Salud, Ciencia y Tecnología - Serie de Conferencias. 2024; 3:659
doi: 10.56294/sctconf2024659

Category: Education, Teaching, Learning and Assessment

REVIEW

Gamification and Computational Thinking in Education: A systematic literature review

Gamificación y pensamiento computacional en la educación: Una revisión sistemática de la literatura

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Cite as: Triantafyllou SA, Sapounidis T, Farhaoui Y. Gamification and Computational Thinking in Education: A systematic literature review. Salud, Ciencia y Tecnología - Serie de Conferencias. 2024;3:659. https://doi.org/10.56294/sctconf2024659

Submitted: 14-11-2023 **Revised:** 08-02-2024 **Accepted:** 12-03-2024 **Published:** 13-03-2024

Editor: Dr. William Castillo-González

ABSTRACT

The rapid development of gamification and computational thinking seems to open up new educational horizons by providing new opportunities for students to acquire the basic digital skills needed for their cognitive development. Gamification, on the side, flourishes because it brings about high degree of participants' engagement in an activity. Accordingly, on the other side, the growing scientific interest in computational thinking centers on the fact that it provides a fruitful field of dialogue in the research community for the development of critical and analytical thinking of students. Hence, this paper aims to synthesize knowledge about gamification and computational thinking for improving education for the benefit of students. Specifically, this paper describes: (a) the theoretical background of gamification in learning and education, (b) relevant studies in literature and their findings, and (c) specific gamified applications of STEM [Science, Technology, Engineering, Mathematics] which have been developed to this subject area. Four databases were searched, and 37 papers were finally selected for this review. The findings from the presented learning theories set the foundation on how students obtain knowledge, and the relevant studies in the field of gamification and computational thinking showed some first positive outcomes stemming some first research attempts which need further examination. Furthermore, it seems that with the right use of game mechanics and elements, well-designed applications of STEM gain students' interest to learn through gameplay and motivate them to cultivate computational thinking and problem-solving skills.

Keywords: Computational Thinking; Gamification; (Primary And Secondary) Education.

RESUMEN

El rápido desarrollo de la gamificación y el pensamiento computacional parece abrir nuevos horizontes educativos al proporcionar nuevas oportunidades para que los estudiantes adquieran las competencias digitales básicas necesarias para su desarrollo cognitivo. La gamificación, por un lado, prospera porque genera un alto grado de compromiso de los participantes en una actividad. Por otro lado, el creciente interés científico en el pensamiento computacional se centra en el hecho de que proporciona un fructífero campo de diálogo en la comunidad investigadora para el desarrollo del pensamiento crítico y analítico de los estudiantes. Por lo tanto, este artículo pretende sintetizar el conocimiento sobre la gamificación y el pensamiento computacional para mejorar la educación en beneficio de los estudiantes. Específicamente, este trabajo describe: (a) los antecedentes teóricos de la gamificación en el aprendizaje y la educación, (b) estudios relevantes en la literatura y sus hallazgos, y (c) aplicaciones específicas gamificadas de STEM [Ciencia, Tecnología, Ingeniería, Matemáticas] que se han desarrollado para esta área temática. Se realizaron

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búsquedas en cuatro bases de datos y finalmente se seleccionaron 37 artículos para esta revisión. Los hallazgos de las teorías de aprendizaje presentadas sientan las bases sobre cómo los estudiantes obtienen el conocimiento, y los estudios relevantes en el campo de la gamificación y el pensamiento computacional mostraron algunos primeros resultados positivos derivados de algunos primeros intentos de investigación que necesitan un examen más detallado. Además, parece que con el uso correcto de la mecánica y los elementos del juego, las aplicaciones bien diseñadas de STEM ganan el interés de los estudiantes por aprender a través del juego y les motivan para cultivar el pensamiento computacional y las habilidades de resolución de problemas.

Palabras clave: Pensamiento Computacional; Gamificación; Educación (Primaria Y Secundaria).

INTRODUCTION

Computational thinking is a multifaceted skill that embraces problem-solving techniques, methods, and logical reasoning to solve complex problems step by step. It emerges from many different scientific fields with special interest to be gathered mostly around the computing research area (Wing, 2008; Duncan, 2018). According to Duncan (2018), a lot of scientific interest is focused on how to embody computer science, computer programming, and computational thinking in the school curricula and especially in K-12 education. In 2018, at the New Zealand Digital Technologies curriculum proposed about digital technology, special emphasis was given on *"Computational Thinking"* (Duncan, 2018; Wang, 2016). Already since 2017, Shute et al. (2017), conceptualized computational thinking as an umbrella term which embraces the following aspects: *"Abstraction*, *Algorithm Design*, *Evaluation*, *Generalization*, *Iterative Improvement*, *Information Representation*, *Precise Communication*, and *Problem Decomposition"*.

On the other side, gamification is a technology with the potential to make learning fun and enjoyable for learners as long as it is well-designed (Kayımbaşıoğlu et al., 2016). Specifically, it integrates features derived from video games to a non-game context to divert students into active learners developing computational thinking, digital skills, and problem-solving strategies (Soboleva, 2021; Triantafyllou, 2022a, 2022b; 2022c; Triantafyllou & Sapounidis, 2023). Gamification when well-organized, well-implemented and tailored to the students' needs, could facilitate teachers to create effective learning experiences for their students (Kayımbaşıoğlu et al., 2016; Kim et al., 2018). According to Kim et al. (2018), gamification might help to achieve the following: (i) to increase students' motivation for learning and participation in the learning process, (ii) to enhance students' academic performance and the learning process in general, (iii) to help maintain easily gained information and recall previous knowledge, (iv) to provide immediate feedback to learners while they are working on a specific learning task, (v) to bring about behavioral changes, (vi) to provide students the opportunity to monitor and control their learning, and (vi) to encourage teamwork among students.

Soboleva et al. (2021) claim that gamification or gamified learning is a teaching approach that could be utilized in combination with computational thinking for the development of the problem-solving skills needed for the 21st century. However, a heterogeneous landscape still exists around the research area of gamification and computational thinking. To the best of the authors' knowledge there are not many research papers in this subject area with findings that can be applied directly in the school curricula of primary and secondary education. Also, due to the limitation of the number of research studies conducted in the gamification and computational thinking field, and because of incomplete or no systematic recording of all the relevant studies, there is a research gap to be addressed. This systematic review tries to address this research gap by presenting the theoretical background of gamification to support learning, in conjunction with a detailed description of findings stemming from research concentrated on gamification and computational thinking. Furthermore, examples of gamified applications of STEM are described, which utilize game mechanics and game elements to help students cultivate computational thinking skills in everyday learning practice.

Background

Computational thinking, Gamification and STEM related content

Computational thinking is a term which was first used by Papert, who later transformed it into "*procedural thinking*" (Papert, 1980, 1991). Papert in 1980, tried to examine this new concept which embraces ideas related to computation through software and hardware computer systems (Lodi & Martini, 2021; Papert, 1980). He developed the learning theory of *Constructionism*, which extended the *Constructivism* of Piaget (Sjøberg, 2010) and claimed that students could construct their own knowledge by creating a real artifact. For Papert (1980), knowledge is not directly transferred from the teacher to the students. Students create their own knowledge not by memorization but through experimentation. For this reason, he designed with his team the *Logo* programming language in the Epistemology and Learning Group at the MIT Media Lab (Papert 1980, 1991).

Thus, with this user-friendly programming language students could consciously engage in activities that are meaningful to them such as coding a computer program or constructing a robot (Lodi & Martini, 2021; Papert, 1980, 1991).

Wing (2006) has introduced and unified under the umbrella of *"computational thinking"*, computer science basic principles, such as problem-solving tasks and system design processes. She described computational thinking as a broad concept that encompasses a skillset containing "*abstraction*, *generalization*, *algorithmic thinking*, *modularity*, *decomposition* and *debugging*" among others, and it is not limited to basic computer literacy and adequacy to use digital devices.

In the upcoming years, technological advancement with the utilization of computing in numerous research areas, led to a rise of computational thinking and to a need for people with creative thinking and the ability to solve problems (Perković et al., 2010; Settle et al., 2012). Computational thinking attracted the researchers' interest, especially in the context of education (Wing, 2006; Perković et al., 2010; Sengupta et al., 2013; Psycharis & Kallia, 2017; Monteiro et al. 2017). Wing since 2006, had claimed that computational thinking is a key skill that every student needs to have in addition to the other three key skills of reading, writing and numeracy. Furthermore, "programming" or "coding" skill has been added as a basic digital skill of the 21st century and was closely related to computational thinking (Selby & Woollard, 2013; Yee Lye & Hwee Ling Koh, 2014). Govender and Grayson (2006), Denning (2009), and Beecher (2017), claimed that while students learn how to program, they could cultivate the following skills: "*problem solving*, *logical thinking*, *algorithmic thinking*, and *Computational Thinking* (*CT*)". According to Rojas-López and García-Peñalvo (2019), the teaching process of computer programming could act as a scaffold for developing a computational thinking skillset which can be useful to many scientific fields, and especially in the scientific domain of Science, Technology, Engineering, Arts and Mathematics (STEAM).

However, while some researchers have agreed that computational thinking is important because not only does it help to solve a problem but to adopt a problem-solving strategy too (Govender and Grayson, 2006; Beecher, 2017), still nowadays there is not a consensus among them on computational thinking's conceptualization. Also, there is not a consensus on which other "types" of thinking such as *problem solving*, *logical thinking* and *algorithmic thinking* among others, are considered fundamental for the cultivation of *computational thinking* (Selby & Woolard, 2013). Denning (2009), Lee et al. (2011), Sneider et al. (2014), Grover et al. (2016), Beecher (2017), and Komm et al. (2020) claimed that computational thinking is a continuously growing concept which resembles various thinking processes, such as *mathematic*, *engineering*, *algorithmic*, and *design thinking* among others.

Undoubtedly, Wing (2006) in the paper "*Computational Thinking*" argued that computational thinking should be a basic skillset of every student in school learning (Voogt et. al., 2013). On the other side, according to Kalelioğlu et al. (2016) and Li et al. (2020a), Wing's definition was too abstract to be embodied directly to primary and secondary education. Since then, more studies have been conducted aimed to examine this new umbrella-term entitled as "*computational thinking*" (Bers, 2017). However, so far, it remains unclear which features of computational thinking can be integrated into the school curricula of primary and secondary education.

In an effort to search for new directions for the development of computational thinking in learning and education, it should be noted that many facets of computational thinking seem to be combined efficiently with game-based and STEM disciplines (Atmatzidou & Demetriadis, 2016; Tsarava et al., 2017). Among the various learning approaches related to computational thinking, the following four seem to be the most suitable in school learning: (i) *problem-based learning* (Kwon et al., 2021; Wang, Shen, & Chao, 2021), (ii) *collaborative learning* (Hsu et al., 2018), (iii) *project-based learning* (Kim et al., 2018; Trilles & Granell, 2020) and (iv) *gamified learning* (Landers, 2014). With focus on integrating gamification into computational thinking, gamified learning is a learning approach that might fits in the development of computational thinking, because it embodies competitive game mechanics and game elements into the classroom and helps students to learn through gameplay (Landers, 2014; Kim et al., 2018).

Gamification is an emerging technology, which came to the forefront since the late 2010s, and offered an alternative approach in learning by introducing game elements and mechanics in a non-game context (Deterding et al., 2011; Kim et al., 2018; Jácome-Amores et al., 2021). Some first research studies aimed to examine gamification and computational thinking were already conducted since 2011. Basawapatna et al. (2011), with the help of an app entitled as AgentSheets, have managed to track the progress of instructors' and students' skill to identify computational thinking patterns. AgentSheets was a multi-application simulation builder which allowed non-developers to create their own simulations and games (Repenning, 1993, 2017). Ioannidou et al. (2011) have examined computational thinking patterns to identify the knowledge acquired from game design into STEM domains. Specifically, in their paper they referred to the iDREAMS project, which main objective was to improve Computer Science education in K-12 schools and strengthen students' motivation for learning. Special focus in the project was given on the game design and the development of computational thinking

https://doi.org/10.56294/sctconf2024659

skills of students through an approach referred as Scalable Game Design. Kotini & Tzelepi, (2015) in their study, proposed a gamification-based framework for developing learning activities of computational thinking. In addition, Grover et al. (2016) have prepared a course entitled as "*Foundations for Advancing Computational thinking (FACT)*" to pass the teaching of algorithm problem-solving to high school students. This course was designed with the following basic goal orientation which was to get a comprehensive insight of students' computational learning, and to motivate middle schoolers to participate and learn algorithmic problem solving. Ortiz et al. (2016) and Madariaga et al. (2023), have investigated gamification and gamified robotics within STEM context and identified a set of game elements (e.g., points, badges, leaderboards) which seem to affect in a positive way students' attendance, motivation, and engagement to achieve learning goals in STEM and computer science subjects.

Findings and Limitations of Previous Reviews

There have been only a few systematic reviews in literature to contribute to a better scientific understanding in the subject area of gamification and computational thinking in education (primary and secondary). For instance, in a systematic review, Aroonsiwagool and Tuntiwongwanich (2021) have conducted a synthesis of related studies for the development of computational thinking through the combination of gamification teaching approach and programming to enhance students' motivation for learning. 31 studies were selected from documents published in research databases. The findings showed that the development of computational thinking through comprehensive coding knowledge and gamification, was a pedagogical challenge due to the various features included under the umbrella-term of computational thinking. According to Aroonsiwagool & Tuntiwongwanich (2021), learning goals and any learning intervention should be run after the analysis of students' needs through given questionnaires for the development of a computational thinking skillset.

Additionally, in a meta-analytic review, Sun et al. (2021) have conducted a meta-analysis of 22 empirical studies to investigate the development of students' computational thinking learning efficacy with the use of educational games. They have examined different factors (sample size, game usage mode, game tools, grade level) that are related to computational thinking skills acquisition. The findings after the meta-analysis, showed that educational games seem to have a positive effect on students' computational thinking skillset improvement.

All the above-mentioned, lead us to consider, that so far, despite the upcoming research interest for integrating gamification into computational thinking, there are not many research papers with findings in this specific subject area. Thus, a more detailed examination of how gamification and computational thinking can be integrated into school learning seems to be necessary, in order to set a basic theoretical foundation for further utilization of them. The theoretical background of gamification offers the opportunity of choosing new learning styles (such as gamified learning or gamification teaching approach) that could help students to develop computational thinking skills through gameplay.

This systematic literature review based on studies from the existing literature, presents the basic theoretical background related to gamification, and outlines the findings of research studies on gamification and computational thinking in learning and education. Furthermore, it focuses on specific applications of STEM which have been developed and utilize gamification to help students develop computational thinking skills.

Research Questions

This review tries to answer three basic research questions:

1. What is the theoretical background of gamification in learning and education?
2. Are there studies using gamification to develop computational thinking in educational context and what are their findings?
3. Are there any specific STEM applications to facilitate students to acquire computational thinking skillset through gamification?

METHOD

A systematic literature review in a subject area helps to identify research questions, as well as to clarify the purpose for a review and how this study would contribute new findings to the existing knowledge in literature (Vicente-Saez & Martinez-Fuentes, 2018). In the next sections, the research methodology of this review is described in detail to present how the basic data of this study were collected for analysis.

Search Strategy in Google Trends

At first, the authors have entered the keywords "Gamification" and "Computational thinking" to detect the worldwide interest for gamification and computational thinking, since 2006 which was the year when Wing made computational thinking to be a central topic of scientific interest (Wing, 2006, 2008). Also, in 2008, the term "gamification" was first appeared in a blog post by Brett Terrill (2008). Therefore, this criterion urged authors to decide this chronological order to run their search and explore the scientific interest for gamification and computational thinking.

Analysis of collected data from Google Trends

The following figure (see figure 1) represents an interactive chart of Google trends, for the keywords "gamification" and "computational thinking". Y-axis in the chart presents the search interest over time of the two compared concepts (Computational thinking and Gamification). From the chart, we can notice a growing interest for computational thinking (blue line) and gamification (red line).

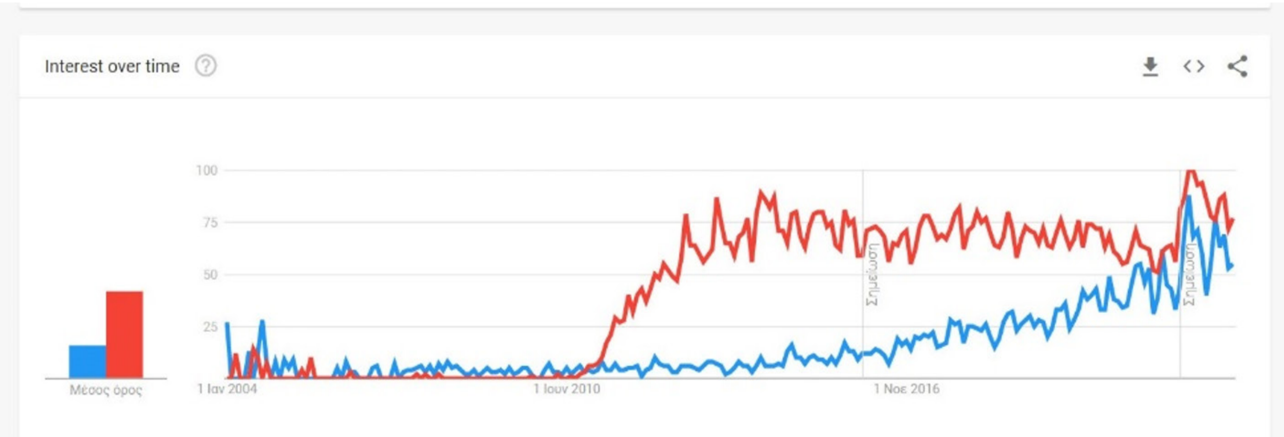

Figure 1. Illustration of Google trends, for the keywords "computational thinking" and "gamification". (https://trends.google.com/trends/). [Accessed 30/01/2023]

Search strategy in databases

Four different databases were selected to identify eligible documents that met the inclusion criteria. These databases were Scopus, ScienceDirect (Elsevier), ACM Digital Library, and Springer Link.

The databases were queried using as search terms the words "Gamification" and "Computational Thinking" in the title, abstract, or keyword.

Search Strategy and selection of studies in the Scopus database

The first step for our research, was to run a detailed search in the Scopus database to find Scopus indexed documents on gamification and computational thinking published from 2006-2023 (the 2023 data refer to February 2023). The database of Scopus was queried using the following search string: *TITLE – ABS – KEY ({Gamification} AND {Computational thinking}) AND PUBYEAR >2005* (a search in the field including titles, abstracts, and keywords in the Scopus database, accessed February 24, 2023). The total number of publications amounted to 86.

Data Collection from the Scopus database and Analysis

Of 86 documents, in the main subject areas of published documents, Computer Science accounted for 35 documents (40,2 %), Social Sciences accounted for 18 documents (21,2 %), Engineering accounted for 12 documents (13,4 %), and Mathematics accounted for 9 documents (10,6 %) (see Figure 2). Next, in figure 3, the number of published documents in Scopus database in the research topic of Gamification and Computational Thinking is presented. The results illustrate that more studies need to be conducted on the topic of gamification and computational thinking. Specifically, the results coming from the search in Scopus database are the following: 1 Scopus-indexed paper on gamification and computational thinking in 2014, 2 publications in 2015, 4 publications in 2016, 7 publications in 2017, 9 publications in 2018, 12 publications in 2019, 12 publications in 2020, 23 publications in 2021, 14 publications in 2022, and 2 publications in 2023 (the 2023 data are incomplete so far) (see figure 3).

As for affiliations, the following universities and institutions had the highest rank, with 3 documents from the King Mongkut's Institute of Technology Ladkrabang; 3 documents from the SS Cyril and Methodius University; 3 documents from the Vyatka State University; 2 documents from the Center for innovations and digital education in DIG-ED, 2 documents from the University of Crete; 2 documents from the Hong Kong Polytechnic University; 2 documents from the University of Wollongong; 2 documents from the Universidad Rey Juan Carlos and 2 documents from the Hong Kong Metropolitan University (see figure 4).

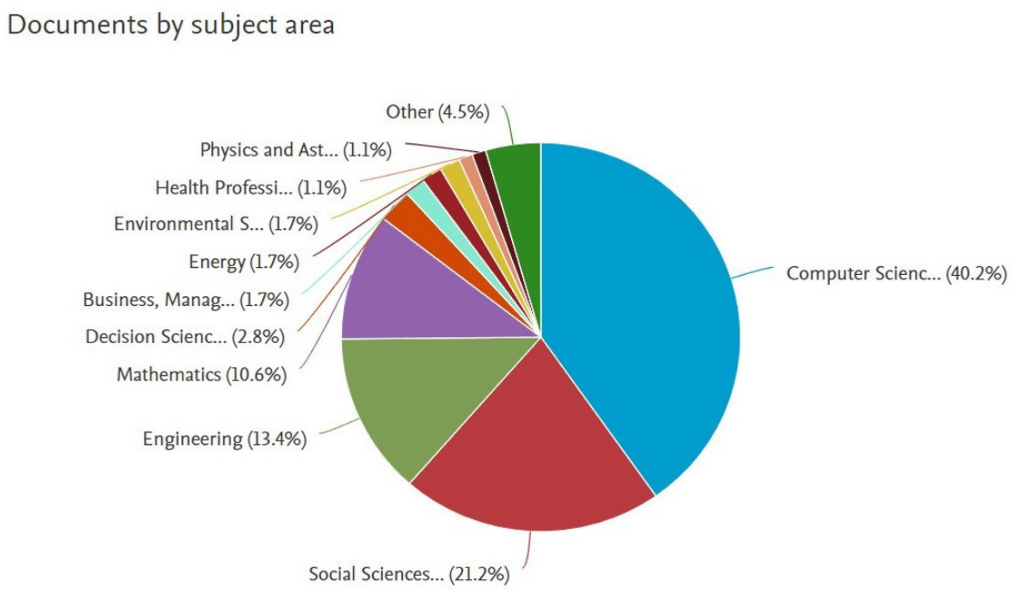

Figure 2. Scopus Indexed documents by subject area

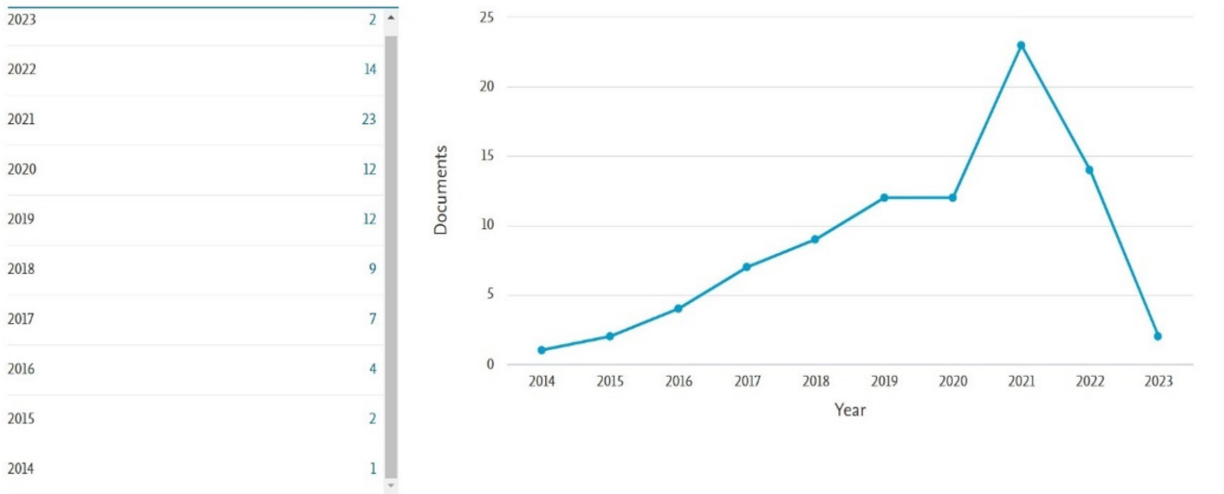

Figure 3. Scopus Indexed documents om Gamification and Computational Thinking
Note: the 2023 data refer to February 2023.

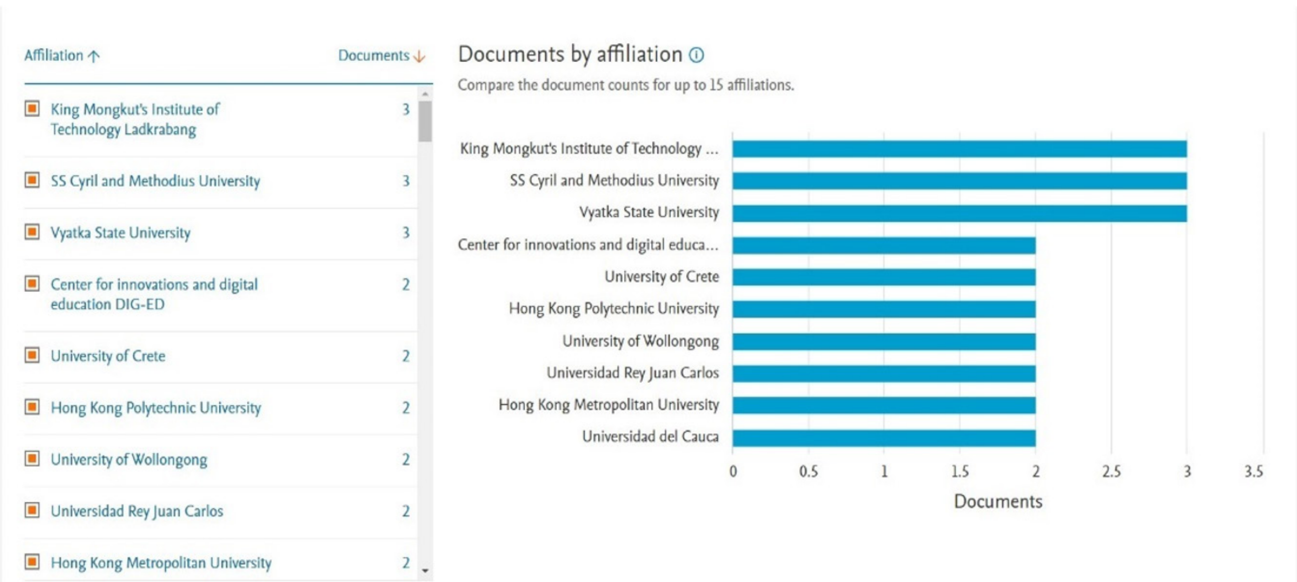

Figure 4. Scopus Indexed Documents by affiliation

Of 86 documents, articles accounted for 21 documents; conference papers accounted for 38 documents; 23 documents accounted for conference reviews; 3 documents accounted for book chapters and 1 document was a review. Also, after a search for documents per year by source, of 86 documents, the bigger number of papers was published to the following source: 12 documents were published in *Lecture Notes in Computer Science* including *Subseries Lecture Notes in Artificial Intelligence* and *Lecture Notes in BioInformatics*; 5 documents were published in *ACM International Conference Proceeding Series*; 5 documents in *Ceur Workshop Proceedings*; 3 documents in *Communications in Computer and Information Science*; 2 documents in *Lecture Notes in Networks and Systems* and 2 documents in *Sustainability Switzerland* (see figure 5).

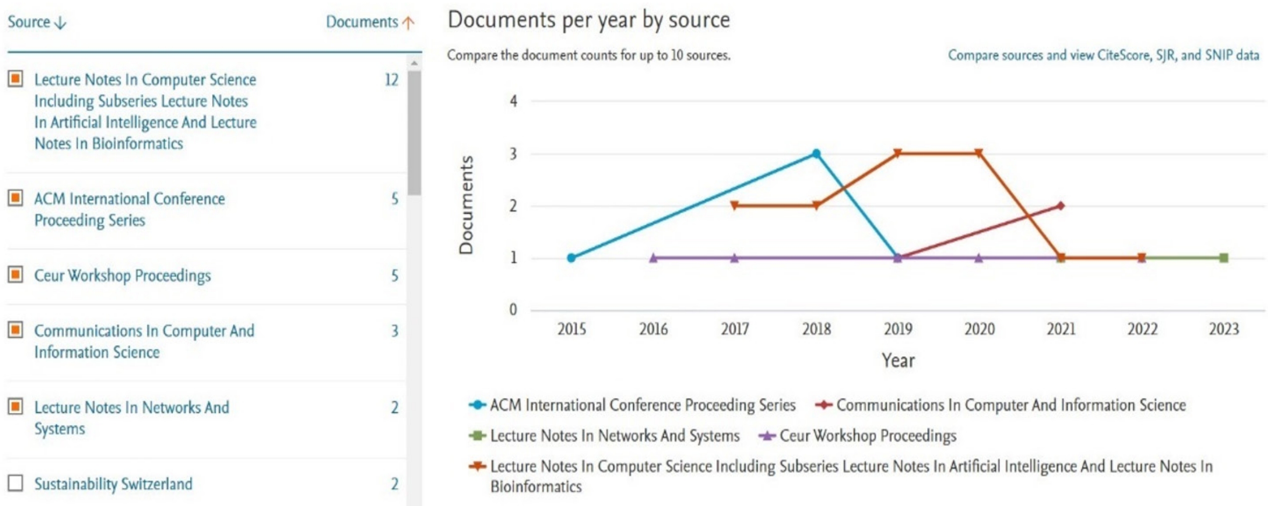

Figure 5. Scopus Indexed Documents per year by source

After the initial search in Scopus database, we continued with a more detailed and focused search process in other bibliographic databases to find more publications of high scientific rigor. The bibliographic databases accessed, included Science Direct (Elsevier), ACM Digital Library and Springer Link.

Selection of studies in the Science Direct (Elsevier) database

A search in the Science Direct (Elsevier) database to find documents on our research topic, published from 2006-2023 (the 2023 data refer to February 2023) was conducted. The database was queried using the search terms: *({Gamification} AND {Computational Thinking}) AND Year: 2006-2023)*(a search in the field including titles, abstracts, and keywords in the Science Direct (Elsevier) database, accessed February 24, 2023). The total number of publications amounted to 269.

Data Collection from the Science Direct (Elsevier) database and Analysis

Of 269 documents, there were 28 review articles; 193 research articles; 6 Encyclopedia documents; 25 book chapters; 1 Conference abstract; 1 Case report; 2 Editorials; 1 Mini review and 12 other documents. Also, the number of documents published per year was the following: 3 documents in 2013, 6 documents in 2014; 11 documents in 2015; 20 documents in 2016; 15 documents in 2017; 20 documents in 2016; 15 documents in 2017; 27 documents in 2018; 26 documents in 2019; 35 documents in 2020; 48 documents in 2021; 55 documents in 2022, and 24 documents in 2023 (the 2023 data are incomplete so far). According to the subject area of the 269 documents, Computer Science accounted for 106 documents; Social Sciences accounted for 98 documents; Psychology accounted for 45 documents; Business, Management and Accounting accounted for 33 documents; Engineering accounted for 29 documents; Decision Sciences accounted for 14 documents; Medicine and Dentistry accounted for 13 documents; Energy accounted for 10 documents; Arts and Humanities accounted for 8 documents, and Environmental Science accounted for 8 documents. In addition, a search that was conducted for documents by publication source, showed that of 269 documents, the bigger number of publications was at the following academic journals: 27 documents were published in *Procedia Computer Science*, 19 documents were published in *Computers in Human Behavior* and 17 documents were published in *Computers & Education*.

Selection of studies in the ACM Digital Library database

Next, a search in the ACM Digital Library database to find documents on our research topic, published from 2006-2023 (the 2023 data refer to February 2023) was conducted. The database was queried using the following search string: *[All: "gamification"] AND [All: "computational thinking"] AND [E-Publication Date: (01/01/2006 TO 02/24/2023)]* (a search in the field including titles, abstracts, and keywords in the ACM Digital Library database, accessed February 24, 2023). The total number of publications amounted to 115.

Data Collection from the ACM Digital Library database and Analysis

Of 115 documents, 98 documents were published in Conference Proceedings, 9 documents were published in Academic Journals, 5 documents were published in Magazines, 2 documents were Newsletters, and 1 document was a report.

Data Collection from the Springer Link database and Analysis

Finally, a search in the Springer Link database to find documents on our research topic, published from 2006-2023 (the 2023 data refer to February 2023) was conducted. The database was queried using the following search string: *"Gamification" AND "Computational Thinking" within 2006 – 2023* (a search in the field including publication titles, abstracts, and keywords in the Springer Link database, accessed February 24, 2023). The total number of publications amounted to 550. Specifically, of 550 documents, 310 were books, 157 were Conference Proceedings, 147 were book chapters, 82 were conference papers, 80 were articles, 13 were Reference Work Entries, and 10 were Reference Works. According to the subject area of the 550 documents, Computer Science accounted for 225 documents; Education accounted for 146 documents; Engineering accounted for 101 documents; Business and Management accounted for 28 documents, and Political Science and International Relations accounted for 7 documents.

A synopsis of the indexed papers in databases

The total number of papers mentioned on bibliographic databases, the selected papers, and a synopsis of findings for each database is presented in Table 1 and illustrated in figure 6.

Table 1. Findings of indexed papers in databases

Databases and Digital Libraries	Total number of publications from 2006-2023 (the 2023 data refer to February 2023)
Scopus	86
ScienceDirect (Elsevier)	269
ACM Digital Library	115
Springer Link	550

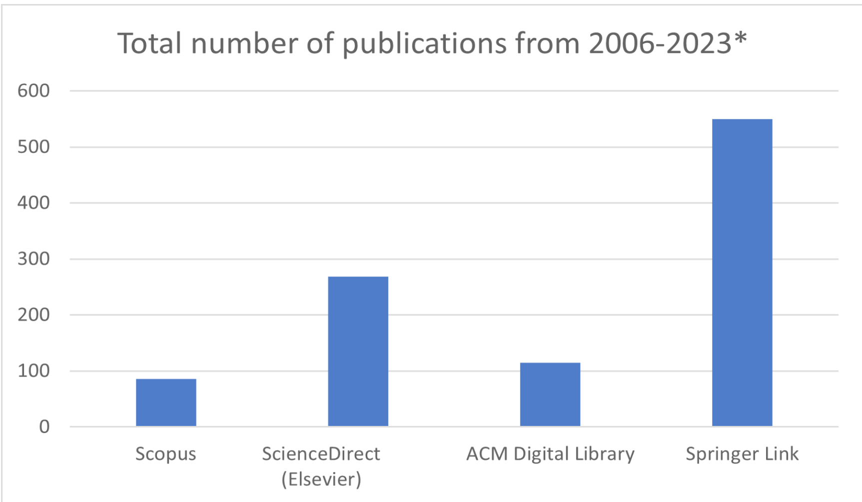

Figure 6. The Indexed papers in databases
Note: the 2023 data refer to February 2023.

Critical appraisal and Selection of studies

For this systematic review, the selection criteria were chosen to be aligned with the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)* statement. The PRISMA statement contains a 27 items checklist and a four-stage flow diagram that seems to fit perfectly with the objectives of our systematic review. PRISMA cannot be considered as tool for assessment of the quality of our review, but it can support the accountability and consistency in the process of documentation of a detailed analysis of systematic reviews published in the literature.

For the critical appraisal of the reviewed documents, the following criteria were examined for each

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document:

1. Did the authors formulate research questions regarding gamification and computational thinking in education, in their full-text papers?
2. Were the research methods in the selected documents for review clearly explained?

Conducting a search strategy with the criteria mentioned above and with some extra added criteria (see table 2), more papers with specific titles and abstracts for the subject of this systematic review were found. Every paper that met the above-mentioned rules and criteria was chosen to be included in the systematic review. For papers that it was difficult to make a straight decision after reading their title and abstract so as to select them for this study, the final decision to read in detail their full text was chosen.

Table 2. Criteria for the selection of documents for the systematic review

Specific Criteria	Documents included	Documents excluded
Language	English	Other languages
Publication Type	Full-text peer-reviewed documents	Magazine articles, reports, and grey literature publications
Study topic	Gamification and Computational Thinking in Education	Other topics of research

Summary and synthesis of studies

After conducting this overall search process 37 papers were finally selected from the total number of papers initially found. The papers are presented in table 3. The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flowchart for study selection is shown in figure 7.

Furthermore, after deciding which papers fit the research criteria, the decision to classify the selected 37 papers according to their research methods was chosen (see table 4). Seven studies contained experiment methods, two studies presented the method of interviews, seven studies were surveys, five studies were conceptual studies, one study was based on observation method, nine studies were studies of review type, three studies were based on case studies methods, and three studies contained mixed research methods (see table 4).

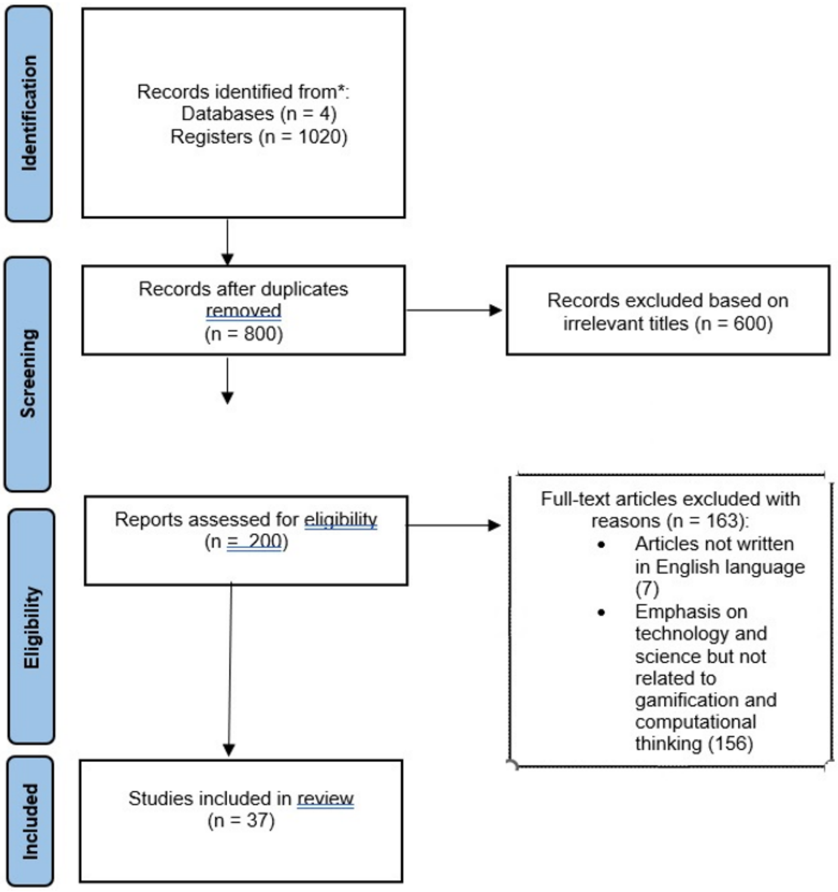

Figure 7. The PRISMA flowchart for the selection of studies

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Table 3. List of the 37 selected papers reviewed in this study

No. of selected papers	Paper title	Authors	Year
1	Computational Thinking through Design Patterns in Video Games	Barbero, Gómez-Maureira, Hermans	2020
2	A Literature Review: Fostering Computational Thinking Through Game-Based Learning in K-12	Tatar	2019
3	Assessing Computational Thinking: The Relation of Different Assessment Instruments and Learning Tools	Vaida Masiulionyte-Dagiene, Jevsikova,	2022
4	Analyzing Students' Computational Thinking and Programming Skills for Mathematical Problem Solving	Hansen, Hadjerrouit	2022
5	Want more? Learn less: Motivation affects adolescents learning from negative feedback.	Zhuang, Feng, & Liao	2017
6	Formation of Computational Thinking Skills Using Computer Games in Teaching Mathematics	Soboleva, Sabirova, Babieva, Sergeeva, Torkunova	2021
7	Computational Thinking, Between Papert and Wing	Lodi & Martini	2021
8	The effect of challenge-based gamification on learning: An experiment in the context of statistics education	Legaki, Xi, Hamari, Karpouzis, & Assimakopoulos	2020
9	Computational thinking embedded in engineering design: capturing computational thinking of children in an informal engineering design activity	Ehsan, Rehmat, Cardella	2021
10	Computational Thinking in Computer Science Classrooms: Viewpoints from CS Educators	Good, Yadav, Mishra	2017
11	How to learn and how to teach computational thinking: Suggestions based on a review of the literature	Hsu, Chang, Hung	2018
12	Studies of student engagement in gamified online discussions	Ding, Kim, Orey	2017
13	Exploring the Progression of Early Programmers in a Set of Computational Thinking Challenges via Clickstream Analysis	Eguíluz, Guenaga,Garaizar, Olivares-Rodriguez	2017
14	Facilitating Computational Thinking through Game Design	Wu & Richards	2011
15	Review on the teaching of programming and computational thinking in the world	Belmar	2022
16	Gamification of MOOCs and Security Awareness in Corporate Training	Triantafyllou & Georgiadis	2022
17	Are students getting used to learning technology? changing media usage patterns of traditional and non-traditional students in higher education	Dolch & Zawacki-Richter	2018
18	User-based Evaluation of Gamification Elements in an Educational Application	Andrade & Law	2018
19	Situating Learning in communities of practice. Perspectives on socially shared cognition	Lave	1991
20	Effect of the Children's Health Activity Motor Program on motor skills and self-regulation in head start preschoolers: An efficacy trial	Robinson, Palmer, Bub	2016
21	Self-determination theory, Development of Self-Determination Through the Life-Course	Adams, Little & Ryan	2017
22	Fostering development of work competencies and motivation via gamification	Sailer, Hense, Mandl, and Klevers	2017
23	Kim, S., Song, K., Lockee, B., & Burton, J. (2018). Gamification in Learning and Education. Gamification in Learning and Education.	Kim, Song, Lockee & Burton	2018
24	Collaborative Game-Based Environment and Assessment Tool for Learning Computational Thinking in Primary School: A Case Study	Zapata-Cáceres, Martín-Barroso & Román-González	2021

25	Computational Creativity Exercises: An Avenue for Promoting Learning in Computer Science	Peteranetz, Flanigan, Shell, Soh	2017
26	A systematic review of computational thinking in science classrooms	Ogegbo & Ramnarain	2021
27	Development of rubric to measure children's creativity in Game Design	Lailifarhanamd, Maizatulhayati, Norzuhaidah, Ummuhusna & Norasikin	2021
28	Supporting future teachers to promote computational thinking skills in teaching stem—a case study	Tripon	2022
29	Computational Thinking in Small Packages. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 12518 LNCS, 170-181. https://doi.org/10.1007/978-3-030-63212-0_14	Komm, Hauser, Matter, Staub, & Trachsler	2020
30	A Critique and Defense of Gamification	Hung	2017
31	Increase of confidence for the solution of problems in preuniversity students through Computational Thinking	López & García-Peñalvo	2018
32	Characterizing Computational Thinking for Tertiary Education Learning	Sidek, Hayati, Yatim, Soh Said	2020
33	On Computational Thinking and STEM Education	Li, Schoenfeld, A. diSessa, Graesser, Benson, English, Duschl	2020
34	Gamification Design Patterns for User Engagement	Triantafyllou & Georgiadis	2022
35	Computational Thinking Patterns. Online Submission.	Ioannidou, Bennett, Repenning, Koh, & Basawapatna	2011
36	A Framework for Computational Thinking Based on a Systematic Research Review.	Kalelioğlu, Gülbahar & Kukul	2016
37	Fostering Programming Practice through Games.	Paiva, Leal & Queirós	2020

Table 4. The research methods used in reviewed documents

Methods	Studies
Experiment	(Sailer et al., 2017), (Barbero et al., 2020), (Duncan, 2018), (Soboleva et al., 2021), (Wu & Richards, 2011), (Andrade & Law, 2018), (Legaki et al., 2020)
Interview	(Ehsan et al., 2021), (Good et al., 2017),
Survey	(Boom et al., 2022), (LailiFarhanaMd et al., 2021),(Peteranetz et al., 2017), (Robinson et al., 2016), (Dolch & Zawacki-Richter, 2018), (Kalelioğlu et al., 2016), (Paiva et al., 2020)
Conceptual Studies	(Adams et al., 2017), (Lave, 1991), (Lodi & Martini, 2021), (Zhuang et al., 2017), (Ioannidou et al., 2011),
Observation	(Hung, 2017)
Reviews as a research methodology for concepts foundation	(Tatar, 2019), (Triantafyllou & Georgiadis, 2022b), (Li et al., 2020b), (Sidek et al., 2020), (Ogegbo & Ramnarain, 2022),(Belmar, 2022), (Hsu et al., 2018), (Hansen & Hadjerrouit, 2023), (Ding et al., 2017)
Case Studies	(Tripon, 2022), (Zapata-Caceres et al., 2021), (Dagiene et al., 2017)
Mixed methods	(Komm et al., 2020), (Kim et al., 2018), (Triantafyllou & Georgiadis, 2022a)

RESULTS

This is one of the most basic stages of our review where we focused on giving answers to our research questions.

1. What is the theoretical background of gamification in learning and education?

Gamification has attracted the research interest of researchers, in the subject area of gamification utilization in education, aiming to improve student motivation, engagement, and academic achievements (Kim et al., 2018; Soboleva et al., 2021). On the other side, criticism of gamification was concentrated on assigning score points, badges, and other virtual goods, as a way to attract students' interest for learning (Hung, 2017). However, findings from the existing literature have shown that in many cases gamification seems to bring about positive outcomes when properly implemented in the educational context (Tan et al., 2017; Kim et al., 2018; Zapata-Caceres et al., 2021). Several research studies showed that gamified learning tasks intended to enhance the development of computational thinking skills have a positive effect on student learning progress (Tatar, 2019).

The main theories in literature related to gamification are: (i) *Motivation theory*, (ii) *Achievement Goal Theory*, (iii) *Self-Determination Theory*, (iv) *Social Learning Theory and Situated Learning Theory*, and (v) *Feedback* (Kim et al., 2018; Triantafyllou & Georgiadis, 2022a; Triantafyllou & Georgiadis, 2022b).

Conceptualizing the theoretical background of gamification is not an easy subject of study. The authors have tried after carefully studying the relevant theories to the field, to describe the following basic theories related to gamification.

Motivation Theory

At first, motivation theory refers to motivation, as a necessary factor playing a crucial role to the outcome of a gamification project (Komm et al., 2020). Motivation can be divided into intrinsic and extrinsic motivation. Intrinsic motivation is the motivation that derives from internal characteristics of a persons' personality. Ryan and Deci (2000) have mentioned that intrinsic motivation seems to be more significant than extrinsic motivation in terms of learning progress and academic achievements. Extrinsic motivation is a form of motivation that is influenced by external characteristics, like rewards. According to Ryan and Deci (2000), extrinsic motivation can be described as "*a construct that pertains whenever an activity is done in order to attain some separable outcome*".

It is difficult to decide which motivation arises as the most suitable for learning (Dolch & Zawacki-Richter, 2018; Kim et al., 2018; Triantafyllou & Georgiadis, 2022a; Triantafyllou & Sapounidis, 2023 & Farhaoui,2022 & Farhaoui, 2023). According to the specific personality traits of everyone, each motivation type could be more effective than the other during the learning process (Komm et al., 2020). Sometimes a combination of the two types of motivation might bring the desirable learning outcomes or it might not work at all.

Achievement Goal Theory

Achievement Goal Theory describes the motives of learners to achieve learning goals. Students seem to be motivated by their strong will to accomplish learning tasks (Triantafyllou & Georgiadis, 2022a). This theory contains two main types of goals: (i) *mastery goals* and (ii) *performance goals* (Pekrun et al., 2014).

Mastery goals reflect the will to gain the necessary skills to achieve a learning task or master a concept. On the other side, performance goals express the need to present "bigger" achievements than the other people.

People with mastery goals seem to demonstrate meaningful self-regulation, high self-efficacy, and academic accomplishments (Robinson et al., 2016). However, careful consideration is needed when setting up performance goals, because they are strongly associated with academic achievements (Van Yperen et al., 2014; Atmatzidou & Demetriadis, 2016). This means, that instructors should carefully consider which performance goals to set up for their teaching, because these goals can affect in a negative way motivation and self-efficacy (Schunk & Mullen, 2012). In addition, performance goals might be different depending on the various student-types.

Related to academic achievements, it may be useful to consider which goals are more effective between the mastery and performance ones. However, achievement goals are not stable, but changeable and dynamic. In fact, after a detailed examination of relevant studies in the literature, the authors have not found many empirical studies that clarify which goals (mastery or performance) might bring better learning outcomes. Darnon, Butera and Harackiewicz (2007), had also mentioned the non-existence of many empirical studies regarding mastery or performance goals' effectiveness in learning. This means that further research is needed to address this gap in the scientific literature.

Self-Determination Theory

Self-Determination Theory can be described as a macrotheory of motivation (Adams et al., 2017; Sailer et al., 2017). According to this theory, individuals' choices are driven by their innate psychological needs: *autonomy*, *competence*, and *relatedness*. In simple words, every person should feel that he/she is in control of his/her behavior. Also, that he/she is capable of accomplishing learning tasks, and that he/she belongs to a community where he/she can interact with peers (Kim et al., 2018; Ryan & Deci, 2000; Deci & Ryan, 2000).

To incentivize students to be *autonomous*, instructors might provide various options for them to choose. For instance, in team-based projects, during the process of choosing a topic to study, students should be free to decide the topic, by discussing it with the teacher. Teachers' role should be facilitating and supportive to help students in their learning journey. The teacher acting as facilitator could support more efficiently the learning process and help students to be autonomous in their learning (Kim et al., 2018).

Gaining *competence* is also closely related to *motivation*. When learners feel sufficient to achieve learning and get small wins by accomplishing learning tasks, then they are intrinsically motivated (Deci & Ryan, 2000). In case a student finds it difficult to accomplish a learning task, the teacher can support the student step by step, and not simply provide a solution to the given problem to be solved.

Relatedness represents a psychological condition where students seem to be more intrinsically motivated when they recognize relatedness from their instructors (Ryan & Deci, 2000; Deci & Ryan, 2000). Specifically, when recognizing a friendly and supportive behavior from teachers, parents or peers, students are encouraged to participate to the learning process (Kim et al., 2018).

Social Learning Theory and Situated Learning Theory

Social learning theory is mainly focused on the observation of behaviors that individuals can learn by observing the behavior of others. According to the social learning theory, learning embodies the process of social interaction and cognitive processing (Kim et al., 2018). Bandura proposed four main conditions of social or observational learning which are: (i) attention, (ii) retention, (iii) reproduction, and (iv) motivation (boone et al., 1977). Bandura mentions that successful learning relies on observational learning, which is to observe the behaviors of others, to recall the behaviors, to be able to reperform the behavior, and have a strong motive to do so (boone et al., 1977).

In the educational context, each learner might achieve learning progress through the observation of the behaviors of parents, teachers, or peers inside the classroom. Therefore, to design and develop a learning environment which is open for providing a model student observation, that is of great significance in social learning (Kim et al., 2018; boone et al., 1977). A characteristic example is a simulation game, where learners can learn through interacting with the game environment and modeling of game characters (Kim et al., 2018).

Situated learning theory, which has many similarities with the social learning theory of Bandura, is focused on learning through social interaction. Lave (1991) mentions that learning is situated, which means that learning is related to context, activities, and culture. In other words, it is a prerequisite according to this theory, knowledge needs to be authentic, and to stem from social interaction and collaboration (Kim et al., 2018; Lave, 1991).

Feedback

Thorndike had firstly mentioned feedback as a means of representing an evaluation outcome or performance (Thorndike, 1911). Feedback is basically a message (verbal or non-verbal) which presents an outcome, which is the product of an evaluation on efficiency and performance. In the educational context, feedback is considered as an important way to facilitate learning (Brookhart, 2008). Feedback can be positive or negative. Positive feedback can be encouraging, because it emphasizes on achievements, while on the contrast negative feedback reflects the weaknesses that need to be resolved. Positive feedback might be effective when trying to change some aspects of behavior of individuals (Burgers et al., 2015; Zhu et al., 2012). Also, negative feedback might be effective when it emphasizes on the weak points that need to be resolved to improve learning (Zhuang et al., 2017).

2. Are there studies using gamification to develop computational thinking in educational context and what are their findings?

The inclusion of game elements and digital services in students' cognitive activity could help to promote learning (Karavaev & Soboleva, 2017; LailiFarhanaMd et al., 2021; Soboleva et al., 2021). Video gaming is a multi-faceted process that demands complex cognitive requirements to develop several skills in learning (Ioannidou et al., 2011; Kühn et al., 2013; Tripon, 2022). It seems to play an important role in human development according to Resnick. Resnick (2007) is the head of Lifelong Kindergarten research lab, and his basic research is mainly focused on developing new technologies and tasks to engage children in a meaningful and creative way of learning. Aiming to focus on pedagogical aspects of learning that takes place inside kindergarten curricula, Mitchel Resnick (2007), suggests a spiral approach named as "*kindergarten approach to learning*" followed by the repetitive cycle: "*imagine, create, play, share, reflect and come back to imagining*".

According to Khutorskoy (2017), the instructor's personality and his/her design skills for creating an educational learning environment, are of great significance, if we consider the fact that by having the choice to implement innovative teaching technologies, he/she can trigger students' interest for learning. Thus, students will start step by step to develop a new type of thinking, well known as "*computational thinking*".

Recent studies have proposed that video games can be the vehicle for developing computational thinking and problem-solving skills (Wu & Richards, 2011; Barbero et al., 2020; Zapata-Caceres et al., 2021; LailiFarhanaMd et al., 2021; Ehsan et. al, 2021; Belmar, 2022). Paiva et al (2020), have investigated in detail under which methodological approaches, learning could be better organized with the use of new didactic tools. Specifically,

https://doi.org/10.56294/sctconf2024659

special emphasis was given to support interactive teaching by trying to increase students' motivation for learning and help them to study the learning material.

However, obtaining the ability to solve complex problems and computational problems, demands strong motivation, engagement and abstraction, both at the stage of understanding the problem to be solved, and through the overall process of coming up with the solution to it (Condori, 2017; Sapounidis et al., 2019). Gamification is presented as a promising solution to increase the level of motivation and engagement in the classroom (Kapp, 2012). The development of computational thinking can be supported when a new approach to learning is adopted (Legaki et al., 2020), and this approach includes the utilization of new learning tools and technologies, including gamification among others (Legaki et al., 2020; Soboleva et al., 2021). According to Yung et al. (2020), gamification resources for digital learning are very effective in the process of the development of computational skills and in the gain of sufficient knowledge of new technologies.

Moreover, there are also frameworks for the development of computational thinking (Kalelioğlu et al., 2016). For example, *LEGA-A learner-centered Gamification Design Framework* (Baldeón et al., 2016), includes gamification strategies and techniques designed having as basis the Bloom taxonomy with main aim to improve learning and computational thinking skills of students. The basic aim of incorporating gamification in the classroom is to attract students' interest for learning and enhance their motivation for active participation and engagement (Condori, 2017; Triantafyllou & Georgiadis, 2022a; Triantafyllou & Georgiadis, 2022b). Also, a paper by researchers from Vanderbilt University in the *Journal of Learning Sciences* showed that students who played games as part of their regular curriculum, were more engaged in class work (Clark et al., 2017).

Finkel (2017) claimed that in a learning environment (e.g., a classroom), a set of steps is required when trying to develop computational thinking. These steps are: (i) *analysis* of the task or problem to be solved, (ii) *decomposition* of the initial problem to smaller parts, (iii) *development* of an *algorithm* (defining a sequence of necessary steps to follow in order to come to a solution of the problem), (iv) *analysis* and *evaluation* of the proposed algorithm. Thus, by using the right game mechanics and elements, gamification could support students' willingness to learn and follow the above-mentioned steps to acquire the necessary problem-solving skills needed to develop computational thinking. Furthermore, another important aspect for consideration, is that in a non-game context, game components such as leaderboards, badges, or points, could act as a feedback mechanism for self-improvement and might lead to augmented positive student emotions (Brookhart, 2008). Thus, students with the use of game-like features could be stimulated to accomplish learning tasks and start to feel autonomous learners. Findings that come from eye-tracking data process, indicate that through visual and enjoyable gamification elements, the learning process is more meaningful, because the concentration of teacher and students is more focused on learning (Andrade & Law, 2018).

LailiFarhanaMd et al. (2021) have tried to identify facets of creativity in game design by utilizing *Torrance Creativity* theory. The *Torrance Creativity* theory has set the Torrance tests of creativity which include four indicators (originality, flexibility, fluency, elaboration) to determine creativity of a person through the game design stage. LailiFarhanaMd et al. (2021) have tried to validate creativity key factors in the rubric of student's creativity in the game design stage. The rubric was created during the design stage of a digital game for use inside the class. Their findings helped to measure the creativity of students and set some key indicators of student's creativity. The rubric of student's creativity would be of great significance for providing quality education in order to help students to develop computational thinking, critical thinking and problem-solving skills.

3. Are there any specific STEM applications to facilitate students to acquire computational thinking skillset through gamification?

Numerous projects have been designed to explore the usability of computational thinking, such as Bebras tasks (Dagiene et al., 2017) and CS Unplugged (Bell & Lodi, 2019) or Kodetu (Eguíluz et al., 2017). In addition, Li et al. (2019, 2020) in their second joint editorial, they have mentioned that "*Computational Thinking is more about Thinking than Computing*". In particular, their studies were concentrated on design thinking in STEM (Science, Technology, Engineering, and Mathematics) education, with special emphasis on how design thinking, as a model of thinking, might be helpful according to the learning needs of every person (Li et al., 2019; Li et al., 2020).

Many research studies indicate computational thinking as a skillset that students should develop in every field of study, in order to cultivate a scientific spirit of conducting research and experiments that will help them to succeed in their learning journey (Lu & Fletcher, 2009; Hsu et al., 2018; Boom et al., 2022). In addition, gamification seems to bring benefits in terms of developing computational thinking in the educational context, because it strengthens the motivation and engagement of students to learn and encourages them to achieve their learning goals (Ding et al., 2017; Tan et al., 2017).

Educational software (Boom et al., 2022) and specifically educational applications like Knowma+, which is developed according to pedagogical strategies, such as learning by questioning, seems like a suitable solution that combines the pedagogical practices and the potential of gamification to strengthen learning (Andrade & Law, 2018). Knowma+ provides meaningful replies to students' questions, which are grouped with a basic criterion, that is their performance level. Some studies also propose that learning by questioning, is a learning strategy which can lead to better cognitive skills. Since students learn to classify their learning experiences and evaluate the benefit of their previous learning experiences and the new gained ones, learning by questioning might help to the learning transition from the short-term into the long-term memory (Crossouard, 2013).

CodeCombat is another STEM application that uses gamification technology for the development of computational thinking. Specifically, CodeCombat ("CodeCombat", n.d.; Kim et al., 2018) is a website that provides an environment to learn to program by using a simulation game. The student creates a game character and starts to learn how to program step by step. Specifically, the student learns about syntax, parameters, methods, loops, variables, strings, arguments, and operators of a programming language. CodeCombat contains various game elements ("CodeCombat", n.d.). The learning progress and the accomplishment of achievements affects the health, the weapons, the speed, and the damage level of the game character. Also, some more game elements included in CodeCombat are points, levels, missions, virtual currency, and rewards. During the gameplay, each student has assignments to accomplish by writing code. Among the programming languages available in CodeCombat for students to choose to learn are JavaScript, Lua, CoffeeScript, and Python ("CodeCombat", n.d.).

Kumon is a private after-school-tutoring organization (*After School Math & Reading Programs - Kumon*, n.d.; Kim et al., 2018). It contains gamification methods that help to gamify the teaching of mathematics via its website (*http://www.kumon.com/resources/*). Kumon includes gamification features that exist in children's games or household items among others via its website. A characteristic game inside Kumon, is "*hopscotch game*", which can be used to learn mathematics through answering specific questions to go to the next level.

CodeMonkey is an online platform that can be used to teach students programming languages like Python or CoffeeScript. Students can learn text-based and block-based coding through an engaging gamified environment with game-like elements (CodeMonkey, n.d.).

The Radix Endeavor is a massively multiplayer online game developed by Scheller Teacher Education Program and Education Arcade at Massachusetts Institute of Technology with a funding from Melinda and Bill Gates Foundation (*The Radix Endeavor*, n.d.; Kim et al., 2018). This online game was developed for high school and middle school students. It contained subjects such as geometry, statistics, probability, algebra, ecology, genetics, evolution, and the major systems of human body. Game players have control of their game character and can take their own decisions through the gameplay. The Radix Endeavor promotes self-directed learning through its learning environment (*The Radix Endeavor*, n.d.). Specifically, students that seem to not actively participate in the learning process inside the classroom, can become active learners by trying to find the necessary information needed to solve a problem without the help of the teacher. Also, students experience collaborative learning because they collaborate with other peers during a quest (*The Radix Endeavor*, n.d.).

DISCUSSION

This systematic literature review has tried to contribute to a better understanding of gamification and computational thinking in the educational context (primary and secondary education). Specifically, through the review of selected studies three basic research questions were examined.

The first research question tried to examine the effectiveness of gamification on learning and education by describing in detail the basic theoretical background related to gamification. Each learning theory or teaching approach shows new pathways to improve learning by utilizing gamification to everyday school practice and helping students to develop a strong motive for developing computational thinking. The basic conclusion is that only when students are truly motivated and engaged in the learning process they can achieve better learning outcomes, overcome the impediments, and gradually start to develop computational thinking.

The second research question tried to investigate relevant studies to gamification and computational thinking in learning and education. There is not a sytematic recording of studies related to gamification and computational thinking subject area. However, a positive observation after examining the existing literature, is that with the right use of game mechanics and elements, gamification has the potential to support students to acquire the necessary problem-solving skills, required to start to develop computational thinking.

The third research question aimed to identify STEM applications that utilize gamification to cultivate computational thinking in primary and secondary education. A set of STEM applications were described in detail with scope of proposing new findings on how to effectively use computational thinking and gamification in school learning. The findings indicated that the above-mentioned applications include gamification features that can help students to improve their learning and cultivate computational thinking skills.

CONCLUSIONS

The rapid development of technology seems to affect various fields, including education. Students should be

https://doi.org/10.56294/sctconf2024659

prepared for the digital skills of the 21st century by developing critical and analytical thinking and computational skills for life and careers in the digital world. Gamification arises like a promising solution to boost students' motivation for learning. There are many learning theories related to gamification which can help students to be autonomous in their learning and incentivize them to develop computational thinking skills. Furthermore, the existence of STEM applications which have been designed with suitable gamification features tailored to learners' needs, seem to help students to develop computational thinking, by attracting their interest in learning through gameplay. Nevertheless, authors have noticed that few documents exist in literature examining computational thinking in relation to gamification in education. Thus, more future studies can add significant findings to this research area for the benefit of students.

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FINANCING
The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

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