thorough systematic data collection process (namely PRISMA), we have ensured a comprehensive sample of high-quality empirical studies. Secondly, there may be concerns about the objectivity of the data analysis and coding process as different scholars may interpret the results and recognize different central themes. This is particularly relevant due to the lack of consensus on the definition of 'game', 'gamification' and 'serious games'. For example, while some scholars may consider a leaderboard as a game element in a non-gaming context, others may view it as a game (van Gaalen et al., 2021). To overcome this limitation and reduce subjectivity, we made a clear distinction between the three forms of game-based learning in the Introduction section, namely serious games, educational games and gamification. Additionally, we utilized a solid theoretical model, ie, Biggs' 3P model, to provide a theory-based structure and grounded the observed categories and thematic analysis of findings. Furthermore, the quality assessment and coding process were conducted by multiple coders to prevent any bias in the coding process. Thirdly, this study included only articles concerning the use of gamification in formal K-12 classrooms for educational purposes, while there are other articles that discuss gamification in extra-curricular courses for students in need or with non-educational purposes. This limitation can be addressed by future review studies with a broader focus. Finally, the proposed framework was developed solely based on the synthesis of available empirical findings. Although it shares parallels with Biggs' 3P model as a solid theoretical foundation for designing effective learning environments, further empirical research is needed to support the validity of this framework. Such research should demonstrate the extent to which aligning the three dimensions (preconditions, learning processes and outcomes) in designing a gamified environment can enhance the positive effects of gamification on K-12 students' learning.

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CONFLICT OF INTEREST STATEMENT

None of the authors has a conflict of interest to disclose.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ETHICS STATEMENT

Given the non-empirical nature of this work (SLR), it was not bound by the ethical considerations associated with empirical studies involving human participants, such as voluntary participation, informed consent, anonymity, confidentiality, potential for harm and results communication. The work was, however, bound by the ethical responsibility to conduct rigorous, academic research.

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