Students' Perspectives on Game-Based Learning and Computational Thinking

Afra Lathifah*, Asrowi Asrowi, and Agus Efendi

***Abstract*—Currently, in the world of education at various levels, efforts are continuously being made to implement computational thinking skills in learning. Constructivism from computational thinking can guide the suitable learning media, which is becoming a trend in education, i.e., game-based learning. The dominance of game-based learning supports computational thinking well, especially at the junior high school level. Some literature may have discussed computational thinking and game-based learning together or separately. However, this does not rule out the possibility that there is still a lack of information for education providers to implement learning well. Therefore, a systematic review conducted in this study will discuss students' perspectives on game-based learning in supporting computational thinking at the junior high school level. The search using the PRISMA approach was sourced from four reliable databases, namely Sage, Scopus, Taylor and Francis, and Wiley. Keywords used for searches such as "computational thinking", "game", "game-based learning", "junior high school", "middle school", and "secondary school". Thus, the final result of the study found three main themes related to strengths, challenges, and ideal ways of learning in a game-based learning environment in support of computational thinking.**

***Index Terms*—Computational thinking, game-based learning, middle school, systematic review**

I. Introduction

Before being conceptualized by Wing [1], Papert had described the idea of *computational thinking* (CT) found in the classroom but with weak supporting facts [2–4]. According to Papert, computational thinking is about "procedural thinking". Shute and Sun *et al*. [5] stated that computational thinking is the foundation of logical thinking which is not only focused on programming but involves all the components of CT. The CT components were classified by Haseski *et al*. [6] into seven themes related to the context of problem-solving, technology, thinking, personal features, operational features, general quality, and social features. Lyon and Magana [7] also mention that computational thinking has various definitions: pattern recognition, adding mathematical insight, creative problem solving, sequence and debugging, abstraction, automation, generalization, decomposition, evaluation, programming knowledge, representative data, and data analysis. Cansu and Cansu [4] stated that CT is a cognitive performance process of an individual's thinking. Supported, Ezeamuzie and Leung [8] define CT into two important main ideas, concepts related to computer science and cognitive thinking in solving problems. This concludes that computational thinking is multi-sided cognitive thinking to solve problems with or without computers that are useful in the computing world.

Meanwhile, several studies still discuss game-based learning (GBL), gamification, and serious games [9, 10]. The GBL learning environment is usually an environment where students play using non-digital or digital media to provide experiences that lead to changes in student knowledge [11–13]. In detail, the appropriate GBL media is if the media used or developed contains promising learning content according to the curriculum so that students can influence their knowledge [9, 14]. Therefore, game-based learning can also be referred to as educational games because it provides a learning environment with games for students while still following the educational goals or curriculum used.

Computational thinking and game-based learning share the same foundation: constructivism. The pedagogical experience of constructivism can be digital, tangible, or even conceptual [15]. Constructivism theory makes the individual the center of learning. In the learning process associated with Piaget's theory, experience actively influences students to create knowledge related to computational thinking [16]. Furthermore, Papert's learning framework shows that knowledge will be built every time students complete a challenge in a game [17]; the increase in thinking and changing patterns of access to understanding occurred because of the use of technology [18]. This makes the game-based learning environment and CT have a link. Saidin *et al*. [19] and Tatar and Eseryel [20], support that the existence of GBL can encourage computational thinking. Especially at this time, applying GBL in assisting CT is more commonly found at the junior high school level [17, 21].

Many studies have discussed computational thinking and GBL together. However, it was found that teachers had difficulties learning the use of GBL media that supported CT [22], and there was uncertainty in learning outcomes [23]. This is supported by Hooshyar *et al*. [24], who stated that it was difficult to know the effectiveness and reliability of game-based learning on students' performance. Therefore, according to Hsu *et al*. [17] recommendation in learning, it is necessary to understand how students respond when faced with different learning conditions. This study will explore the literature in depth by taking from students' perceptions of learning to use GBL media to support CT. The research results will provide additional information for practitioners or education providers, especially at the junior high school level.

II. Method

Contributions to the theory of computational thinking and

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game-based learning are constantly evolving. Therefore, conducting an in-depth literature review is necessary to determine the renewal of these two topics. This research was performed using a systematic literature review following the PRISMA 2020 approach for article selection [25]. There are several stages based on PRISMA 2020, i.e., identification, screening, and inclusion.

A. Identification

In the identification process, selecting the articles used is carried out. Four databases use to expand the search: Scopus, Wiley Library, Sage, and Taylor and Francis. The method for each database uses an advanced search that filters every important word according to the title, abstract, and keyword sections. After searching using essential words, when grouped, we will get the results for each article in the database without duplicates. The terms used when searching can be seen in Table I.

TABLE I: IDENTIFIED RECORD RESULTS

Keywords	Database	Final Result
- Game computational thinking	Sage	31
- Game based learning computational thinking	Scopus	763
- Game based learning computational thinking junior high school	Taylor and Francis	53
- Game based learning computational thinking middle school - Game based learning computational thinking secondary school	Wiley	22
Total records identified		869

The initial identification results before the screening stage showed that some articles delete. This exception was made based on the results of identification with the help of software (such as Endnote, Mendeley, or Zotero), 72 articles due to duplicate databases, and 66 articles because there was no author information.

B. Screening

The screening process is the process of filtering articles with several provisions through three stages. First, articles conducted the screening in this study based on the title, abstract, and keywords. Even though we have entered important words when searching for the beginning, it does not rule out the possibility of articles that are not appropriate. So it is known that there are 268 articles issued after screening in the title, abstract, and keyword sections. Second, there are 99 article records published that cannot access in total, so it is not easy to read. Furthermore, thirdly, the article is narrowed down again by the provisions that the researcher has determined to produce quality articles that are suitable for use. Category for article screening:

- Year period, research only uses research from 2017-2021 to obtain the latest data.
- Language, research only uses English so as to avoid misinterpretation.
- The type, type of journal record screening does not accept articles from books, conferences, or literature reviews.
- Participant, this research is limited to identifying those in the junior high school category.
- Other reasons include no discussion about the relationship between CT and game-based learning.

C. Included

The final process at PRISMA will produce articles worthy of further explanation in the results and discussion sections. In the PRISMA chart, there are two types: studies and reports. Based on the PRISMA guidelines, reports are usually complementary studies articles published in conferences or books. Because it has used the previous screening provisions, there are no reports ($n = 0$). The final result of PRISMA will discuss 28 study articles.

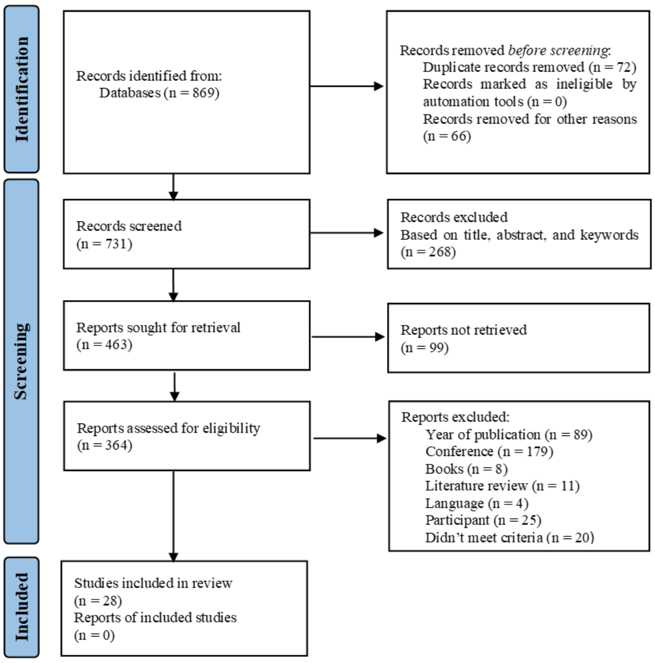

Fig. 1. PRISMA flowchart employed in this study.

As depicted in Fig. 1, the article selection process involved searching four databases using related keywords, yielding 869 articles filtered by categories described in the previous PRISMA stage. The screening results produced articles considered appropriate and relevant to the theme, such as 28 articles focused on game-based learning related to middle school-level computational thinking. Furthermore, Fig. 2 shows that the selected articles published between 2017 and 2021 were the most published in 2019 with 11 articles, followed by 2021 with seven articles, 2020 with six articles, 2018 with three articles, and 2017 with only one article. This show that the publication of game-based learning on computational thinking at the middle school level is a trend in 2019.

The country distribution of the articles used in this study was calculated. Based on Fig. 3, of the 28 articles, the countries relevant to the theme are found on the continent: Europe (Spain 14%, Greece 11%, London and Norway 7% each, Malta, Finland, Poland, and Austria, respectively 3%); followed by America (United States 29% and Brazil 4%);

and Asia (China, Taiwan, Malaysia, and Thailand 4% each).

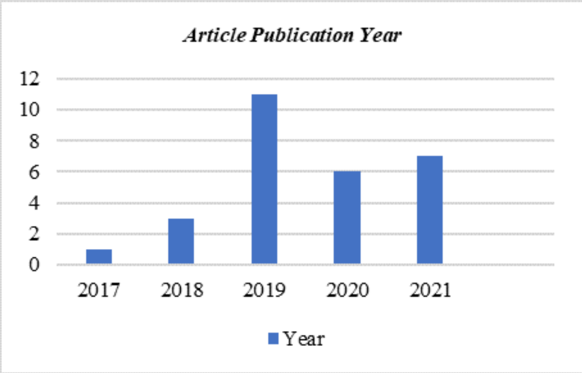

Fig. 2. Diagram of article publication year.

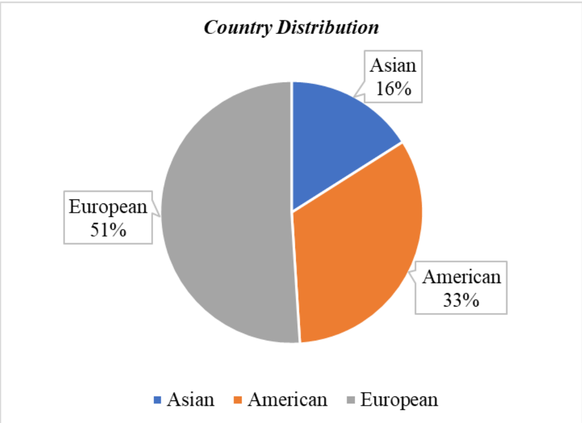

Fig. 3. Country distribution of articles used in this study.

The inductive thematic approach is the process of identifying common themes in each study article. This process involves six stages: introduction, generation, theme search, theme review, definition and naming, and reporting. During the study selection, the introduction stage carries out according to the process shown in the PRISMA flow chart. We then use generation, search, review, definition, and naming to conceptualize the matrix. Based on the matrix concept, the exploration will focus on students' perceptions which produce three main themes: cognitive and affective sides, challenges, and ideal strategies related to game-based learning and computational thinking. The results and discussion section will discuss these three themes in more depth.

III. Results and Discussion

Some of the literature that has been encountered usually starts by discussing: the development of the definition or component of CT to interventions to support it [26], teachers' perspectives on computational thinking [27], the influence of CT development in a particular area [28, 29], specific subjects that support CT [30, 31], and impact of game-based learning in supporting computational thinking [20, 21, 32]. The existing literature provides an opportunity for further exploration. The systematic literature review conducted in this study will discuss game-based learning in supporting computational thinking that focuses on students' points of view at the junior high school level. This is to provide preparation or deeper insight for educators or education providers in the application of learning so that three main discussion points are obtained.

A. Student's Affective and Cognitive Sides

The games presented in a game-based learning environment are usually considered fun, entertaining, enjoyable, and engaging [33–37]. This high interest and enthusiasm lead students to get new game-based learning media experiences [38, 39]. Moreover, according to Altaie and Jawawi [40], game-based learning can be successful because it is created based on students' needs. The activity in the game environment is, of course, the process of students exploring knowledge by interacting with media. The more motivated students are, the longer the media use duration [41–43]. Students who initially may be passive will become active in repeating quizzes or games, either mission that have not been or have been completed [33, 40]. This illustrates that the response of students to game-based learning is very positive.

Game-based learning is instrumental in directing students to improve learning outcomes, especially computational thinking. The CT components found in the study when using GBL at the junior high school level were very diverse. These are problem decomposition, algorithm, abstraction, pattern recognition, generalization, data representation, logic, parallelism, loops, conditional, function, user interaction, synchronization, sequence, debug, flow control, input and variable, data structure, iterative, and operators. The existing CT components direct the research to classify it into two types: the general CT concept and focusing on coding/programming. Data representation and pattern recognition will be categorized into generalizations because of similar characteristics [44]. The general idea of CT will consist of abstraction, algorithm, decomposition, generalization, and evaluation. This is also supported by Sun, *et al.* [45] and Tsai, *et al.* [46], who have adopted these five components in their research. Meanwhile, CT elements related to coding or programming using GBL media at the junior high school level will mainly connect to logic, parallelism, loops, conditionals, and functions. However, Zhang and Nouri [47] had previously shown that the practical CT categories in junior high school consisted of sequences, loops, events, parallelism, conditionals, operators, data, and input/output. Therefore, the selection of elements of computational thinking in game-based learning classes must be appropriate, either with or without coding skills.

B. Student Weaknesses

Several countries have implemented computational thinking at the kindergarten to university level [48]. The findings of this study indicate that the average subjects used at the junior high school level for the implementation of game-based learning to support computational thinking related to computer science [35, 38, 49]. Makes some students sometimes must have a digitization experience. This is supported by Asbell-Clarke, *et al.* [41], who states that at least students should have a learning experience that utilizes digitization. Digitization means that students can use digital devices or other applications that give them access to and manage information.

The digital era also makes the learning process encountered in game-based learning activities dominated by the setting where students are game designers [42, 50, 51]. The learning process experienced is where students are given media so that they contribute to creating a game. Usually, the topics or themes that students produce are problems faced in the real world or not [35, 38]—making student learning outcomes meaningful [33, 42]. However, unfortunately in the learning process, students found several challenges.

When students act as game designers, they can go beyond digitization, with their coding or programming focusing on specific structures or concepts that are sometimes abstract and complex [52, 53]. Sometimes, students feel that the activity is too complicated and requires time to adapt [42, 50, 54]. In coding/programming activities, it also shows that there can be significant differences in learning outcomes between male and female students [55, 56]. On the other hand, several studies have shown that the experience of digitizing/coding [56] and gender [53, 57] are not a problem in training computational thinking using GBL media. Therefore, regardless of the need for coding or programming skills, Kanellopoulou *et al*. [57] stated that learning programming would be complicated initially, but if you experience it, it will be better. Sun and Hu *et al*. [45] and Zhao and Shute [58] show that students can gain coding experience by practicing using Code.org.

C. Student Learning Manner

How students learn can initially be traced to the ability of school administrators. The connection with CT being embedded in the curriculum through the subject of CS is indisputable due to the study of de Paula *et al*. [59] and Pardo [60] also point out that the implementation of game-based learning in supporting computational thinking can be applied to the subject of humanities (art/visual, literature/language, or ethics). It is known that in addition to learning arrangements carried out in formal classes, some apply to extracurricular activities [39, 55], workshops [36, 42, 51, 61, 62], or seasonal camps [49, 54]. Then, there is a classification of learning approaches caused by the media used by students.

In detail, two types of approaches are created in game-based learning to support computational thinking, i.e., plugged and unplugged. Plugged is a game approach requiring a power source, commonly known as digital technology, using a computer or mobile phone [30]. This study found several plugged game base learning media using Scratch, MIT AI, Kodetu, Zoombinis, or other video games. Meanwhile, unplugged is a game approach that comes on pen-paper [34] or board games [39, 63]. The plugged approach that dominates this search may occur because the plugged display is more attractive [45]. However, if the school is located in a limited area, poor facilities and internet conditions can make unplugging an alternative to using game-based learning approaches to support computational thinking [34].

When viewed during the learning process, there are ways that students can improve their computational thinking when using game-based learning media. In the beginning, it is crucial to provide simple material step by step for students to get an overview of learning [36, 37, 39, 42]. This is necessary, especially for some students who feel this is a unique or first-time experience. When students show difficulties, let students try to solve their problems first, or it can be called trial error. Students understand the feedback they receive from the media, and they learn so that they redesign their mindset and subsequent actions [34, 61]. Students also become active in asking students who have advanced [33, 61]—directing fellow students to work together or collaborate in achieving learning goals [38, 49, 63].

Furthermore, when forming a group, make arrangements that consider team harmony, such as balancing student characteristics from learning styles, communication interactions, and the number of members, so that it does not become dominant over one person later [36, 42]. However, suppose students still cannot achieve success. In that case, the teacher can pay attention to students, such as constructive verbal persuasion, so that they can continue the task more effectively [34]. In addition, it is also essential to maintain the level of student focus by paying attention to the duration of a game and game series that is continuous or can be in the form of a project [50, 57].

IV. Conclusion

Positive responses from students make game-based learning an alternative learning environment that can be applied to support computational thinking. Interest, fun, enthusiasm, motivation, usefulness, and new experiences are attitudes found when students use game-based learning media. Then, directing students to the creation of computational thinking, a series of students’ cognitive thinking. Some of the CT components found at the junior high school level are dominated by the concepts of abstraction, algorithms, decomposition, generalization, and evaluation. Meanwhile, related to programming or coding, CT components contribute to aspects of logic, parallelism, loops, conditionals, functions, user interaction, synchronization, sequences, debugging, flow control, input and variables, data structure, iterative, and operators.

Implementing game-based learning activities that support computational thinking is certainly not easy, and there must face obstacles. Some of the challenges faced are that sometimes students must be proficient in using digital, have experience in coding or programming, and, not infrequently, have student passivity. This makes the need for a good strategy for meaningful learning. There are several ways that students can learn well in the classroom, such as providing initial direction for students, providing games that suit student needs on an ongoing basis, making students learn from mistakes, collaborating with peers, and actively asking the teacher if still having problems. Hence, this study also illustrates that if the process carried out by students has been tried well, the results are also good. Over time students will be able to continue to process in developing their computational thinking.

This research still has limitations, such as the database, keywords, and the level of students used. Indirectly, this study also shows that the dominance of subjects is still related to computers and the distribution of countries that apply game-based learning to support computational thinking is still uneven. Therefore, the findings of the study encourage further investigation into the integration of CT and GBL from the perspectives of students studying the social, humanities, or arts. Furthermore, it can determine which game elements are important or which types of games are appropriate for GBL media in improving the CT skills of junior high school students.

APPENDIX

APPENDIXES A. SELECTED STUDIES

Authors and Year of Publicaton	Participants	Subject Domain	Tools
Altanis *et al.* (2018) [38]	12-15 years old students	Computer Science (CS)	Scratch and Kinect
Altaie and Jawawi (2021) [40]	8-13 years old students	N/A	Gamification on Moodle
Asbell-Clarke *et al.* (2021) [41]	Grade 3-8th	CS, Technology or Robotic, Math, and Science	Zoombinis
Attard and Busuttil (2020) [37]	Secondary school students and teachers	Computing or programming	MIT AI
Çakır *et al.* (2021) [61]	Grade 6-10th	Computer Science	Skyscraper Game
de Paula *et al.* (2018) [59]	13-14 years old students	Art and Literature (Humanities)	Beowulf
Egu luz *et al.* (2020) [62]	Secondary school students	Computer Science	Kodetu
Garneli and Chorianopoulos (2019) [50]	Middle school students	Computer Science	Scratch
Kanellopoulou *et al.* (2021) [57]	9-16 years old students	Programming	Kodetu
Kuo and Hsu (2020) [63]	Secondary school students	Computer Science	Robot City
Lakanen and Kärkkäinen (2019) [55]	Middle or high school students	Computer Science	Jypeli
Leonard *et al.* (2021) [54]	Kindergarten-Grade 8th	Computer Science	VEntI
Panskyi *et al.* (2019) [64]	9-14 years old students	Programming	Scratch
Papadakis (2020) [53]	Middle or high school students	Computer Science	MIT AI
Papavlasopoulou *et al.* (2019) [42]	Grade 3rd-12th	Computer Science	Scratch
Richard and Giri (2019) [33]	Grade 9th	CS and Engineering	Lilypad, Modkit, Scratch
Rowe *et al.* (2021) [43]	Grade 3-8th	STEM	Zoombinis
Schez-Sobrino *et al.* (2020) [65]	12 years old students	Computer Science	RoboTIC
Pardo (2018) [60]	Secondary school students	Science Humanities (Ethics, Visual, Art, Language)	MIT AI
Sharma *et al.* (2019) [51]	8-17 years old students	Computer Science	Scratch
Steinmaurer *et al.* (2019) [56]	Grade 7-8th	Computer Science	sCool
Sun, Hu, *et al.* (2021) [45]	Grade 7th	Computer Science	Scratch and Bebras
Thomas *et al.* (2017) [49]	Grade 6-8th	Computer Science	Scratch and MIT AI
Threekunprapa and Yasri (2020) [34]	Secondary school students	Computer Science	Paper Flowchart
Tucker-Raymond *et al.* (2019) [35]	Grade 8th Science teachers and students	Computer Science	Scratch
Turchi *et al.* (2019) [36]	Secondary school students	N/A	TAPASPlay
Wangenheim et al. (2019) [39]	Secondary school students	Computing or programming	Splash Code
Zhao and Shute (2019) [58]	Grade 8th	Computer Science	Penguin Go

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

AUTHOR CONTRIBUTIONS

Afra Lathifah analyzed the papers, constructed the matrix concepts, and wrote the draft of an article. Asrowi Asrowi and Agus Efendi supervised the research and reviewed the initial manuscript; all authors approved the final version.

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