Use of Gamification in Primary and Secondary Education: A Systematic Literature Review

Ana Vrcelj [ID]
University of Rijeka, CROATIA

Nataša Hoić-Božić* [ID]
University of Rijeka, CROATIA

Martina Holenko Dlab [ID]
University of Rijeka, CROATIA

Abstract: Gamification in education refers to the application of game design elements and game principles in teaching with the goal of increasing students' motivation and engagement, which contributes to more successful achievement of learning outcomes. Gamification can be used in education at different levels, from primary and secondary schools to universities and adult education. An analysis of the literature on the use of gamification in education has shown that it is more common in university education and less common in primary and secondary schools. Nonetheless, experience shows that games and numerous digital tools are successfully used in schools for the purpose of gamification, although this is generally not supported by the relevant research published in the papers. The research presented in this paper represents a systematic review of the literature on relevant research on the use of gamification in primary and secondary schools to explore the field and make recommendations for future research. The conclusion is that research on gamification should continue to suggest appropriate pedagogical and technological frameworks which would facilitate the use of gamification in schools by teachers.

Keywords: *Game design elements, gamification in education, systematic literature review.*

Introduction

The term gamification has gained great interest and popularity since 2010 and the concept was introduced in 2002 by a British programmer Nick Pelling (Dreimane, 2021). Although there is no single definition of gamification applicable to different fields such as education, marketing, healthcare, business, etc., today it is most often described as the application of certain elements and principles of game design in a context that is different from games (Dichev & Dicheva, 2017). The purpose of gamification is not to exclusively include digital games, but to gamify activities through some game-based elements such as avatars, badges, virtual points, levels, stories, challenges, leaderboards, awards, etc. (Gibson et al., 2013; Toda et al., 2020).

Gamification in education refers to the application of elements of game design and game principles in the classroom to increase student motivation and engagement. Gamification uses mechanics, aesthetics, and thinking from the player's point of view to engage students and promote learning and problem-solving (Osatuyi et al., 2018; Pal'ová & Vejačka, 2020).

In theory, the use of gamification in education can improve student engagement by transforming tasks into games that motivate students through rewards when they succeed and can also encourage desirable behaviour change. The use of gamification elements promotes students' motivation and engagement in the classroom, and furthermore, successful adoption of learning outcomes (Martínez-Hita et al., 2021; Park & Kim, 2021; Plantak Vukovac et al., 2018).

In practice, gamification has shown significant results in creating more accessible and cost-effective e-learning materials compared to digital games. The main difference between gamification and educational (serious) games is that gamification does not require a complete digital game design (Rugelj, 2015), which is an advantage from a financial perspective. Another advantage of gamification is that various elements of game design can be used and applied in simple digital tools such as learning management system (LMS) and quiz tools (Vrcelj et al., 2021). Due to its simplicity,

---

* **Corresponding author:**
Nataša Hoić-Božić, University of Rijeka, Faculty of Informatics and Digital Technologies, Croatia. ✉ natasah@inf.uniri.hr

gamification is much more suitable for implementation and enforcement in primary and secondary education, than learning with the help of specially designed educational games.

Although gamification can be used in education at different levels, from primary and secondary schools to universities and lifelong learning programmes, the analysis of literature on the use of gamification has shown that it is more present in university education and less in primary and secondary schools. Therefore, this paper focuses on primary and secondary schools with the aim of contributing to systematic research on gamification at these levels of education.

The paper presents the systematic literature review (SLR) (Okoli, 2015; Okoli & Schabram, 2010) of relevant research on the use of gamification in primary and secondary schools to explore the field and make recommendations for future research. The research identified the level of education, teaching model, subject, methods and activities of learning and teaching used in gamification, which digital tools and game design elements are used in gamification, the nature and aim of research on gamification, and whether gamification has a positive impact on students and in what ways. The data collected with the SLR was used to create recommendations for future research on gamification in education, particularly in primary and secondary schools.

Literature Review

In their review paper, authors Dichev and Dicheva (2017) examine the impact of gamification on increasing motivation and developing student engagement in teaching by using elements of game design in educational settings. They also critically examine how the use of game design elements affects the achievement of educational outcomes. The authors conducted their SLR study mainly at the university level, and only a very small percentage of 13.7% related to primary and secondary education (K-12 level). Out of 51 papers selected for detailed analysis, only 7 are related to education in schools. The research included various elements related to gamification, such as learning subjects, game elements, learning activities, and gamification achievement test scores. The authors noted the positive impact of gamification in educational settings but pointed to the growing number of studies on the effectiveness of gamification in educational contexts that are unconvincing and insufficiently supported by evidence.

Authors Mora et al. (2017) conducted a systematic literature review on gamification at the university level. The focus of the review is to examine the framework for the development of gamification considering the age-appropriateness of students and the type of elements of gamification in higher education environments. The conclusion of the review showed the dominance of gamification elements in business environments, while the available gamification tools were much less present in general activities such as education and health. The authors note that most publications in higher education do not follow the formal design of the gamification process. Moreover, most publications focus on describing experiences, i.e., the so-called. "ad hoc method" and thus do not contribute to the research of other researchers and teachers.

Toda et al. (2020) conducted research and produced a paper that does not follow the methodology of a systematic literature review but describes taxonomies or frameworks for classifying and describing gamification elements. The authors also proposed their own taxonomy by classifying gamification elements into five categories and listing the advantages and disadvantages for each of the categories. The authors are expecting that future more comprehensive research will provide guidelines for implementing gamification in the classroom and bring these guidelines closer to teachers.

In the review paper (Hamari et al., 2014) authors conducted a systematic review of the literature on gamification in general (not just in education) to determine if gamification is useful. They emphasized the motivational possibilities of gamification and examined its impact on the psychological aspects of motivation. They concluded that the effects of gamification are positive in almost all studies analysed, but that more research is needed to confirm this, especially since the research mainly uses qualitative methods.

One of the most recent reviews (Nieto-Escamez & Roldán-Tapia, 2021) examines the experience of using gamification in secondary schools and universities during the pandemic COVID-19. The paper does not use SLR methodology, and the authors describe 11 case studies on the use of gamification, grouped by subject or field (chemistry, biology, medicine, computer science, business). They analysed the impact of gamification on student motivation and learning outcomes and found them to be positive, but also concluded that more research is needed to confirm this, especially since there was no comparison with learning outcomes in a traditional setting without gamification.

The paper (Plantak Vukovac et al., 2018) presented research on gamification in primary and secondary schools. The research included a survey of teachers about the use of gamification elements in classroom activities and about their attitudes towards gamification in general. The results showed that only one third of the participants were familiar with the concept of gamification, while the rest had never participated in professional training on gamification. The authors pointed to a large gap in the educational system, where teachers reported a lack of knowledge when talking about gamification, a lack of time, and a lack of interest in improving teaching methods.

A study of the existing literature showed that gamification is prevalent in higher education, which means there is a scarcity of work showing the results of gamification in elementary and secondary schools. Based on the review of the

work, it can be concluded that there is still a need for a new, high-quality, systematic review of the literature which would prove the sustainability of the long-term benefits of gamification for educational purposes. Since most of the research was conducted in higher education institutions, the authors of the reviews see the possibilities for further research in other educational settings such as elementary and secondary schools. Overall, the authors conclude that the use of gamification elements increases student motivation and engagement. However, they point out that many empirical studies in recent years have focused on descriptive evidence of gamification's effectiveness and that it is difficult to draw valid conclusions from such studies. Therefore, they emphasize the importance of continuing research in this area.

Methodology

This study follows a guide for conducting a systematic literature review (SLR) by Okoli and Schabram (2010) which was developed for information science research and meets the needs of authors who combine social science and technical science research methods, which is very common in the field of e-learning as learning using information and communication technology. SLR is divided into following primary steps (Okoli, 2015; Okoli & Schabram, 2010) namely: (1) identify the purpose and define the research questions, (2) establish the protocol, (3) search databases for literature and apply practical screen, (4) appraise quality, (5) extract data, (6) synthesize studies (analysis), and (7) present and discuss the findings.

Purpose and Research Questions

The purpose of this systematic literature review is to explore the field of gamification in education with a focus on elementary and secondary schools to provide recommendations for future research. This goal will be accomplished by answering the following research questions:

Q1: For which educational levels, instructional models, subjects, teaching methods and activities is gamification used?

Q2: Which digital tools are used for gamification?

Q3: Which elements of game design are used for gamification?

Q4: What kind of research has been done on gamification and what is its goal?

Q5: Does gamification have a positive impact on students and in what ways?

This systematic literature review focuses on the use of gamification at the primary or secondary level, and it is important for future research to know whether gamification occurs in face-to-face (f2f) instruction, online instruction, or in a hybrid instructional model. It is also important to investigate for which subject (e.g., mathematics, history, computer science) or domain (e.g., STEM, foreign language learning) gamification is used, as well as for which teaching methods and activities (e.g., new content learning, homework, problem-based learning, tests, discussions).

Based on Q2, the authors want to investigate which digital tools (including digital games) and learning environments are used in gamification and whether they are all available as free/commercial tools or whether they are proprietary tools developed by the authors themselves. They also need to determine whether one or more elements of game design are used and what those elements are (Q3).

Based on Q4, the authors want to determine what type of research has been conducted on the success of gamification (qualitative, quantitative, or mixed) and which evaluation methods were used in the research (e.g., interview, questionnaire, experiment) and what was the goal of the research. It is particularly important to determine whether and how gamification has positively impacted students (Q5) - whether it has influenced increased motivation, greater satisfaction, greater learning success, improved communication, or some other aspect related to student engagement in the educational process.

All research questions were selected to address the goal of conducting research on gamification in school-based education of students. In this area, it is important to determine the educational level, instructional model, subject, and teaching methods and activities used for gamification (Q1), the digital tools (Q2) and game design elements (Q3) used in gamification, the nature and purpose of the research on the success of gamification (Q4), and whether gamification has a positive impact on students and in what way (Q5). All data collected will be used to determine recommendations for future investigation in the area of gamification in elementary and secondary schools and for future scientific work.

Protocol

As part of the protocol established prior to the implementation of the SLR, it was determined that this research should include work related to gamification in education in elementary and secondary schools, published in English journals and conference proceedings over the past five years. The protocol included the two main bibliographic databases for literature searches in this area, namely Web of Science and Scopus. English search terms (keywords) were also selected. In addition, other inclusion and exclusion criteria were selected for the papers, which are explained in the following subsections. The roles of three authors are agreed upon and tasks assigned during this step.

Searching for Literature and Practical Screen

In order to find the papers related to gamification in primary and secondary education (and not in universities and adult education, such as courses or the like), the restrictions were placed on the abstract where the protocol searched for the keywords „education", „learning", „teaching", „elementary", „primary", „secondary", „K-12" and abstracts with the keyword "*university*" were excluded. A search using the same query in Web of Science and Scopus yielded 291 articles. The search query in the Web of Science database was: *TI=(gamif*) AND (AB=(learning) OR AB=(education) OR AB=(teaching) OR AB=(K-12)) AND (AB=(elementary) OR AB=(primary) OR AB=(secondary)) NOT (AB=(university))*, and the search query in the Web of Science database was: TITLE (*gamif**) AND ABS (*teaching*) OR ABS (*learning*) OR ABS (*education*) OR ABS (*K-12*) AND ABS (*elementary*) OR ABS (*primary*) OR ABS (*secondary*) AND NOT (ABS (*university*)).

Since the query found a large number of papers that met the search criteria, it was necessary to perform a practical screening or reduce the number of papers by applying some basic inclusion and exclusion criteria. In this way, many articles were excluded without in-depth review or reading.

In addition to the abstract restrictions applied previously, basic restrictions were applied regarding the year of publication, and only recent articles published between January 2018 and January 2022 were considered. In addition, only articles from English-language journals and proceedings were considered. After applying the basic exclusion and inclusion criteria listed in Table 1 and deleting duplicate studies, 154 papers remained.

Table 1. Basic Inclusion and Exclusion Criteria

No	Inclusion criteria	Exclusion criteria
1.	Studies from 2018 do 2022	Studies older than 2018
2.	Primary studies published in journals and conference proceedings	Literature reviews and book chapters
3.	Papers that are written in English	Papers that are not written in English

Quality Appraisal

In the next phase, quality assessment continues, i.e., the exclusion of articles that are of insufficient quality based on the reading of summaries or a cursory review of the texts without in-depth reading. The quality criteria are listed in Table 2.

The exclusion criterion was again applied to papers related to higher education that could remain among the selected studies because the abstract of the paper did not highlight the educational level to which the research referred and had not been excluded in the previous step. The exclusion criterion was also applied to papers that contained only an abstract in English but whose content was written in another language. A cursory reading excluded papers that did not conduct research or describe the results, papers that did not refer to the teaching process, papers that did not list elements of gamification and/or digital tools, and papers that did not describe true gamification but used a game in education or Game Based Learning (GBL).

Table 1. Additional Inclusion and Exclusion Criteria

No	Inclusion criteria	Exclusion criteria
1.	Papers describing research results	Papers in which the results of the research are not described, or the research has not yet been conducted
2.	Papers written entirely in English and available as full text	Papers in which the abstract is available only in English or are not available as a full text
3.	Papers that relate to the teaching process	Papers that do not relate to the teaching process
4.	Papers that relate to elementary and secondary students	Papers that relate to university students or adult learners
5.	Papers that list the elements of gamification and/or digital tools	Papers that do not list the elements of gamification and/or digital tools presented
6.	Papers that describe the use of gamification	Papers that describe the use of games or GBL

The two authors manually critically screened the abstracts of the extracted 154 papers to check whether they should be included in further analysis. The authors used a quality appraisal checklist relied on a 4-point scale. For each of the 6 inclusion/exclusion criteria, the authors (coders) had to decide whether they met one of the options: 'yes', 'no', 'unclear', and 'n/a'.

Reliability was assessed through an intercoder agreement (O'Connor & Joffe, 2020). Percentage agreement was used to measure intercoder agreement since the only challenge was to identify papers describing research with primary and secondary school students that present research findings. Percentage of decisions that are agreements (both coders agree on how to code a paper) was calculated. Agreement between coders was .88. For most of the papers, both

reviewers marked the list element "Research results are described" with the N/A option and these papers were excluded from further analysis. After all criteria were met, 20 articles remained for detailed analysis.

Data Extraction

After identifying all articles that should be included in the review, it is necessary to systematically extract the corresponding data from each of the described studies. All citations were exported from the Scopus and Web of Science databases. The concepts were separated from the research questions, and the text was coded exactly as it appeared in the English-language articles. The text was coded by the researchers, i.e., no special software tool was used because only a small number of studies need to be analysed and errors (e.g., misspellings) are easier to detect. The collected data on the articles were inserted into Microsoft Office Excel and analysed in the following step.

Considering that there were only 20 papers left, both authors independently prepared the spreadsheets with extracted data, and the final control was performed by the third author. As a result of this phase, a detailed final table with data was prepared for 20 works that were analysed in the next step.

Analysis

To sum up, the database yielded a total of 291 papers. After applying the criteria, 20 papers remained for analysis in this study (Figure 1).
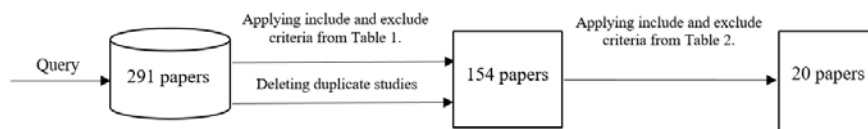

Figure 1. Flow of the SLR Process

The analysis step, also known as synthesize studies (Okoli, 2015) involves combining the facts extracted from the studies by using quantitative approach. As described earlier, using basic and additional inclusion and exclusion criteria, this study only considers papers that relate to primary and secondary school students and in which the described research findings are available. Of these 20 papers, 19 are from scholarly journals and only one is from a conference proceeding.

Figure 2 shows the number of articles to be analysed by year of publication. Most of the studies were conducted in 2021 (7 studies). Considering the countries where the studies were conducted, most of them are from Spain (7 studies), while other countries are represented with one or two works each. Territorially, 11 papers were published in European Union countries, while other papers (9) were published in different Asian countries. The synthesis of other results is presented in Table 3 which shows the list of papers with codes ID1, ID2, to ID20 used in the rest of the paper. In the next chapter, the findings of the SLR are discussed in terms of the defined research questions.
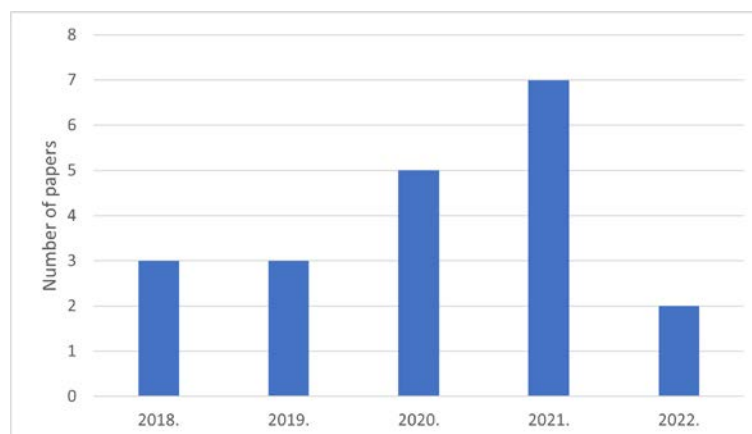

Figure 2. Number of Papers by Year

Table 3. Description of Studies Based on Analyzed Characteristics

Paper	Context	Digital tools	Elements of game design	N	Type of the research	Results
ID1 (Martínez-Hita et al., 2021)	Spain 4th grade of primary school History F2f model	Comb. of various tools	Stories, avatars, challenges, points, leaderboards, badges, awards, progress bars	44	Quantitat. Quasi-experiment with pre-post test	Positive: more successful achievement of learning outcomes
ID2 (Barahona Mora, 2020)	Spain 1st grade of secondary school Spain, English, History Hybrid model	ClassDojo system	Points, avatars, awards, stories, feedbacks/ progress bars	21	Quantitat. Empirical research (points from the system), observing students	Positive: promoting positive student behaviour in the instructional process
ID3 (Pozo Sánchez et al., 2020)	Spain 4th grade of primary school Native language (Spanish) Hybrid model	PeerWise	Levels, points, badges, leaderboards	60	Quantitat. Quasi-experiment with a questionnaire	Positive: more intense communication and interaction between students
ID4 (Park & Kim, 2021)	South Korea Final grades of primary school Physics, chemistry, biology Online (COVID-19)	Science level up	Points, leaderboards	140	Quantitat. Pre-post surveys	Positive: increased student motivation
ID5 (Hursen & Bas, 2019)	Cyprus 4th grade of primary school Science F2f model	ClassDojo	Badges, avatars, leaderboards	16	Mixed methods Quantitat. (pre-post test) Qualitat. (interview with students and parents)	Positive: increased student motivation
ID6 (Alshammari, 2020)	Saudi Arabia 6th grade of primary school Native language (Arabic) Hybrid model	Proprietary system	Points, levels, badges, rewords, feedbacks, leaderboards	58	Quantitat. Experiment (pre-post test, attitude survey)	Partly positive: more successful learning and increased students' motivation and satisfaction but without impact on students' confidence and attention
ID7 (Otero-Agra et al., 2019)	Spain All grades of secondary school F2f model	Proprietary application	Points, feedbacks	489	Quantitat. Quasi-experiment with testing of skills	Positive: more successful achievement of practical skills
ID8 (Lam et al., 2017)	Hong Kong 4th grade of secondary school Foreign language (English) Hybrid model	Edmodo	Points, leaderboards	72	Mixed methods Quantitat. (quasi-experiment with pre-post test, Edmodo messages) Qualitat. (interview with students and teachers)	Partly positive: increased students' motivation but without impact on more successful achievement of learning outcomes
ID9 (Anunpattana et al., 2021)	Japan Primary school All subjects F2f model	Kahoot!	Points, leaderboards	120	Mixed methods Quantitat. (Kahoot! quizzes results) Qualitat. (interview with students)	Positive: challenges have positive impact on students' motivation and more successful learning

Table 3. Continued

Paper	Context	Digital tools	Elements of game design	N	Type of the research	Results
ID10 (Jagušt et al., 2018)	Croatia 2nd and 3rd grade of primary school Mathematics F2f model	Proprietary application Math Widget	Points, leaderboards, stories, challenges	54	Mixed methods Quantitat. (quasi-experiment: log analysis) Qualitat. (interview with group of students)	Partly positive: increased students' achievement level in learning mathematics, but demotivating effect of competition on some students
ID11 (Dimitriadou, 2018)	Greece 5th grade of primary school Foreign language (English) Hybrid model	Moodle	Badges, progress bars, avatars, levels, stories	22	Quantitat. Survey	Positive: increased student interest and motivation for learning
ID12 (Leitão et al., 2022)	Portugal, UK Final grades of primary school Biology Hybrid model	Mobile application Ocean Literacy	Points, badges, leaderboards (PBL)	98	Quantitat. Pre-post survey	Positive: increased student motivation
ID13 (Idris et al., 2020)	Malesia 3rd grade of primary school Foreign language (English) F2f model	Kahoot!	Points, leaderboards	31	Quantitat. Quasi-experiment with a pre-post test	Positive: more successful achievement of learning outcomes
ID14 (Sánchez-Rivas et al., 2019)	Spain Primary school Natural Sciences F2f model	Proprietary mobile application	Points, leaderboards	217	Quantitat. Test, survey	Positive: increased student motivation
ID15 (Li & Wah Chu, 2020)	China 4th grade of primary school Native language (Chinese) F2f model	Proprietary application Reading Battle	Points, leaderboards	57	Mixed methods Quantitat. (tests) Qualitat. (interview with students, parents, teachers)	Positive: improved reading skills, such as speed, vocabulary, and comprehension
ID16 (Lam & Tse, 2022)	Hong Kong Primary and secondary school English, Chinese, mathematics F2f model	Kahoot! Quizlet, web apps for drawing	Stories, leaderboards	>600	Mixed methods Quantitat. (tests, surveys for students and teachers) Qualitat. (observations in classroom, interview with teachers)	Partly positive: gamification has a positive effect on students, but it has not been concluded whether some gamification strategies are better than others
ID17 (Ghaban, 2021)	Saudi Arabia Primary and secondary school All subjects Online (COVID-19)	Proprietary platform Madrasati, applications Wordwall, Quizizz, Liveworksheets	Points, leaderboards, progress bars	123	Quantitat. Surveys, pre-post tests	Partly positive: improvement in digital skills and abilities, but the lack of physical/verbal interaction with other students

Table 3. Continued

Paper	Context	Digital tools	Elements of game design	N	Type of the research	Results
ID18 (Lopez et al., 2021)	Brazil, Spain Primary and secondary school STEAM subjects (mostly Mathematics) F2f model	Escape room, other online games and tools	Points, leaderboards, progress bars, rewards	56	Quantitat. Surveys for teachers	Partly positive: students' progress in acquiring mathematical skills, but some teachers without the knowledge about using gamification
ID19 (Meng et al., 2021)	China 4th and 5th grade of primary school Foreign language (English) F2f model	Proprietary application Reading Battle	Points, badges, leaderboards, levels	41	Mixed methods Quantitat. (pre-post surveys) Qualitat. (interview with students and teachers, observations)	Positive: improved reading skills, such as speed, vocabulary, and comprehension
ID20 (Ricoy & Sánchez-Martínez, 2022)	Spain 3rd grade of primary school Ecology Hybrid model	DeviantArt, Los Cokitos, tools for drawing	Points, leaderboards, rewards	156	Qualitat. Students' and teachers' e-diaries	Positive: improved awareness about environmental protection, improved digital skills

Findings

Q1: For Which Educational Levels, Instructional Models, Subjects, Teaching Methods and Activities is Gamification Used?

Educational level was considered as part of the analysis. Twelve papers (ID1, ID4, ID5, ID6, ID10, ID11, ID12, ID13, ID14, ID15, ID19, ID20) described research at the primary educational level, 4 papers described research at the secondary level (ID2, ID3, ID7, ID8), and 3 papers described both primary and secondary educational levels (ID16, ID17, ID18).

In addition to the educational level covered by the papers, the instructional model was also examined, resulting in the following data: 11 papers (ID1, ID5, ID7, ID9, ID10, ID13, ID14, ID15, ID16, ID18, ID19) included a face-to-face model, 7 papers included a hybrid model (ID2, ID3, ID6, ID8, ID11, ID12, ID20), and only 2 papers described the implementation of gamification exclusively online (ID4, ID17). It should be noted that both papers that included an online teaching model were conducted during the COVID-19 pandemic. In the hybrid teaching model, gamification is used during the f2f phase (ID3) or both phases. ID8 is used to promote motivation during the online teaching phase.

After dividing the studies into categories according to the teaching model, the papers are categorized according to the subjects or areas in which gamification has been applied. Although most papers describe the application of gamification in one subject, it should be noted that some papers describe its application in multiple subjects or areas. The most common areas incorporating elements of game design are science and foreign language learning, with 6 papers in each.

Natural sciences refer to: Physics (ID4, ID14), Mathematics (ID10, ID16, ID18), Biology/Nature (ID4, ID5, ID12, ID14, ID20), Chemistry (ID14, ID18). The most frequent foreign language (6 papers) is English (ID2, ID8, ID11, ID13, ID16, ID19). It is followed by learning the native language and literature (5 papers: ID2, ID3, ID6, ID15, ID16) and history (2 papers: ID1, ID2).

In 2 contributions (ID9, ID17), the authors state that all subject areas are covered (without explicitly mentioning the respective subject). One contribution (ID7) refers to the contents of first aid.

Gamification and game design elements were mainly used in learning new content (ID1, ID4, ID5, ID6, ID8, ID12, ID16, ID17, ID18, ID20). Contributor ID7 used gamification to acquire new practical skills as one of four learning and teaching methods for mastering first aid techniques. In ID19 students are mastering reading in English as a foreign language. In learning new content, some contributions took a special approach, such as ID1, where historical content is taught using the method called "historical thinking". ID12 and ID20 also stand out for their tailored approach to learning biology/ecology, where students master a special concept called "Ocean Literacy" in ID12 and acquire new habits and knowledge about paper/plastic recycling, electricity, and water consumption in ID20.

Some papers (ID9, ID11, ID13, ID14, ID15, ID17) use gamification and game design elements to test students through online quizzes for the purpose of formative assessment. Some other papers (ID6, ID10) use gamification and game

design elements to practice tasks, but also for formative purposes. Of all the papers organized by type of assessment, paper ID6 stands out because in addition to formative assessment, gamification and game design elements are used for summative purposes, i.e., to assess what has been learned. Moreover, ID2 and ID5 use game design elements to practice tasks in the form of homework, while ID2 and ID3 promote collaboration and interaction among students. Of all the works, ID5 and ID20 stand out because they involve parents in the whole process.

In conclusion, gamification and game design elements are mainly used for elementary students in a variety of subjects from the natural and social domains. They are used in face-to-face classes or in a hybrid instructional model and, to a lesser extent, exclusively online. Gamification is used in learning new content, but even more commonly for the purpose of formative assessment of various subjects, especially in elementary education for activities such as homework, knowledge tests, and practice assignments.

Q2: What Digital Tools are Used for Gamification?

The analysis of the papers showed that some contributions (ID6, ID7, ID10, ID12, ID14, ID15, ID17, ID19) implemented their own applications, while others used publicly available digital tools and platforms. The ID10 uses Math Widget proprietary application, developed as part of the SCOLLAm project. Math Widget is a custom mobile learning platform used in lower elementary classrooms to create interactive scenes in the teaching process and practice math material. ID7 authors use their own application to master first aid techniques, while ID12 authors use their own mobile application Ocean Literacy to master the content of biology subject. ID15 and ID19 use proprietary tool Reading Battle to practice reading and vocabulary learning for Chinese as a native language (ID15) and English as a foreign language (ID19). Also, worth mentioning is the work of ID17, which created an entire platform for online instruction in all subjects during the COVID-19 pandemic at the state level.

Authors ID2 and ID5 use the free application ClassDojo, which is primarily intended for awarding points based on student behaviour in the teaching process. Some authors use digital tools, applications, and platforms commonly known in schools, e.g. Moodle (ID11), Kahoot! (ID13, ID16), Edmodo (ID8), while the other part of authors use very specific applications such as Level Up! (ID3), Peer Wise (ID4), and Los Cokitos (ID20). Unlike Level Up! which is an app designed as an adventurous role-playing game, Peer Wise is a more serious platform that allows students to answer questions and have a discussion among students on the platform. The Los Cokitos application contains a combination, i.e., several types of games such as memory games, puzzles, jigsaw puzzles, etc.

Q3: What Elements of Game Design are Used for Gamification?

As part of the analysis, elements of game design used for the purpose of gamification in teaching processes were observed. According to the collected data, most of the works (8) use a combination of two game design elements (ID4, ID7, ID8, ID9, ID13, ID14, ID15, ID16), 4 works (ID5, ID12, ID17, ID20) use three elements, while others use more than three game design elements.

The work with the most game design elements is ID1, and the game design elements included in it are stories, avatars, challenges, points, leaderboards, badges, awards, progress bars. Most often two game design elements are used in combination, namely points and leaderboards (ID4, ID8, ID9, ID13, ID14, ID15). This design is generally used very frequently because it is easy to implement. Figure 3 shows the representation of the game design elements.
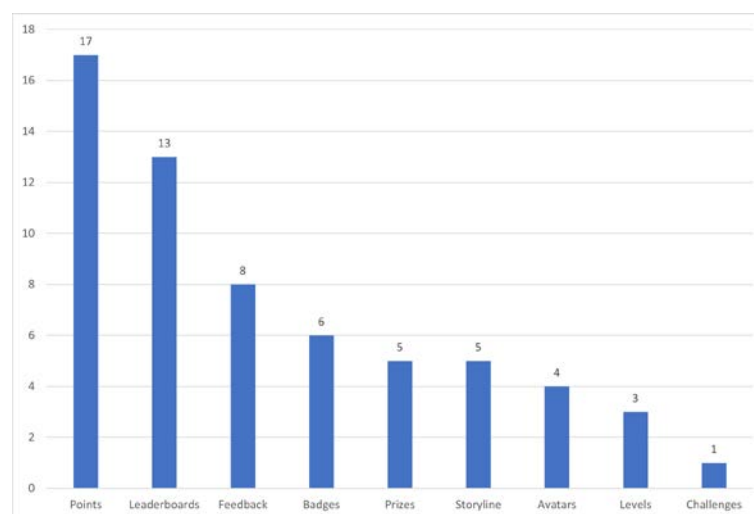

Figure 3. Game Design Elements

Q4: What Kind of Research has Been Done on Gamification and What is its Goal?

Of the 20 observed works, with the exception of work ID20 with qualitative research (analysing students' and teachers' e-diaries), all the others use a quantitative type of research. In addition, papers ID5, ID8, ID9, ID10, ID15, ID16, and ID19 use additional qualitative research through interviews, reading electronic diaries of students and teachers, or through observations. This is also the case for ID5, which aims to investigate the impact of gamification on students' motivation to learn science subjects and students' and parents' attitudes toward gamification. ID8 surveyed students and teachers with the goal of finding out whether students are more successful in learning and more active in online learning as a result of the blended learning model with and without gamification. In ID10, the authors compared the success of four types of learning activities: without gamification and with competitive/collaborative/adaptive gamification, on student learning and achievement, while ID15 and ID19 investigated whether gamification has an impact on children's reading and whether gamification affects motivation. In addition to motivation, these papers also examined the effects of gamification on improving reading interest and vocabulary.

In analysing the papers, 10 papers conducted a quantitative study using a quasi-experimental method with a questionnaire (ID3, ID6, ID9, ID10, ID11, ID12, ID14, ID16, ID18, ID19), while 8 papers used pre- and post-tests (ID1, ID5, ID6, ID7, ID8, ID13, ID16, ID17). It should be noted that one paper (ID2) used empirical research (results from the game system), while another (ID8) used data from the digital tool used (messages in Edmodo). In paper ID10, the authors used a log analysis of their own Math Widget application.

Most papers (9) examined the effects of motivation and satisfaction on learning success (ID4, ID5, ID6, ID8, ID11, ID12, ID15, ID16, ID19). 3 papers (ID1, ID7, ID13) analyzed the impact of gamification on the realization of learning outcomes, i.e., whether students learned more successfully, while ID6 examined the effects of gamification on increasing students' confidence. Specific studies such as ID2, which examined the effects of gamification on improving student behaviour, should be highlighted, as should the ID4 study, which promoted motivation through the use of online gamification, and the ID14 study, which conducted performance comparisons between gamified tests and the traditional method based on teacher observations. In addition, the ID7 study should be highlighted due to the specifics of the field (the effectiveness of four methods for mastering first aid techniques, one of which is gamified), and the ID10 study due to the complexity of the research conducted through four different activities (without gamification and with competitive, collaborative, and adaptive gamification). Also highlighted was the work of ID16, which examined three gamification strategies (gamified digital lessons, mini-games, contests) and their impact on student engagement and motivation.

Most studies were conducted in schools with students, varying in number from 16 (ID5) to 489 (ID7), and in some studies divided into experimental and control groups. Some studies also included parents (ID5, ID20) and 4 studies also included teachers (ID14, ID17, ID18, ID20).

Q5: Does Gamification Have a Positive Impact on Students and in What Ways?

Most of the papers concluded that gamification has a positive impact on students when it comes to learning content or motivation to learn, but there are also papers that report only a partial positive result (ID6, ID8, ID10, ID16, ID17, ID18). One of the works with a partial positive result is ID10, in which the results showed that gamification helped to increase students' achievement level in learning mathematics, but on the other hand, due to the competition, it had a demotivating effect on some students who performed worse. A partial positive result was obtained in the work of ID6, in which gamification had a positive impact on more successful learning and increased students' motivation and satisfaction but did not leave a positive impact on students' confidence and attention. In addition, ID8's work, which also found increased motivation, had a partial positive result due to the lack of focus and difference in learning performance compared to hybrid instruction without gamification. In addition to the improvement in digital skills and abilities, ID17 cites the lack of physical/verbal interaction with other students. In ID18, mathematics teachers state that they perceive students' progress in acquiring mathematical skills as a benefit of gamification, but that they lack knowledge about the use of gamification as well as several examples of gamified content that they could use in their teaching.

Below, the most interesting papers that show the positive results of gamification are highlighted. For example, four papers (ID1, ID7, ID9, ID13) showed a positive and more successful achievement of learning outcomes, while six papers (ID4, ID5, ID11, ID12, ID14, ID15) showed a positive impact on motivation.

In addition, ID2 investigated the effects of gamification on promoting positive student behavior in the instructional process. The research results showed that the use of gamification had a positive impact on student behaviour through the application Class Dojo. Similarly, ID3 investigated the impact of gamification on modern methods (flipped classroom, collaborative learning), as well as on student interaction and collaboration. The research results showed that communication between students improved and became more intense.

ID4 investigated the impact of gamification on motivation to learn new content in the online environment using self-assessment of students from subjects such as physics, chemistry, and biology during the pandemic COVID-19. The

analysis showed that the Science Level Up application had a positive impact on motivation, self-efficacy, intrinsic motivation, better grades, and comprehension.

Another contribution worth highlighting is the work of ID11, which conducted a study on gamification in relation to student motivation in learning a foreign language (English). Students were surveyed several times, and the study found that students' interest and motivation to learn increased significantly.

Discussion

The results of this study support previous studies that found that there are still few papers presenting the results of gamification in elementary and secondary schools (Dichev and Dicheva, 2017; Mora et al., 2017). If we analyse the articles by year of publication, we can see that the number of research papers has been increasing since 2018, which is certainly positive. We can notice a lack of systematic research on the implementation of gamification in schools during the pandemic COVID-19, which can be justified by the short time available to publish results related to current activities (Nieto-Escamez & Roldán-Tapia, 2021).

The review found that even among the papers related to the school context, only 20 papers actually described the research conducted. The main challenge was finding papers that included described research with primary and secondary students, as many papers only narratively describe the use of gamification (Nieto-Escamez & Roldán-Tapia, 2021). This is consistent with previous findings - that the number of studies on the effectiveness of gamification in educational contexts is unconvincing and insufficiently supported by evidence (Dichev & Dicheva, 2017) and that most publications focus on describing experiences with the so-called "ad hoc method" (Mora et al., 2017). However, it should be emphasised that the research presented in this paper shows some progress in the number of articles, if we compare the analysed number of articles with the articles from the analysis conducted in 2017 (Dichev and Dicheva, 2017), in which only 7 out of 51 articles were related to education in schools.

In relation to the first research question, the results show that gamification and game design elements are used for students in a variety of subjects from natural and social fields. They are used in face-to-face classes or in a hybrid instructional model and, to a lesser extent, exclusively online. Gamification is used in learning new content, but more often for the purpose of formative assessment of various subjects, for activities such as homework, knowledge tests, and practice assignments. These findings support one of the recent reviews (Nieto-Escamez & Roldán-Tapia, 2021) describing different studies of gamification in schools during the pandemic COVID -19. It is interesting to note that although the elements of game design are implemented using information and communication technology, there are no studies that have been conducted exclusively in the subject of computer science (informatics) in primary or secondary education. Authors Dichev and Dicheva (2017) describe a different result, most gamification studies in their review deal with computer science (CS) and information technology (IT).

Regarding the digital tools used for gamification (Q2), the research did not find that one of the digital tools is used more often for gamification than the others. It was confirmed that popular, publicly available, free, and commercial digital tools or e-learning platforms, which are not exclusively intended for gamification, can implement game design elements if used effectively (Pal'ová & Vejačka, 2020; Vrcelj et al., 2021). Some researchers have developed and implemented their own tools, but it is important to emphasize that these are simpler tools for gamification of the teaching process and not complex educational (serious) games as described by Rugelj (2015).

For the third research question, the results of this study support previous research that found that the purpose of gamification is to gamify activities by combining at least two game design elements (Gibson et al., 2013; Toda et al., 2020). Studies describe different combinations of all elements according to the taxonomy proposed by Toda et al. (2020), namely points, leaderboards, feedback, badges, awards, stories, avatars, levels, and challenges. Most commonly, points and leaderboards are used in combination, which is partially consistent with the finding that a combination of points, badges, and leaderboards (acronym PBL) is most common in gamification implementations (Dichev & Dicheva, 2017).

The results of this study show that most of the papers use a quantitative research type, very often with additional qualitative research (Q4). The reviewed collection of studies on gamification is very diverse in terms of the instruments used: pre-post surveys, questionnaires, interviews, quasi-experiments with tests of skills, quiz results, classroom observations, gamification system scores, etc. On the other hand, in an older review paper (Hamari et al., 2014), the authors conclude that almost all the studies reviewed have used mainly qualitative methods, which are less reliable to confirm the results.

It is important to emphasize that the common feature of all the studies is that the research was conducted, and the results were described, which was not the case in some previous reviews (Hamari et al., 2014; Mora et al., 2017; Nieto-Escamez & Roldán-Tapia, 2021; Toda et al., 2020). Regarding the stated aims of the studies, most of the studies reviewed examined the effects of motivation and satisfaction on learning success. Few analysed the effects of gamification on the realization of learning outcomes, i.e., whether students learned more successfully. This finding is in

line with other studies that emphasized the motivational possibilities of gamification and examined its impact on the psychological aspects of motivation (Dichev & Dicheva, 2017; Hamari et al., 2014).

Finally, regarding the impact of gamification on students (Q5), most studies concluded that gamification has a positive impact on students, especially when it comes to learning motivation, but there are also works that report only a partial positive result. These findings support previous studies Dichev & Dicheva, 2017; Hamari et al., 2014; Nieto-Escamez & Roldán-Tapia, 2021), but it is important to emphasize that the difference is that no study notes a negative impact of gamification on students.

Conclusion

This paper describes a systematic literature review of gamification in education with a focus on elementary and secondary schools. In selecting the papers for analysis, the main criterion was to find papers that describe the methodology and results of research on the success of gamification. In addition, the level of education, the instructional model, the methods and activities of learning and teaching for which gamification is used, the digital tools and game design elements used in gamification, and whether gamification has a positive impact on students were examined.

Twenty papers were included in the detailed analysis. The results showed that gamification was mainly used in science subjects in elementary school, but very often also in learning a foreign or native language. It was used during f2f teaching or in a hybrid model and most often for the purpose of learning new content and formative assessment. Teachers used available digital tools as well as their own tools, i.e., gamified e-learning systems. Although different design elements of the game were used, a combination of points with leaderboards was common.

All but one of the studies conducted were quantitative studies (sometimes supplemented by qualitative studies), and the respondents were mostly students. Almost all studies concluded that gamification has a positive impact, especially on students' motivation, but also on more successful realization of learning outcomes, and it should be noted that no study showed negative effects of gamification on students.

As mentioned in the paper, due to the increasing presence of digital technology in the daily environment, it is necessary to use it in education, and one of the ways to do this is to introduce gamification. A number of studies report that the main benefits of gamification are to increase students' motivation, awareness, and engagement.

Because of its ease of use and greater availability compared to more expensive digital learning games, gamification and its elements have the potential for widespread application in education. For this reason, gamification and the use of game design elements have a promising future, especially post-pandemic, when students and teachers are better trained in the use of various digital educational tools and are more computer literate.

Recommendations

The first recommendation is for future researchers-reviewers who want to conduct contemporary research on gamification in schools. The results of this study show that there are not yet enough studies showing the results of gamification in primary and secondary schools. The field of gamification in primary and secondary schools has not been sufficiently researched. In particular, there was a lack of systematic research on the implementation of gamification in schools during the pandemic COVID-19. It is hoped that after 2021, there will be more studies on the implementation of gamification in primary and secondary schools, especially in relation to COVID-19. Therefore, the recommendation is to continue research related to the implementation of gamification to provide a broader pedagogical-technological framework for the implementation of gamification in primary and secondary schools.

Other recommendations are directed to researchers who want to implement gamification in schools and conduct research to confirm its effectiveness. It should be emphasized that there are no general rules or procedures for implementing gamification in education. It is recommended that the gamification method depends primarily on the age of the students, the topic, the objective, and the learning outcomes to be achieved. It is suggested to use a combination of game design elements and existing digital tools. It is also possible to create your own gamified tools or learning systems to incorporate methodological empirical research with data from systems such as game scores, logs, etc.

In research, the objectives of the study should be clearly defined. It is recommended not only to study students' motivation and satisfaction in learning, but also to analyse the impact of gamification on the achievement of learning outcomes.

The results of studies on the implementation of gamification in education show that a mixed methods approach using qualitative and quantitative methods is needed. One possible recommendation for research approach in this area is the Design Based Research (DBR) methodology (Wang & Hannafin, 2005), which emphasises collaboration between researchers and teachers during iterative analysis, design, development, and implementation. A gamification-based learning model is designed to be tested in the natural environment of schools in multiple phases and corrected as often as necessary after testing. The main advantage over experiments is that DBR is conducted in a real environment and not in conditions isolated from everyday life, which is especially important when the respondents are younger people or students in primary and secondary schools. In DBR, teachers in schools play an important role. The research should

be conducted as a combination of qualitative interviews with teachers and students, observation of classroom interactions, analysis of student work, etc., and quantitative data collection, not only surveys and knowledge tests, but also analysis of records from the event log of digital tools.

Limitations

The first limitation of this review is related to the fact that only certain bibliographic databases were searched. Although the recognized databases Web of Science and Scopus were selected to find the highest quality articles, it can be assumed that accessing a larger number of digital databases would yield different results.

The second limitation is related to the query that was used to find works in digital databases. Using more or different keywords in a query could result in more articles because different authors name the same terms differently. It can be assumed that there are studies that fit the purpose of this work but were not included in the query results due to differently defined terms.

The final limitation of this study is the inclusion and exclusion criteria. With the exception of papers that only narratively describe the research but do not mention methodology and specific results, the number of papers to be analysed has significantly decreased. In addition, some of the selected papers had an unrepresentative sample or a small number of respondents.

Funding

Authorship Contribution Statement

Vrcelj: Conceptualization, design, data acquisition, data and statistical analysis, writing. Hoić-Božić: Conceptualization, drafting manuscript, supervision, securing funding, final approval. Holenko Dlab: Conceptualization, critical revision of manuscript, supervision.

References

Alshammari, M. T. (2020). Evaluation of gamification in e-learning systems for elementary school students. *TEM Journal, 9*(2), 806-813. https://doi.org/10.18421/TEM92-51

Anunpattana, P., Nor Akmal Khalid, M., Iida, H., & Inchamnan, W. (2021). Capturing potential impact of challenge-based gamification on gamified quizzing in the classroom. *Heliyon, 7*(12), Article e08637. https://doi.org/10.1016/j.heliyon.2021.e08637

Barahona Mora, A. (2020). Gamification for classroom management: An implementation using ClassDojo. *Sustainability, 12*(22), Article 9371. https://doi.org/10.3390/su12229371

Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education, 14,* Article 9. https://doi.org/10.1186/s41239-017-0042-5

Dimitriadou, S. (2018). Designing and implementing a gamified system based on self determination theory in the Moodle learning platform. In L. Gómez Chova, A. López Martínez & I. Candel Torres (Eds.), *Proceedings of the 11th International Technology, Education and Development Conference* (pp. 3707-3714). IATED. https://doi.org/10.21125/inted.2017.0904

Dreimane, S. (2021). Gamification before its definition – An overview of its historical development. In L. Gómez Chova, A. López Martínez & I. Candel Torres (Eds.), *Proceedings of the 15th International Technology, Education and Development Conference* (pp. 7187-7193). INTED. https://doi.org/10.21125/inted.2021.1434

Ghaban, W. (2021). Can games and gamification improve online learners' outcomes and satisfaction on the Madrasati platform in Saudi Arabia? In X. Fang (Ed.), *HCI in games: Serious and immersive games. Third International Conference, HCI-Games 2021, Part II* (Vol. 12790, pp. 189-200). Springer. https://doi.org/10.1007/978-3-030-77414-1_14

Gibson, D., Ostashewski, N., Flintoff, K., Grant, S., & Knight, E. (2013). Digital badges in education. *Education and Information Technologies, 20*(2), 403-410. https://doi.org/10.1007/s10639-013-9291-7

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? - A literature review of empirical studies on gamification. In R. H. Sprague (Ed.), *47th Hawaii International Conference on System Sciences* (pp. 3025-3034). IEEE. https://doi.org/10.1109/HICSS.2014.377

Hursen, C., & Bas, C. (2019). Use of gamification applications in science education. *International Journal Emerging Technologies in Learning, 14*(1), 4-23. https://doi.org/10.3991/ijet.v14i01.8894

Idris, M. I., Mohd Said, N. E., & Hua Tan, K. (2020). Game-based learning platform and its effects on present tense mastery: Evidence from an ESL classroom. *International Journal of Learning, Teaching and Educational Research, 19*(5), 13-16. https://doi.org/10.26803/ijlter.19.5.2

Jagušt, T., Botički, I., & So, H.-J. (2018). Examining competitive, collaborative and adaptive gamification in young learners' math learning. *Computers & Education, 125*, 444-457. https://doi.org/10.1016/j.compedu.2018.06.022

Lam, P., & Tse, A. (2022). Gamification in everyday classrooms: Observations from schools in Hong Kong. *Frontiers in Education, 6*, Article 630666. https://doi.org/10.3389/feduc.2021.630666

Lam, Y. W., Hew, K. F., & Chiu, K. F. (2017). Improving argumentative writing: Effects of a blended learning approach and gamification. *Language Learning & Technology, 22*(1), 97-118. https://doi.org/10125/44583

Leitão, R., Maguire, M., Turner, S., & Guimaraes, L. (2022). A systematic evaluation of game elements effects on students' motivation. *Education and Information Technologies, 27*, 1081–1103. https://doi.org/10.1007/s10639-021-10651-8

Li, X., & Chu, S. (2020). Exploring the effects of gamification pedagogy on children's reading: A mixed-method study on academic performance, reading-related mentality and behaviors, and sustainability. *British Journal of Educational Technology, 52*, 160-178. https://doi.org/10.1111/bjet.13057

Lopez, P., Rodrigues-Silva, J., & Alsina, A. (2021). Brazilian and Spanish mathematics teachers' predispositions towards gamification in STEAM education. *Education Sciences, 11*(10), Article 618. https://doi.org/10.3390/educsci11100618

Martínez-Hita, M., Gómez-Carrasco, C. J., & Miralles-Martínez, P. (2021). The effects of a gamified project based on historical thinking on the academic performance of primary school children. *Humanities and Social Sciences Communications, 8*, Article 122. https://doi.org/10.1057/s41599-021-00796-9

Meng, N., Cameron Lee, S. Y., & Wah Chu, S. K. (2021). A pilot ethnographic study of gamified English learning among primary four and five students in a rural Chinese primary school. In K. Toeppe, H. Yan, S. K. W. Chu (Eds.), *Diversity, divergence, dialogue: 16th International Conference, Iconference 2021* (Vol. 12645, pp. 575–586). Springer. https://doi.org/10.1007/978-3-030-71292-1_45

Mora, A., Riera, D., González, C., & Arnedo-Moreno, J. (2017). Gamification: A systematic review of design frameworks. *Journal of Computing in Higher Education, 29*(3), 516-548. https://doi.org/10.1007/s12528-017-9150-4

Nieto-Escamez, F. A., & Roldán-Tapia, M. D. (2021). Gamification as online teaching strategy during COVID-19: A mini-review. *Frontiers in Psychology, 12*, Article 648552. https://doi.org/10.3389/fpsyg.2021.648552

O'Connor, C., & Joffe, H. (2020). Intercoder reliability in qualitative research: Debates and practical guidelines. *International Journal of Qualitative Methods, 19*. https://doi.org/10.1177/1609406919899220

Okoli, C. (2015). A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems, 37,* 879–910. https://doi.org/10.17705/1CAIS.03743

Okoli, C., & Schabram, K. (2010). *A guide to conducting a systematic literature review of information systems research* (Working Paper). SSRN. https://doi.org/10.2139/ssrn.1954824

Osatuyi, B., Osatuyi, T., & De La Rosa, R. (2018). Systematic review of gamification research in IS education: A multi-method approach. *Communications of the Association for Information Systems, 42*, 95-124. https://doi.org/10.17705/1CAIS.04205

Otero-Agra, M., Barcala-Furelos, R., Besada-Saavedra, I., Peixoto-Pino, L., Martinez-Isasi, S., & Rodriguez-Nunez, A. (2019). Let the kids play: Gamification as a CPR training methodology in secondary school students. A quasi-experimental manikin simulation study. *Emergency Medicine Journal, 36*(11), 653-659. https://doi.org/10.1136/emermed-2018-208108

Pal'ová, D., & Vejačka, M. (2020). Gamification tools improving university students' involvement in the education process. In M. Koricic, K. Skala, Z. Car, M. Cicin-Sain, V. Sruk, D. Skvorc, S. Ribaric, B. Jerbic, S. Gros, B. Vrdoljak, M. Mauher, E. Tijan, T. Katulic, P. Pale, T. Galinac Grbac, N. F. Fijan, A. Boukalov, D. Cisic & V. Gradisnik (Eds.), *Proceedings of the 43rd International Convention on Information, Communication and Electronic Technology (MIPRO)* (pp. 581-586). IEEE. https://doi.org/10.23919/MIPRO48935.2020.9245113

Park, S., & Kim, S. (2021). Is sustainable online learning possible with gamification?—The effect of gamified online learning on student learning. *Sustainability, 13*(8), Article 4267. https://doi.org/10.3390/su13084267

Plantak Vukovac, D., Škara, M., & Hajdin, G. (2018). Korištenje i stavovi nastavnika o igrifikaciji u osnovnim i srednjim školama [Teachers' usage and attitudes toward gamification in primary and secondary schools]. *Zbornik Veleučilišta u Rijeci, 6*(1), 181-196. https://doi.org/10.31784/zvr.6.1.14

Pozo Sánchez, S., Lopez Belmonte, J., Fuentes Cabrera, A., & López Núñez, J. A. (2020). Gamification as a methodological complement to flipped learning—An incident factor in learning improvement. *Multimodal Technologies and Interaction, 4*(2), Article 12. https://doi.org/10.3390/mti4020012

Ricoy, M.-C., & Sánchez-Martínez, C. (2022). Raising ecological awareness and digital literacy in primary school children through gamification. *International Journal of Environmental Research and Public Health, 19*(3), Article 1149. https://doi.org/10.3390/ijerph19031149

Rugelj, J. (2015). Serious computer games in computer science education. *EAI Endorsed Transactions on Serious Games, 2*(6), 1-7. http://doi.org/10.4108/eai.5-11-2015.150613

Sánchez-Rivas, E., Ruiz-Palmero, J., & Sánchez-Rodríguez, J. (2019). Gamification of assessments in the Natural Sciences subject in primary education. *Educational Sciences: Theory & Practice, 19*(1), 95-111. https://doi.org/10.12738/estp.2019.1.0296

Toda, A. M., Klock, A. C., Oliveira, W., Palomino, P. T., Rodrigues, L., & Shi, L. (2020). Analysing gamification elements in educational environments using an existing gamification taxonomy. *Smart Learning Environments, 6*, Article 16. https://doi.org/10.1186/s40561-019-0106-1

Vrcelj, A., Hoić-Božić, N., & Holenko Dlab, M. (2021). Using digital tools for gamification in schools. In M. Koricic, K. Skala, Z. Car, M. Cicin-Sain, S. Babic, V. Sruk, D. Skvorc, S. Ribaric, B. Jerbic, S. Gros, B. Vrdoljak, M. Mauher, E. Tijan, T. Katulic, J. Petrovic, T. Galinac Grbac, N. F. Fijan & V. Gradisnik (Eds.), *Proceedings of the 44th International Convention on Information, Communication and Electronic Technology (MIPRO)* (pp. 848-852). IEEE. https://doi.org/10.23919/MIPRO52101.2021.9597137

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5-23. https://doi.org/10.1007/BF02504682