
**International Journal of Innovation and Learning**

ISSN online: 1741-8089 - ISSN print: 1471-8197
https://www.inderscience.com/ijil

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**DOI:** 10.1504/IJIL.2024.10056340

**Article History:**

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|---|---|
| Received: | 23 August 2022 |
| Last revised: | 17 November 2022 |
| Accepted: | 26 November 2022 |
| Published online: | 01 December 2023 |

# Identifying influential factors in computational thinking research via game-based learning: a comprehensive content analysis

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**Abstract:** This paper aims to review the research on developing computational thinking (CT) through game-based learning (GBL). The study is conducted over two periods, period 1 from 2010 to 2015 and period 2 from 2016 to 2020. A total of 41 published qualified articles were found based on keywords. The content analysis from the research articles provides the principal characteristics, the profile of international publication patterns and influential factors. The results indicate that the main characteristics are elementary schools for research background. The profile of international publication trends in the study is leading in the USA, ranking first among selected publications from the journal of *Computers and Education*, and the widespread authors in this period. Influential factors are Scratch popular language programming/tool. Moreover, to develop CT via GBL, educational effectiveness, design game, confidence, engagement, learning tool, and teaching method education are the factors indicated in the qualified research during the past 11 years.

**Keywords:** computational thinking; game-based learning; GBL; content analysis; literature review; education effectiveness.

**Reference** to this paper should be made as follows: Chen, L-H. and Nguyen, H.T.T. (2024) 'Identifying influential factors in computational thinking research via game-based learning: a comprehensive content analysis', *Int. J. Innovation and Learning*, Vol. 35, No. 1, pp.38–58.

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## 1 Introduction

Computational thinking (CT) has become imperative in the digital age in recent years (Israel-Fishelson and Hershkovitz, 2020). CT has obtained a lot of interest among policymakers, educators, practitioners, researchers, and the general public, including computer enthusiasts and parents, all around the world (Grover et al., 2015; Hershkovitz et al., 2019; Luo et al., 2020; Pérez-Marín et al., 2020; Zhang and Nouri, 2019). CT demonstrates skills and attitudes (Hershkovitz et al., 2019), and everyone will be happy to acquire and implement. CT is a technique for solving issues that blends CS programming principles with logical thinking and can be applied in any discipline to solve problems, despite the challenge (Kazimoglu, 2020). One definition of CT is as a method for solving problems that rely on mental tools and computational methods, with parallelism, heuristic reasoning, and the abstraction and fragmentation of challenge commissions being the most vital aspects (Israel-Fishelson and Hershkovitz, 2020). CT is a procedure for identifying and resolving issues (Kalelioglu et al., 2016), which are not hampered by a single field or discipline. It has proven vital in the analysis of a wide range of real-world computing issues and the development of novel knowledge in a variety of domains (Lin et al., 2020). CT is defined as a skill using ideas from computer science to create systems, resolve issues, and analyse human behaviour (Pérez-Marín et al., 2020). CT is believed to support students in advancing their skills to solve issues, knowledge, and cognition in various areas (Hershkovitz et al., 2019). Researchers now believe that CT can assist pupils in studying Science, Technology, Engineering and Mathematics (STEM) professions and a broader range of subjects (Israel-Fishelson and Hershkovitz, 2020). CT is one of the eight techniques that should be included in K-12 science classes (Hershkovitz et al., 2019). The goal of the attempt is to teach young students to CT (Chen et al., 2017), which is now widely regarded as a skill that everyone needs. In light of the literature review's findings, learning basic programming skills is a very effective

technique for someone to comprehend the concepts of CT (Kanaki and Kalogiannakis, 2018). CT skills must be taught in elementary, middle, and high school (Atmatzidou and Demetriadis, 2016; Snodgrass et al., 2016) to start students' cognitive growth at a younger age (Buitrago Flórez et al., 2017).

Educational digital games are becoming increasingly popular (Weintrop et al., 2016) as a tool (Bers et al., 2014; Jenson and Droumeva, 2016) to bring play into the classroom (Sáez-López et al., 2016). Digital games have gained popularity as an educational method since they turn to study enjoyable, and as a result, increase learning experiences and bring instructional activities to the forefront of students' minds (Kanaki and Kalogiannakis, 2018). These programming environments are appealing to young people as motivators (Pellas and Peroutseas, 2017). While interest-driven activity is still vital, increasingly structured CS programmes intentionally teach and analyse CT practices, which combine problem-solving, CT skills, and computing discipline principles (Grover et al., 2017). Visual programming environments are available for beginning programmers emphasising the advantages of programming behaviours for game-based learning (GBL) problem-solving methods (Panskyi et al., 2019).

CT has been included in school curricula all across the world (Voogt et al., 2015), and many online platforms, particularly GBL environments, are currently encouraging its growth (Hershkovitz et al., 2019). In various situations, a crucial component of informal education in the modern world increasingly emphasises CT and game activities for young learners (Sharma et al., 2019). As part of their educational programme or outreach programme (Libeskind-Hadas and Bush, 2013), an increasing number of organisations are developing and delivering coding game activities (Sharma et al., 2019). Children develop CT skills (Nouri et al., 2020), problem-solving methods, and abstract thinking through the process of creative programming (Choi et al., 2017) in a game-based environment (Panskyi et al., 2019). When learning to programme, three themes connected to CT skills emerged: computational concepts, computational viewpoints and computational practices. Instructors believe that when students programme, they improve CT skills (Nouri et al., 2020). For learners' CT, a puzzle-based algorithm learning programme is helpful (Choi et al., 2017). A fundamental aspect of current informal learning is CT and game coding activities for young students in various contexts. Consequently, a growing number of organisations are designing and offering coding activities as part of their outreach efforts or educational programmes. The design of these coding game activities is critical for meaningful engagement and collaboration (Sharma et al., 2019).

Children's perspectives were affected by highly engaging (Ching et al., 2018) and cooperative coding game exercises (Sharma et al., 2019). The authors discovered that gameplay provides a fun setting, and CT skills can develop through collaborative learning (Turchi et al., 2019). The study underscores the vital leverage for CS access in elementary classrooms to enhance CT and motivation (Bhatt et al., 2021) in coding game sessions among young students. To thrive in today's digital world, they grow crucial soft skills such as imagination, cooperation, abstraction and perseverance (Tran, 2019). Students who showed a greater interest in programming had a greater understanding of programming's relevance, influence, creativity, and greater programming self-efficacy in CT education. Additionally, pupils with a more positive collaboration attitude have outstanding self-creation efficiency compared to others (Kong et al., 2018). Through hands-on computer experiments to enhance CT, students are engaged and motivated in problem-solving actively, learning and improving the process of a sharper sense of

intuition for grasping complicated ideas. Children construct games while studying physical science, offering the essential concepts of object-oriented CT and programming, although these principles are not mentioned explicitly (Kanaki and Kalogiannakis, 2018).

According to previous studies, researchers are fascinated by students' CT skills and the advantages of GBL. Therefore, the effectiveness of GBL connected with CT skills has drawn extraordinary attention from researchers. Moreover, the majority of the published review studies of CT development mostly concentrated on learning CT via Scratch (Zhang and Nouri, 2019), educational technology (Ching et al., 2018), and learning and teaching CT (Hsu et al., 2018). However, there is not enough substantial evidence on CT through GBL research on factors influencing it. The study aims to help student learning and teacher teaching and to recognise the current circumstance for supporting researchers' future research orientation. An overview of students' CT skill growth as a consequence of GBL is necessary. The study chose the quality articles published between 2010 and 2020 from two massive reputable and qualified data sources – Web of Science (WoS) and Scopus. This method takes advantage of state-of-the-art research on GBL to assist students in arising CT skills. In addition, it gives substantial proof of research trends during this period. The focus of this study is on three main issues, such as the profile of global publication trends, the main characteristics, and factors of influence on students through learning game-based to raise CT skills. This setting can be beneficial for researchers to monitor potential changes in CT skills via GBL during the periods. The present study, thus, aims to provide an in-depth content analysis for the characteristics of the research on CT through GBL from 2010–2020, and we pursue to answer the following research questions:

RQ1 What is the profile of the international publication patterns?

RQ2 What are the main characteristics of the developments of CT via GBL studies?

RQ3 What factors are generated in the development of CT via GBL studies?

The methodology of this investigation is covered in Section 2, followed by results and discussion in Section 3, and we conclude the study in Section 4.

## 2 Methodology

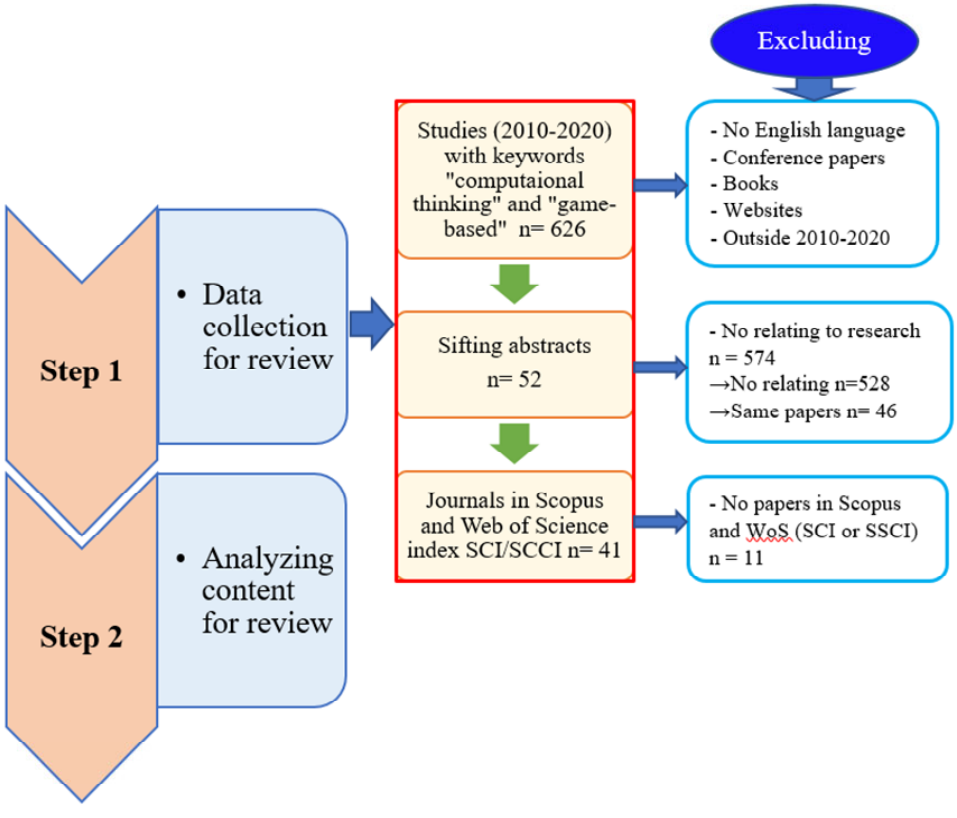
The procedure and methods in Figure 1, utilised to perform this research have been discussed. The research technique is conceptualised into two steps namely collecting the review and analysing the content for the review (Bhatt et al., 2021). The following steps of the paper offer detailed discussions when collecting the review.

### *2.1 Step 1: data collection for review*

Data are collected for review from the Scopus and WoS databases for published academic articles (Tang et al., 2020). The authors decide to use these databases because of their massive and quality database. The WoS database has an enormous scope of features and a strong reputation as a premier database, with a more expansive range of publications and a more selective approach such as international scientific indexing (ISI) and impact elements of the journal in Journal Citation Report (Bhatt et al., 2021). The WoS covers a wide range of high-quality, high-impact journals in a variety of fields,

including science education and educational technology (Li and Tsai, 2013). The reviewed literature was discovered using the WoS database, which included journals from the Social Sciences Citation Index (SSCI) and the Sciences Citation Index (SCI) databases (Bhatt et al., 2021; Li and Tsai, 2013; Tang et al., 2020). The Scopus database was employed as a literature source to expand the coverage of investigations. Scopus is the largest of the world's abstract and citation databases (Gupta et al., 2020) of peer-reviewed scientific literature, as well as high-quality web sources, according to its website (Li and Tsai, 2013).

**Figure 1** The procedure and methods (see online version for colours)




The process of collecting data is vital in the paper for investigating a content analysis of literature reviews. This research combines CT and GBL, which are two interdependent concepts. They are keywords used to search for published papers. The Scopus and WoS databases are the foremost source to search for keywords, as CT and GBL research articles were published from 2010 to 2020. Searching for literature was employed in February 2020.

The following approaches were used to identify the reviewed research papers. In the search for journal articles from a keyword, CT was combined with a keyword, game-based, using the 'and' operator in Scopus. The keyword search yielded 24 papers, then selected as original papers. For identifying the number of journals for the research,

backward citations of original papers were used to identify journals that focused on CT via GBL. Only journal papers published in English were taken into consideration. Conference papers have also eliminated this journal during the investigation because instead of conferences, researchers from several academic areas favour publishing in journals (Gupta et al., 2019). Book chapters and website links were found and removed from the results. Therefore, this search resulted in 626 journal articles. Sifting abstracts of the papers have addressed the domain of CT through GBL. It was found that 528 papers were not related to the topic mentioned. This investigation resulted in 52 journal articles after removing 46 duplicate journals. To ensure the quality of research, eight journals that were not in the Scopus database and not in SCI or SSCI index from the WoS database were not considered. At the end of the search process, 41 qualified journals were sifted for this study by the WoS and Scopus databases and the stated topic.

### *2.2 Step 2: analysing the content of the review*

The content analysis period was conducted in this paper as the second stage. A grounded theory content analysis' main goal classifies scientific data to conceptually and categorically discover the fundamental dynamics. According to a prior study, text analysis can help researchers uncover key trends and critical discoveries that have yet to be revealed (Tang et al., 2020).

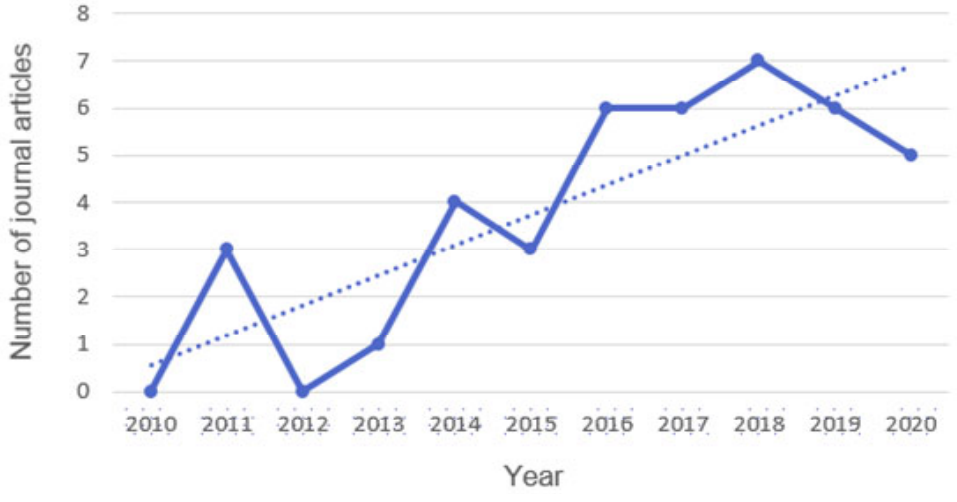
An approach of content analysis is performed on the identified journal articles. The vital information which matches the research questions were identified initially (Li and Tsai, 2013). In light of the above-stated research questions, the profile of the international publication, main characteristics, and factors for the development of CT via GBL was identified from the research content. The profile of the international publication was classified according to the most productive countries, the most active authors, and the most influential journals. The main characteristics and factors for the development of CT via GBL were detected according to background settings. Factors for the development of CT via GBL were divided into pedagogy, cognition, attitude, curriculum and psychomotor.

## 3 Results

### *3.1 The profile of international publication trends*

A summary of selected publications on CT through GBL in two periods, period 1 (P1) (2010–2015) and period 2 (P2) (2016–2020), is shown in Figure 2. In P1 (2010–2015), a trend of sluggish growth in terms of journal articles, countries, authors, and journals occurs, followed by a more pronounced upward tendency in P2 (2016–2020). The curated journal articles tend to increase from 2010 to 2020. In P1, the number of articles in 2012 decreased to balance 2010 and continued to grow until 2014, at the end of P1, 2015 decreased slightly. The number of papers continued to grow in 2016 to reach the balance of 2017. Then, the published articles increased slowly in 2018 and gradually decreased towards the end of P2. The upward trends of the publications help researchers observe potential changes in CT publications through GBL as the productive countries, the active authors, and the influential journals.

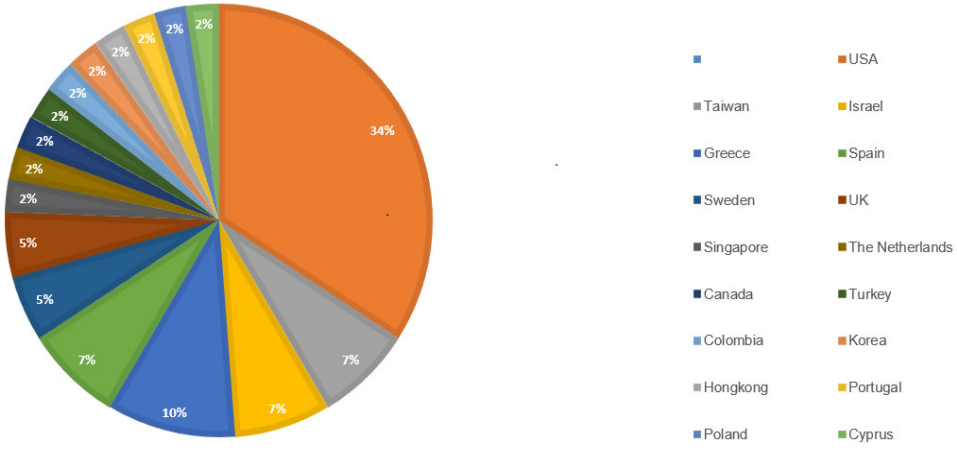
**Figure 2** The trend of published journal articles between 2010 and 2020 (see online version for colours)




## *3.2 The productive countries*

According to the analysis results from the WoS and Scopus sources, the 41 journal articles found between 2010 and 2020 were published in 17 different countries. In P1 and P2, the most published articles were the USA at 34% and Greece at second with 10%. Taiwan, Israel, and Spain with 7%, and Sweden and the UK with 5% are the 4th and 5th countries. 25% of the remaining countries account for 2% of publishing. The percentage of journal articles distributed into countries is shown in Figure 3.

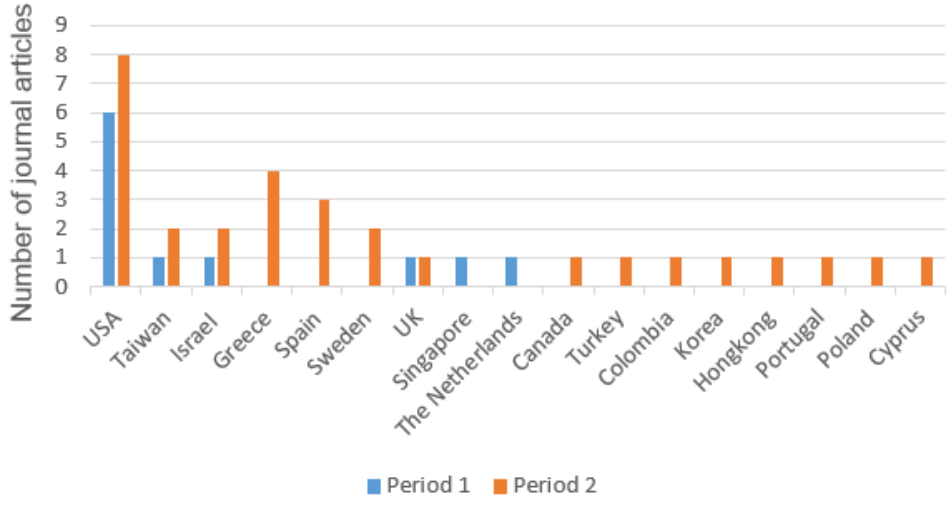
**Figure 3** Country classification of journal article (see online version for colours)




Moreover, the USA is the top published article in periods 1 (n = 6) and 2 (n = 8) relating to CT through GBL. In Stage 2, the top 2 and 3 countries in publishing are Greece (n = 4) and Spain (n = 3), respectively. Taiwan, Israel, and Sweden are the top 4 countries in

publishing also in P2. The remaining countries are in the top 5 in publishing articles. Accordingly, the quantity of articles released during the second period is twice that of the first period. The classification of papers into countries is presented in Figure 4.

**Figure 4** Classification based on country (see online version for colours)




It is found that the USA is the leading country in interest in the topic of developing CT through GBL from 2010 to 2020. Behind the USA is Greece, and then the scope of this topic spread to other countries. In P1 from six countries interested in this topic increased three times to 16 countries in P2.

### *3.3 The prolific authors*

Table 1 represents the authors of the selected articles in a wide range in both periods. That means that each journal article has a different author. From two large and reputable data sources – WoS and Scopus, 41 selected publications were on 41 separate authors. P1 has 11 authors from 11 articles. The number of authors interested in CT through GBL in P2 is three times more than in P1.

### *3.4 The influential journals*

During 2010 and 2020, the first and second most popular journals were *Computers and Education* and *Computers in Human Behavior* at 22% and 10%, respectively. The top 3 journals (7%) in popularity are the *Journal of Educational Computing Research*, *ACM Transactions on Computing Education* and *The International Journal of Game-Based Learning*. The two types of journals in the top 4 are 5%, and 33% of the remaining journals are 2%. The classification of selected articles into quality journals is presented in Figure 5.

**Table 1** Author of the selected article

| *Year* | *No.* | *Author* | *Country* |
|---|---|---|---|
| 2011 | 1 | Matthew Berland | USA |
| | 2 | Kazimoglu, Cagin | UK |
| | 3 | Ursula Wolz | USA |
| 2013 | 4 | Libeskind-Hadas, Ran | USA |
| 2014 | 5 | Lye, Sze Yee | Singapore |
| | 6 | Bers, Marina Umaschi | USA |
| | 7 | Chang, Chih-Kai | Taiwan |
| | 8 | Rubinstein, Amir | Israel |
| 2015 | 9 | Joke Voogt | The Netherlands |
| | 10 | Repenning, Alexander | USA |
| | 11 | Shuchi Grover | USA |
| 2016 | 12 | Saez-Lopez, Jose-Manuel | Spain |
| | 13 | Jennifer Jenson | Canada |
| | 14 | Filiz Kalelioglu | Turkey |
| | 15 | David Weintrop | USA |
| | 16 | Atmatzidou, Soumela | Greece |
| | 17 | Snodgrass, Melinda R. | USA |
| 2017 | 18 | Buitrago Florez, Francisco | Colombia |
| | 19 | Grover, Shuchi | USA |
| | 20 | Chen, Guanhua | USA |
| | 21 | Nadia Benakli | USA |
| | 22 | Choi, Jeongwon | Korea |
| | 23 | Pellas, Nikolaos | Greece |
| 2018 | 24 | Kanaki, Kalliopi | Greece |
| | 25 | Jose Garcia-Penalvo, Francisco | Spain |
| | 26 | Kong, Siu-Cheung | Hong Kong |
| | 27 | Yu-Hui Ching | USA |
| | 28 | Hsu, Ting-Chia | Taiwan |
| | 29 | Jose Marcelino, Maria | Portugal |
| | 30 | Garneli, Varvara | Greece |
| 2019 | 31 | Panskyi, Taras | Poland |
| | 32 | Turchi, Tommaso | UK |
| | 33 | Hershkovitz, Arnon | Israel |
| | 34 | Yune Tran | USA |
| | 35 | Jalal Nouri | Sweden |
| | 36 | Zhang, LeChen | Sweden |
| 2020 | 37 | Lin, Szu-Yin | Taiwan |
| | 38 | Kazimoglu, Cagin | Cyprus |
| | 39 | Israel-Fishelson, Rotem | Israel |
| | 40 | Diana Pérez | Spain |
| | 41 | Luo, Feiya | USA |

**Figure 5** Distributing articles into top journals (see online version for colours)

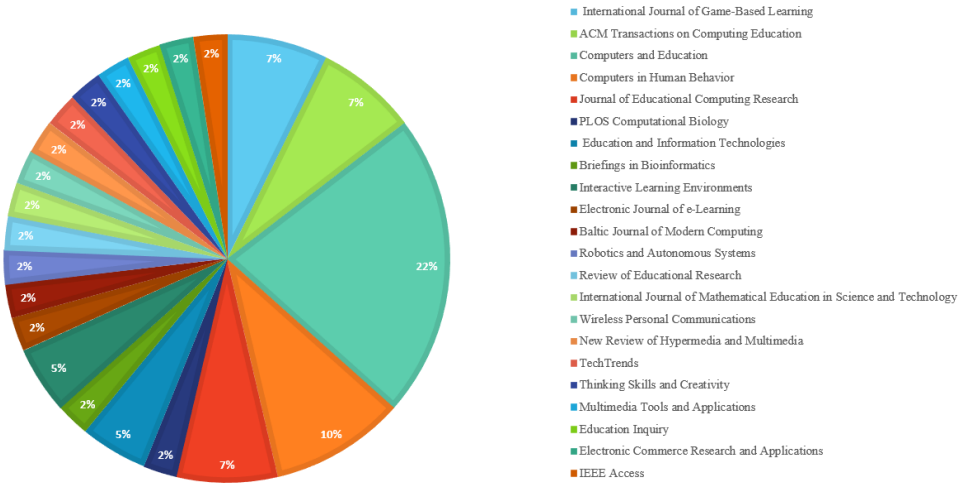
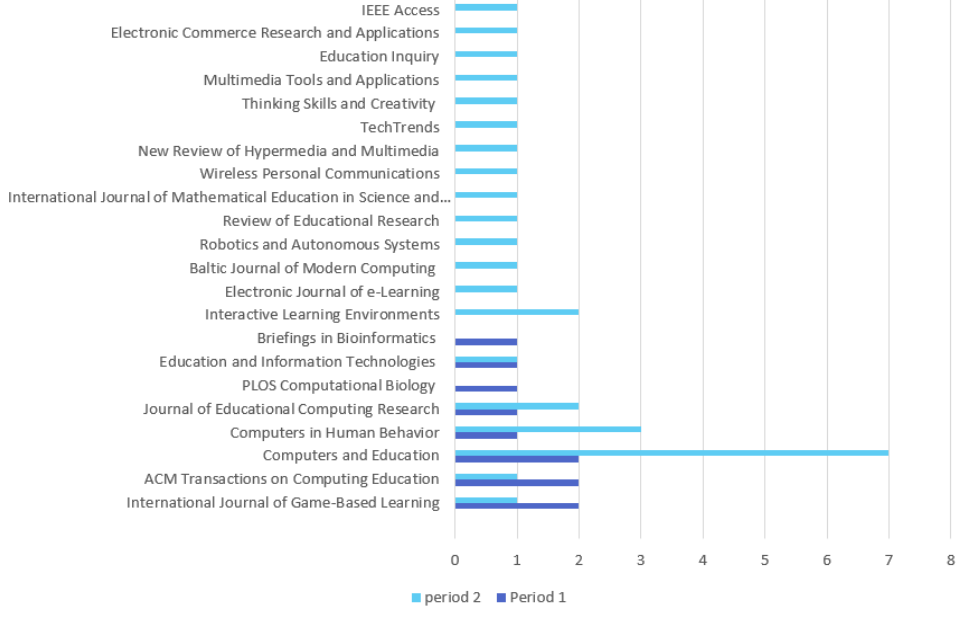



**Figure 6** Title of leading journals (see online version for colours)




The selected studies on CT through GBL have been published in 22 quality journals. The highlight is that the number of articles distributed in journals in P2 is more than in P1. For example, articles are published in eight journals in P1 and 20 in P2. Remarkably, the top journals are *Computers and Education* in the first period and *Computers in Human Behavior* in Stage 2. *ACM Transactions on Computing Education* and *Computers and Education* in the second stage, and *Journal of Educational Computing Research* and *Interactive Learning Environments* in P2 are the top 3 journals. Regarding the published

articles in the remaining journals, the number of journals in P2 was three times higher than in P1. The title of the leading journals is shown in Figure 6.

Figures 5 and 6 show that the journal *Computers and Education* related to the development of CT through GBL was the most influential during the period 2010 to 2020. Next is the journal *Computers in Human Behavior*. After that, the number of journals related to this topic increased sharply by 2.5 times in P2 compared to P1.

### *3.5 Background setting*

Background data is used in studies about developing CT via game-based. Participants included in the selected research areas are higher education, high school, middle school, elementary, preschool, and others. The outcomes of the background settings are shown in Figure 7. In the divide into participants in the research, higher education (n = 7) has the most numerous followed by middle school (n = 5), preschool (n = 3), and elementary (n = 2) in Stage 1. High school is the low study participant in Stages 1 and 2 and the lowest in other participants, such as teachers and pre-university. However, elementary (n = 21) in Stage 2 increases more than ten times in Stage 1. Thus, this participant is at the top of the selected studies. Middle school (n = 14) is the top 2 participants in the published research, tripling P1. It was followed by preschool (n = 11) despite a nearly quadrupling P1. It is followed by preschool (n = 11) despite quadrupling from Stage 1. Although higher education was in the top 1 in P1, it decreased two times in Stage 2 (n = 5). So it is only higher than high school (n = 5) and other participants (n = 4).

**Figure 7** Participants in the selected research (see online version for colours)

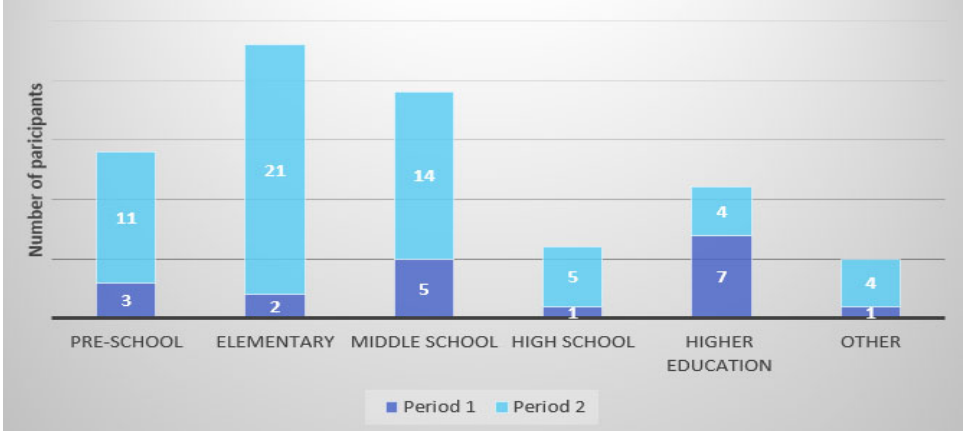
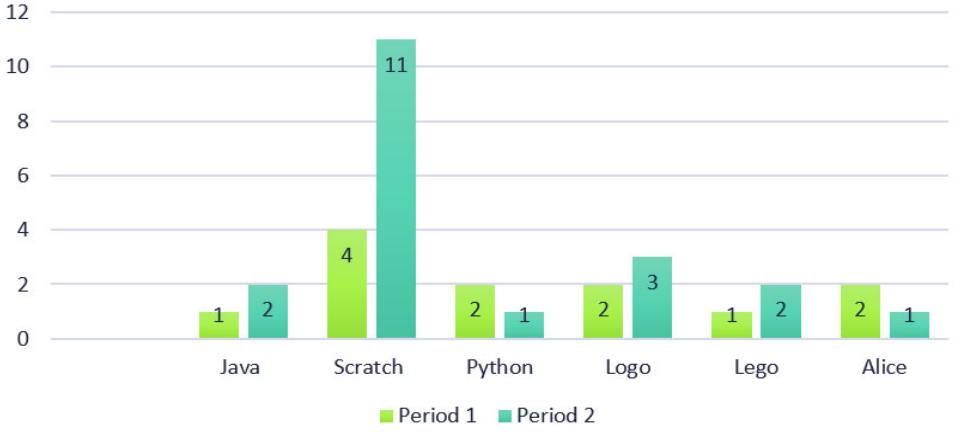



Figure 7 shows that researchers in the field of CT through GBL are the most attracted to higher education in period one from 2010 to 2015 and least concerned in high school and other participants. Next to the researchers excited are middle school, preschool, and elementary school in descending order of priority. In P2 from 2016 to 2020, researchers are particularly attentive to elementary in CT through GBL. Next, middle school and preschool ranked in the top 2 and 3 of interest, respectively. High school is of higher interest than higher education and other participants. That means that higher education in Stage 2 is of the smallest amount of fascination even though they are of most interest to researchers at Stage 1.

### *3.6 Classification of programming languages/tools*

Programming languages/tools used in the published studies of CT through GBL are considered. The results show that the programming languages/tools are intensively diverse for Stages 1 and 2. Figure 8 shows that some programming languages/tools are found from 2010 to 2020, namely Java, Scratch, Python, Logo, Lego and Alice. In particular, Scratch leads both periods in usage, with P1 (n = 4) leaping ahead of P2 (n = 11). Next is Logo, periods 1 and 2 (n = 2-3). Two types of programming languages/tools are the same in two stages, Alice and Python with Stages 1 and 2 (n = 2-1), and Java and Lego with Stages 1 and 2 (n = 1-2) reversely. In addition, the number of programming languages used in P1 is nine but not found in Stage 2. Appendix demonstrates clearly that the number of types of programming languages (n = 35) increased significantly in Stage 2 but not found in Stage 1, such as block-based (n = 3), Code.org, Scratch4SL, Robotics (n = 2), the others (n = 1). That demonstrates the variety of programming languages used in CT through GBL.

**Figure 8** Programming language/tool (see online version for colours)




Based on the above data, there is a high upward trend in the number and variety of programming languages in P2, especially Scratch. Researchers promote the use of numerous programming languages for GBL to help students develop CT.

### *3.7 Classification of characteristic factors*

In this study, the factors that influence CT via GBL include cognitive domain, curriculum, attitude, pedagogical method and psychomotor. The cognitive domain is understood as the learning results of domains on academic, knowledge, mental, problem-solving, educational effectiveness, creation, reflexive education, critical education, creative self-efficacy, programming self-efficacy, abstract thinking, perception and technology at home. The curriculum is described as related to integrating CT in curriculum, curriculum design, design course, guidelines, design games, support guidance programmes, association computational creativity and CT, and supplements to the framework. Attitude is included motivation, engagement, confidence, enthusiasm, fun, commitment, fascination, joyousness, behaviours, persistence and interest. The

pedagogical method is considered the teacher's teaching method toward teaching and learning activities such as teaching method, teaching tool, learning tool and learning activities. The pedagogical method helps students improve learning result, attitude and skills. Psychomotor has included abilities, social, intuition and physical skills.

**Table 2** Classification of influencing factors

| *Factor* | *Characteristic* | *P1* | *P2* |
|---|---|---|---|
| Cognitive domain | Learning programming | 1 | 0 |
| | Problem-solving | 1 | 3 |
| | Mature understanding | 1 | 1 |
| | Educational effectiveness | 0 | 3 |
| | Creating own games | 0 | 1 |
| | Developing reflexive education | 0 | 1 |
| | Developing critical education | 0 | 1 |
| | Creative self-efficacy | 0 | 1 |
| | Programming self-efficacy | 0 | 1 |
| | Abstract thinking | 0 | 1 |
| | Perception | 0 | 1 |
| | Technology at home | 0 | 1 |
| Curriculum | Integrating CT into the curriculum | 2 | 0 |
| | Curriculum design | 2 | 1 |
| | Design course | 2 | 2 |
| | Guideline | 1 | 2 |
| | Design game | 0 | 2 |
| | Support guidance programmes | 0 | 1 |
| | Association computational creativity and CT | 0 | 1 |
| | Supplements to framework | 0 | 1 |
| Attitude | Positive | 1 | 0 |
| | Interest | 1 | 2 |
| | Motivation | 1 | 5 |
| | Confidence | 0 | 2 |
| | Engagement | 0 | 3 |
| | Enthusiasm | 0 | 1 |
| | Fun | 0 | 1 |
| | Commitment | 0 | 1 |
| | Fascinating | 0 | 1 |
| | Playful | 0 | 1 |
| | Behaviours | 0 | 1 |
| | Persistence | 0 | 1 |

**Table 2** Classification of influencing factors (continued)

| *Factor* | *Characteristic* | *P1* | *P2* |
|---|---|---|---|
| Pedagogical method | Corrective instruction | 1 | 0 |
| | Teaching tool | 1 | 3 |
| | Information processing activities | 1 | 0 |
| | Scaffolding and reflection activities | 1 | 0 |
| | Applied activities | 0 | 1 |
| | Activities | 0 | 1 |
| | Learning activity | 0 | 1 |
| | Learning strategy | 0 | 1 |
| | Collaborative learning | 0 | 1 |
| | Learning tool | 0 | 2 |
| | Teaching method | 0 | 4 |
| | Teaching strategy | 0 | 1 |
| | Refine pedagogy | 0 | 1 |
| | Student-specific supports | 0 | 1 |
| | Instrument | 0 | 1 |
| Psychomotor | Thinking skills | 1 | 0 |
| | Computing experiences | 1 | 1 |
| | Connects to STEM | 0 | 1 |
| | Developing an intuition | 0 | 1 |
| | Social skill | 0 | 1 |
| | Cognitive skill | 0 | 1 |
| | Soft-skills | 0 | 1 |
| | General skills | 0 | 1 |

The results of the factors are shown in Table 2 that influence the development of CT through GBL. They are classified into the cognitive domain, curriculum, attitude, pedagogical method, and psychomotor. According to the cognitive domain, only three characteristics in P1 and nine in P2 are interesting. Researchers are interested in problem-solving (n = 1-3), educational effectiveness (n = 0-3), and mature understanding (n = 1-1) at Stages 1 and 2, but in Stage 2, problem-solving, and educational effectiveness (n = 3) tripled in Stage 1. Learning programming only focuses on a period one without 2. In Stage 2, researchers are more interested in educational effectiveness (n = 2) than the others (n = 1), such as creating their games, developing reflexive education, developing critical education, programming self-efficacy, self-efficacy in creativity, abstract reasoning, perception, and technology use at home. In terms of the curriculum domain, eight characteristics are interesting. Curriculum design (n = 2-1), design a course (n = 2-2), and guideline (n = 1-2) are in periods 1 and 2. In Stage 1, there is only an issue focused on integrating CT into the curriculum. Four new characteristics at Stage 2 without 1, namely designing the game (n = 2), support guidance programmes (n = 1), association computational creativity and CT (n = 1), and supplements to the framework (n = 1) abstracted to the researchers. In the attitude, nine new features in period two are

noticed, in particular, confidence (n = 2), engagement (n = 3), and the others (n = 1). There are two features in both periods, interest (n = 1-2) and confidence (n = 1-5), only positive in P1.

With the pedagogical method, researchers are particularly interested in teaching students. In P1, there are four features of interest such as corrective instruction, information processing activities, scaffolding and reflection activities. The teaching tool is interested in two periods. Stage 2 (n = 3) is three times more than Stage 1 (n = 1). In Stage 2, many features (n = 1-1) are of interest to researchers, especially the teaching method (n = 4), learning tool (n = 2), and others (n = 1).

Regarding psychomotor, like other factors, in Stage 1, only three features are interesting, in which learning performance and computing experiences are in both periods. However, seven characteristics were found by researchers at Stage 2, improvement (n = 2), the others (n = 1) such as connecting to STEM, developing intuition, social skills, cognitive skills, soft skills and general skills.

## 4 Conclusions and discussion

This research aimed to review published papers on developing CT via GBL from 2010 to 2020. The results indicated analysis contents in terms of the profile of the international publication, main characteristics, and factors in the developments of CT via GBL throughout 11 years. In the profile of selected qualification papers, the USA leads focusing on the development of CT via GBL indicated the trend of high-quality publishing in this period. Besides, the authors of sifted articles in a wide range are found, and especially, the authors of P2 are three more than P1. *Computers of Education* is a qualified journal highlighting the most that are explored. In terms of background setting, elementary is most abstracted by researchers during the period.

According to factors influencing CT via GBL, Scratch, the programming language/tool, is engrossed in GBL for developing CT. Scratch has the most attention because of the following. The most widely used computing language is Scratch programming (Ching et al., 2018; Kong et al., 2018) to learn languages, coding, mathematics and 3D model (García-Peñalvo and Mendes, 2018). Scratch was created to be incredibly simple to use (Zhang and Nouri, 2019) by anyone, background, regardless of age, or interests (Marcelino et al., 2018). Programmers can build different scripts in Scratch, a visual programming environment, and learn the fundamentals of programming. Students can share their implemented ideas and computer programmes and post their stories, animations, interactive art and games (Panskyi et al., 2019). However, users go beyond being mere technology consumers and turn into creators in a digitally native civilisation (Marcelino et al., 2018). It is emphasised the significance of enabling students to develop personally relevant programming projects (Hsu et al., 2018; Kong et al., 2018). In the Scratch environment, Brennan and Resnick (2012) are the authors of the CT structure based on students' work (Ching et al., 2018). A web application called Dr. Scratch evaluates Scratch programmes automatically and provides feedback to strengthen CT and programming skills (García-Peñalvo and Mendes, 2018).

Moreover, the factors in P2 increase many times compared to stage 1, like cognitive domain, curriculum domain, attitude, pedagogical method and psychomotor. In detail, educational effectiveness, design game, confidence, engagement, learning tool, and teaching method are hooked by researchers.

When developing CT via GBL, students obtained their cognitive domain with the most prominent is that problem-solving and educational effectiveness. In the last several years, it has become clear that education student is effective in developing skills and learning performance because skills and expertise demonstrate the ability to work and adapt to a dynamic environment in the 21st century. Moreover, CT skills and general skills are identified through digital games. Problem-solving creativity is one of the common themes of 21st-century talents (Nouri et al., 2020). Complex mathematical concepts and problem-solving skills develop through interactive computer games (Benakli et al., 2017). The use of technology to solve problems in an obligatory way is not implied by CT, but it orients students to solve problems via technology (García-Peñalvo and Mendes, 2018). This skill is essential for the 21st century because the ability to solve problems is always appreciated in the information technology age.

Moreover, the results show that a curriculum with design course and design game prevails helps students obtain their achievement and attitude while developing CT via GBL. Design course supports students to improve their learning outcomes (Grover et al., 2015; Libeskind-Hadas and Bush, 2013), learn many various aspects as programming and robotics increase students' interest (Bers et al., 2014), higher confidence (Jenson and Droumeva, 2016), students' social, cognitive and higher order (Pellas and Peroutseas, 2017). When ICT incorporate into the curriculum, students do not just learn to utilise tools but also learn to make tools (García-Peñalvo and Mendes, 2018). Besides, design games are enhanced highly motivated students, large participation rates (Repenning et al., 2015), more engagement (Weintrop et al., 2016), and becomes a novel and captivating way for kids to spend spare time, developing their problem-solving skills and abstract thinking (Panskyi et al., 2019). Video games can improve CT skill development, make it easier for students to learn computer programming (Kazimoglu, 2020), and enhance their learning processes (Benakli et al., 2017). Therefore, a curriculum aligned with the realisation of CT via GBL helps students gain the knowledge and skills required in the digital age.

Students' attitudes are enhanced when CT skills develop through GBL. For example, students are confident in using their CT, improving motivation skills (Kazimoglu, 2020) and engagement in learning (Benakli et al., 2017), problem-solving and comprehending complex concepts (Luo et al., 2020). Student attitudes determine and delineate student success. Students will succeed if students have positive attitudes such as high motivation, confidence, and engagement in learning or adapting to new environments.

The pedagogical method is used in GBL to improve CT skills. The pedagogical method prominently relates to the teaching method, teaching tool, and learning tool to help students grow their performance and attitude. The teaching approach is applied to increase the interests and CT skills of students (Lin et al., 2020), and support learning programming. Students significantly enhance their confidence in using their CT skills (Kazimoglu, 2020). Video games as teaching tools help students engage in learning (Jenson and Droumeva, 2016), support teaching programming to improve CT (Pérez-Marín et al., 2020), and understand abstract concepts and complex problems (Benakli et al., 2017). The suitable method will create learning motivation, attract students' attention to reduce dropout, and improve student learning outcomes in game-based to develop CT. Moreover, psychomotor supports students' grow physical skills, abilities, and interactions with others. Psychomotor helps the student obtain better balance and integration in the learning and living environment.

The findings of this study provide researchers with an overview of research trends in the development of CT through GBL. Through these results, researchers can identify the research participants that have been interested and which programming languages are considered the most. From there, they can take advantage of the next orientation in the future for their research to help achieve the highest efficiency in educating students. Moreover, cognitive domain, curriculum, attitudes, method, and psychomotor are the factors that support students acquire knowledge and skills, and reduce dropout rates. In particular, these factors help students succeed in today's dynamic environment in the digital age.

From the analysis results, this work provides to apprehend the literature construction on CT via GBL papers. Regardless, each methodology has its research limitations. The study is limited till 2020. In this research, keywords are used to search for qualified studies considered likely the first limitation. Two keywords, 'CT' and 'game-based' are used. It should add more keywords in future research. Besides, this research used the source from the WoS to look up journal articles in the SSCI or SCI. In future research, to extend the number of papers, other databases, such as 'Google Scholar' and 'IEEE' should be used to search for quality papers. Besides, to ensure value information, research data should be made a choice the newest. However, in the paper, the research data is used by the WoS and Scopus about CT via GBL. The qualified selected articles are published from 2010 to 2020. In the future, data should select published articles from 2021.

## References

Atmatzidou, S. and Demetriadis, S. (2016) 'Advancing students' computational thinking skills through educational robotics: a study on age and gender relevant differences', *Robotics and Autonomous Systems*, Vol. 75, pp.661–670 [online] https://doi.org/10.1016/j.robot.2015.10.008.

Benakli, N., Kostadinov, B., Satyanarayana, A. and Singh, S. (2017) 'Introducing computational thinking through hands-on projects using R with applications to calculus, probability and data analysis', *International Journal of Mathematical Education in Science and Technology*, Vol. 48, No. 3, pp.393–427 [online] https://doi.org/10.1080/0020739X.2016.1254296.

Bers, M.U., Flannery, L., Kazakoff, E.R. and Sullivan, A. (2014) 'Computational thinking and tinkering: exploration of an early childhood robotics curriculum', *Computers and Education*, Vol. 72, pp.145–157 [online] https://doi.org/10.1016/j.compedu.2013.10.020.

Bhatt, P.C., Kumar, V., Lu, T.C. and Daim, T. (2021) 'Technology convergence assessment: case of blockchain within the IR 4.0 platform', *Technology in Society*, August, Vol. 67, p.101709 [online] https://doi.org/10.1016/j.techsoc.2021.101709.

Brennan, K. and Resnick, M. (2012) 'New frameworks for studying and assessing the development of computational thinking', *Proceedings of the 2012 Annual Meeting of the American Educational Research Association*, Vol. 1, p.25.

Buitrago Flórez, F., Casallas, R., Hernández, M., Reyes, A., Restrepo, S. and Danies, G. (2017) 'Changing a generation's way of thinking: teaching computational thinking through programming', *Review of Educational Research*, Vol. 87, No. 4, pp.834–860 [online] https://doi.org/10.3102/0034654317710096.

Chen, G., Shen, J., Barth-Cohen, L., Jiang, S., Huang, X. and Eltoukhy, M. (2017) 'Assessing elementary students' computational thinking in everyday reasoning and robotics programming', *Computers and Education*, Vol. 109, pp.162–175 [online] https://doi.org/10.1016/j.compedu.2017.03.001.

Ching, Y.H., Hsu, Y.C. and Baldwin, S. (2018) 'Developing computational thinking with educational technologies for young learners', *TechTrends*, Vol. 62, No. 6, pp.563–573 [online] https://doi.org/10.1007/s11528-018-0292-7.

Choi, J., Lee, Y. and Lee, E. (2017) 'Puzzle based algorithm learning for cultivating computational thinking', *Wireless Personal Communications*, Vol. 93, No. 1, pp.131–145 [online] https://doi.org/10.1007/s11277-016-3679-9.

García-Peñalvo, F.J. and Mendes, A.J. (2018) 'Exploring the computational thinking effects in pre-university education', *Computers in Human Behavior*, Vol. 80, pp.407–411, Elsevier Ltd. [online] https://doi.org/10.1016/j.chb.2017.12.005.

Grover, S., Basu, S., Bienkowski, M., Eagle, M., Diana, N. and Stamper, J. (2017) 'A framework for using hypothesis-driven approaches to support data-driven learning analytics in measuring computational thinking in block-based programming environments', *ACM Transactions on Computing Education*, Vol. 17, No. 3 [online] https://doi.org/10.1145/3105910.

Grover, S., Pea, R. and Cooper, S. (2015) 'Designing for deeper learning in a blended computer science course for middle school students', *Computer Science Education*, Vol. 25, No. 2, pp.199–237 [online] https://doi.org/10.1080/08993408.2015.1033142.

Gupta, S., Altay, N. and Luo, Z. (2019) 'Big data in humanitarian supply chain management: a review and further research directions', *Annals of Operations Research*, Vol. 283, Nos. 1–2, pp.1153–1173 [online] https://doi.org/10.1007/s10479-017-2671-4.

Gupta, S., Modgil, S. and Gunasekaran, A. (2020) 'Big data in Lean Six Sigma: a review and further research directions', *International Journal of Production Research*, Vol. 58, No. 3, pp.947–969 [online] https://doi.org/10.1080/00207543.2019.1598599.

Hershkovitz, A., Sitman, R., Israel-Fishelson, R., Eguíluz, A., Garaizar, P. and Guenaga, M. (2019) 'Creativity in the acquisition of computational thinking', *Interactive Learning Environments*, Vol. 27, Nos. 5–6, pp.628–644 [online] https://doi.org/10.1080/10494820.2019.1610451.

Hsu, T.C., Chang, S.C. and Hung, Y.T. (2018) 'How to learn and how to teach computational thinking: suggestions based on a review of the literature', *Computers and Education*, Vol. 126, pp.296–310 [online] https://doi.org/10.1016/j.compedu.2018.07.004.

Israel-Fishelson, R. and Hershkovitz, A. (2020) 'Persistence in a game-based learning environment: the case of elementary school students learning computational thinking', *Journal of Educational Computing Research*, Vol. 58, No. 5, pp.891–918 [online] https://doi.org/10.1177/0735633119887187.

Jenson, J. and Droumeva, M. (2016) 'Exploring media literacy and computational thinking: a game maker curriculum study', *Electronic Journal of E-Learning*, Vol. 14, No. 2, pp.111–121.

Kalelioglu, F., Gulbahar, Y., Kukul, V., Kalelioğlu, F. and Gülbahar, Y. (2016) 'A framework for computational thinking based on a systematic research review', *Baltic J. Modern Computing*, Vol. 4, No. 3, pp.583–596 [online] https://www.researchgate.net/publication/303943002.

Kanaki, K. and Kalogiannakis, M. (2018) 'Introducing fundamental object-oriented programming concepts in preschool education within the context of physical science courses', *Education and Information Technologies*, Vol. 23, No. 6, pp.2673–2698 [online] https://doi.org/10.1007/s10639-018-9736-0.

Kazimoglu, C. (2020) 'Enhancing confidence in using computational thinking skills via playing a serious game: a case study to increase motivation in learning computer programming', *IEEE Access* [online] https://doi.org/10.1109/ACCESS.2020.3043278.

Kong, S.C., Chiu, M.M. and Lai, M. (2018) 'A study of primary school students' interest, collaboration attitude, and programming empowerment in computational thinking education', *Computers and Education*, Vol. 127, pp.178–189 [online] https://doi.org/10.1016/j.compedu.2018.08.026.

Li, M.C. and Tsai, C.C. (2013) 'Game-based learning in science education: a review of relevant research', *Journal of Science Education and Technology*, Vol. 22, No. 6, pp.877–898 [online] https://doi.org/10.1007/s10956-013-9436-x.

Libeskind-Hadas, R. and Bush, E. (2013) 'A first course in computing with applications to biology', *Briefings in Bioinformatics*, Vol. 14, No. 5, pp.610–617 [online] https://doi.org/10.1093/bib/bbt005.

Lin, S.Y., Chien, S.Y., Hsiao, C.L., Hsia, C.H. and Chao, K.M. (2020) 'Enhancing computational thinking capability of preschool children by game-based smart toys', *Electronic Commerce Research and Applications*, Vol. 44 [online] https://doi.org/10.1016/j.elerap.2020.101011.

Luo, F., Antonenko, P.D. and Davis, E.C. (2020) 'Exploring the evolution of two girls' conceptions and practices in computational thinking in science', *Computers and Education*, Vol. 146 [online] https://doi.org/10.1016/j.compedu.2019.103759.

Marcelino, M.J., Pessoa, T., Vieira, C., Salvador, T. and Mendes, A.J. (2018) 'Learning computational thinking and scratch at distance', *Computers in Human Behavior*, Vol. 80, pp.470–477 [online] https://doi.org/10.1016/j.chb.2017.09.025.

Nouri, J., Zhang, L., Mannila, L. and Norén, E. (2020) 'Development of computational thinking, digital competence and 21st century skills when learning programming in K-9', *Education Inquiry*, Vol. 11, No. 1, pp.1–17 [online] https://doi.org/10.1080/20004508.2019.1627844.

Panskyi, T., Rowinska, Z. and Biedron, S. (2019) 'Out-of-school assistance in the teaching of visual creative programming in the game-based environment – case study: Poland', *Thinking Skills and Creativity*, Vol. 34 [online] https://doi.org/10.1016/j.tsc.2019.100593.

Pellas, N. and Peroutseas, E. (2017) 'Leveraging Scratch4SL and second life to motivate high school students' participation in introductory programming courses: findings from a case study', *New Review of Hypermedia and Multimedia*, Vol. 23, No. 1, pp.51–79 [online] https://doi.org/10.1080/13614568.2016.1152314.

Pérez-Marín, D., Hijón-Neira, R., Bacelo, A. and Pizarro, C. (2020) 'Can computational thinking be improved by using a methodology based on metaphors and scratch to teach computer programming to children?', *Computers in Human Behavior*, Vol. 105 [online] https://doi.org/10.1016/j.chb.2018.12.027.

Repenning, A., Webb, D.C., Koh, K.H., Nickerson, H., Miller, S.B., Brand, C., Horses, I.H.M., Basawapatna, A., Gluck, F., Grover, R., Gutierrez, K. and Repenning, N. (2015) 'Scalable game design: a strategy to bring systemic computer science education to schools through game design and simulation creation', *ACM Transactions on Computing Education*, Vol. 15, No. 2, pp.1–31 [online] https://doi.org/10.1145/2700517.

Sáez-López, J.M., Román-González, M. and Vázquez-Cano, E. (2016) 'Visual programming languages integrated across the curriculum in elementary school: a two year case study using "scratch" in five schools', *Computers and Education*, Vol. 97, pp.129–141 [online] https://doi.org/10.1016/j.compedu.2016.03.003.

Sharma, K., Papavlasopoulou, S. and Giannakos, M. (2019) 'Coding games and robots to enhance computational thinking: how collaboration and engagement moderate children's attitudes?', *International Journal of Child-Computer Interaction*, Vol. 21, pp.65–76 [online] https://doi.org/10.1016/j.ijcci.2019.04.004.

Snodgrass, M.R., Israel, M. and Reese, G.C. (2016) 'Instructional supports for students with disabilities in K-5 computing: findings from a cross-case analysis', *Computers and Education*, Vol. 100, pp.1–17 [online] https://doi.org/10.1016/j.compedu.2016.04.011.

Tang, K.Y., Chou, T.L. and Tsai, C.C. (2020) 'A content analysis of computational thinking research: an international publication trends and research typology', *Asia-Pacific Education Researcher*, Vol. 29, No. 1, pp.9–19 [online] https://doi.org/10.1007/s40299-019-00442-8.

Tran, Y. (2019) 'Computational thinking equity in elementary classrooms: what third-grade students know and can do', *Journal of Educational Computing Research*, Vol. 57, No. 1, pp.3–31 [online] https://doi.org/10.1177/0735633117743918.

Turchi, T., Fogli, D. and Malizia, A. (2019) 'Fostering computational thinking through collaborative game-based learning', *Multimedia Tools and Applications*, Vol. 78, No. 10, pp.13649–13673 [online] https://doi.org/10.1007/s11042-019-7229-9.

Voogt, J., Fisser, P., Good, J., Mishra, P. and Yadav, A. (2015) 'Computational thinking in compulsory education: towards an agenda for research and practice', *Education and Information Technologies*, Vol. 20, No. 4, pp.715–728 [online] https://doi.org/10.1007/s10639-015-9412-6.

Weintrop, D., Holbert, N., Horn, M.S. and Wilensky, U. (2016) 'Computational thinking in constructionist video games', *International Journal of Game-Based Learning*, Vol. 6, No. 1, pp.1–17 [online] https://doi.org/10.4018/IJGBL.2016010101.

Zhang, L.C. and Nouri, J. (2019) 'A systematic review of learning computational thinking through scratch in K-9', *Computers and Education*, Vol. 141 [online] https://doi.org/10.1016/j.compedu.2019.103607.

## Appendix

*Programming language/tool in each period*

| *Programming language/tool* | *P1* | *P2* |
|---|---|---|
| Java | 1 | 2 |
| Scratch | 4 | 11 |
| Python | 2 | 1 |
| Logo | 2 | 3 |
| Lego | 1 | 2 |
| Alice | 2 | 1 |
| Stagecast Creator | 1 | 0 |
| Cherp | 1 | 0 |
| Toontalk | 1 | 0 |
| ActionScript | 1 | 0 |
| Frogger | 1 | 0 |
| Sokoban | 1 | 0 |
| Byob | 1 | 0 |
| Snap | 1 | 0 |
| AppInventor | 1 | 0 |
| Code.org | 0 | 2 |
| Block-based | 0 | 3 |
| Scratch4SL | 0 | 2 |
| Video game-based | 0 | 2 |
| Visual block | 0 | 1 |
| Game Maker-game | 0 | 1 |
| RoboBuilder | 0 | 1 |
| FormulaT | 0 | 1 |
| Educational robotics | 0 | 2 |
| Lego mindstorms robot | 0 | 1 |

*Programming language/tool in each period (continued)*

| *Programming language/tool* | *P1* | *P2* |
|---|---|---|
| Game programming | 0 | 1 |
| R | 0 | 1 |
| RoboBuilder | 0 | 1 |
| Puzzles (algorithm learning) | 0 | 1 |
| ViMAP | 0 | 1 |
| Matlab | 0 | 1 |
| Turtle Art | 0 | 1 |
| AgentCubes | 0 | 1 |
| Scalable game design | 0 | 1 |
| C | 0 | 1 |
| C + + | 0 | 1 |
| Simulation | 0 | 1 |
| TAPASPlay | 0 | 1 |
| Google's Blockly | 0 | 1 |
| code.org's Blockly | 0 | 1 |
| Analogue | 0 | 1 |
| RoBots | 0 | 1 |
| Text-based | 0 | 1 |
| Arduino robot | 0 | 1 |
| Smart toy | 0 | 1 |
| Tangible user interface (TUI) | 0 | 1 |
| Adhoc game | 0 | 1 |
| CodeMonkey (TM) | 0 | 1 |
| Dash robot | 0 | 1 |
| Blockly app | 0 | 1 |