Development of game-based learning media to encourage students’ computational thinking

Afra Lathifah*, Sebelas Maret University, Kentingan, Jl. Ir Sutami No.36, Kec. Jebres, Kota Surakarta, Jawa Tengah 57126, Indonesia

Asrowi Arrow, Sebelas Maret University, Kentingan, Jl. Ir Sutami No.36, Kec. Jebres, Kota Surakarta, Jawa Tengah 57126, Indonesia

Agus Efendi, Sebelas Maret University, Kentingan, Jl. Ir Sutami No.36, Kec. Jebres, Kota Surakarta, Jawa Tengah 57126, Indonesia

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Abstract

Technological developments in the 21st century require educators to teach computational thinking (CT) to their students. Educators must have creative ideas in the learning process, one of which is utilizing learning media. Game-based learning (GBL) media is one of the most popular. In this research, we developed a GBL media which is part of this type of research development. The participants used were junior high school students with a total of 118 students. After testing the effectiveness, it is known that the GBL media developed can be an alternative media that supports students’ better CT learning outcomes. This positive response is supported because the games provided have been adapted to the needs of students. Although this research has contributed to the theory of CT and GBL, this research still has some limitations. In the future, other researchers can deepen by differentiating the subjects, the level of participants, or the type of media used.

Keywords: Computational thinking; game-based learning; junior high school; research and development.

* ADDRESS FOR CORRESPONDENCE: Afra Lathifah, Sebelas Maret University, Kentingan, Jl. Ir Sutami No.36, Kec. Jebres, Kota Surakarta, Jawa Tengah 57126, Indonesia
Email Address: afralathifah@student.uns.ac.id
1. Introduction

Recently, the growth of information and communication technology has made computational thinking (CT) an important capability (Hurt et al., 2023; Liao et al., 2022). Denning (2017) explains the history of the development of CT, which began in the 1940s and bloomed in 2006, which Wing initiated. Cansu and Cansu (2019) have mentioned that CT started in the 1960s, as Papert showed in a study with his colleagues who developed the LOGO programming language to train students to think mathematically and logically. Then came the basic concept of CT, which has a broad meaning that is not limited to computer science but to diverse areas of learning and education (Gouvea, 2023; Taguchi, 2023). In 2011, Wing reconstructed his idea that CT is a method to solve problems by thinking comprehensively in formulating solutions that can be presented and implemented effectively.

CT is concerned with algorithms, either with or without computers (Shute et al., 2017). Haseski et al. (2018) have classified CT into seven themes: problem-solving, technology, thinking, personal, operational, social, and general. According to Lyon and Magana (2020), CT 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. Meanwhile, Ezeamuzie and Leung (2022) define CT as two important main ideas, the concept of computer science and cognitive skills through problem-solving. Several literature studies have attempted to develop a definition of CT, and it can be concluded that CT is an attempt to figure out problems extensively, rationally, and in an orderly manner.

Even though CT has become popular, educators are still looking for ways to integrate it into class. Game-based learning (GBL) is one way to implement CT competencies in grades K–12 (Hsu et al., 2018; Tang et al., 2020). This is due to the similarity of theoretical foundations between computational thinking and GBL, where several studies have shown that game environments also tend to use constructivist theories (Chen et al., 2019; Nadolny et al., 2017; Qian & Clark, 2016; Wang & Zheng, 2020). The concept of GBL often overlaps with gamification and serious games (Al-Azawi et al., 2016; Al Fatta et al., 2018; Krath et al., 2021). GBL is a learning environment provided to students while playing using non-digital or digital media to offer experiences that direct changes in student knowledge (Al-Azawi et al., 2016; Hartt et al., 2020; Plass et al., 2019). GBL media is developed for student learning and contains content according to the curriculum (Al Fatta et al., 2018; Bunt & Gouws 2020). In a similar statement by Karakoç et al. (2020) and Krath et al. (2021), GBL is more about educational content and games to educate so that students as players can improve learning by solving problems and challenges while playing. Meanwhile, gamification and serious games are usually non-educational games that provide training without being entertaining (Karagiorgas & Niemann, 2017). This indicates that GBL can also be called educational games, specifically designed for educational purposes.

Students interact actively and have high motivation in the game environment (Żammit, 2022; Acosta-Medina et al., 2021). Educators also show high self-efficacy when using GBL (Akkaya & Kapidere, 2021). Importantly, GBL is also superior to conventional teaching methods (Hooshyar et al., 2021; López-Fernández et al., 2021; Gyaurov et al., 2022). Therefore, there are several principles when implementing GBL: the teacher must play an active role in fostering students by facilitating games that are under the context or curriculum and must continually update knowledge about GBL from time to time, even if it is necessary to have a professional certificate related to GBL (Foster & Shah, 2020).
GLB found in CT adopts two approaches: plugged and unplugged. Unplugged is a game approach that relies on paper or non-digital (Caeli & Yadav, 2020). Kuo and Hsu’s (2020) research shows unplugged playing activities using board games. Busuttil and Formosa (2020) used logic gates through twisters, building towers, party magic cars, conditional cards, and binary numbers. Threekunprapa and Yasri (2020) used flow blocks. Meanwhile, plug is a game approach that requires a power source, commonly known as digital technology (Lee et al., 2022). Examples of plugged game media used to train CT are the video game ‘Penguin Go’ (Zhao & Shute, 2019), Robo Builder, Formula Tracing (Winthrop et al., 2016), Zoombinis (Asbell-Clarke et al., 2021), Kodu, Lego (Wu, 2018) and the dominant Dr. Scratch (Altanis & Retalis, 2019; Garneli & Chorianopoulos, 2018; Hoover et al., 2016; Troiano et al., 2019). Sun et al. (2022) and Zhao and Shute (2019) also showed that the Code.org website is a GBL media that can train students’ CT. The dissimilarity between unplugged and plugged is the use or non-use of technology. The benefit of unplugged activity is that it can facilitate students without burdening them with computer operating experience (Lee et al., 2022), preventing low interest or self-confidence (Caeli & Yadav, 2020). However, plug-in activities can generate excitement, grab attention, and motivate students (Zhao & Shute, 2019) to learn because of the graphical interface and clear game themes.

1.1. Purpose of study

In the literature, the suggested GBL media are games that are practical, easy to learn, and fun to support CT. However, generating or creating learning media is burdensome for educators (Leonard et al., 2018). Educators find it challenging to create learning media because of technical issues encountered during the process, such as gaming media creator applications requiring programming knowledge (An & Cao, 2017). The constraints of educators’ abilities can be solved by allowing educational technologists to assist educators in developing an application product or learning media. This research will provide materials adapted to the learning environment to develop GBL media products. The research and development procedure begins with analyzing learning conditions, content planning and development, valid product feasibility from material experts, media, instructional design, and students, as well as product implementation and evaluation. Therefore, what is sought in this study is to identify the efficacy of the developed GBL media. The question that arises in this study is as follows:

1. Does the development of GBL media effectively encourage students’ CT?

2. Materials and Methods

2.1. Research model

Research and development are a type of research used by adopting the ADDIE model. This research chose the ADDIE model because it has several benefits for developing products, such as its approach focusing on analyzing interacting components, iterating, creating, and revising.

According to Branch (2009), there are five processes from the ADDIE model based on the acronym: A for the analysis phase to identify what is happening in the learning environment, D for the design phase to verify the plan or product strategy to be produced, D for the development phase is the process of building product (product and product trials will be carried out), I for implementation and E for the evaluation phase will be carried out in conjunction with the goal that the developed media can be widely used and improve CT.
2.2. Participants

Prior to the widespread effectiveness test, the media had received validation from five experts. The class design used is the experimental and the control groups, each of which is 59 junior high school students from 1 city in Indonesia.

2.3. Data analysis

The test was used to determine the effectiveness of student learning when given treatment. Meanwhile, a questionnaire in the form of a questionnaire is used to determine the feasibility of the product. The data obtained from various assessment instruments will be processed using statistical analysis and described descriptively. The hypotheses used in this study are as follows:

H0: The treatment did not make a difference between the CT results before and after the test.

H1: The treatment gave a difference between the CT results before and after the test.

2.4. Ethics

The participants were anonymous. Participation in this study was not mandatory. Permission was sought from the school authorities before the study was conducted.

3. Results

3.1. Results of needs analysis and design of the GBL media

3.1.1. Analysis phase

Based on the preliminary study at the ADDIE stage, it was concluded that the teacher had not used media that integrated CT during the learning process of informatics subjects. At the time of observation of learning in the classroom, the teacher only relied on the module. Lectures, assignments, and practice are the methods most often used by educators. This is what directs research to create learning innovations by developing GBL media that is integrated with the CT concept.

3.1.2. Design phase

At this stage, the product strategy planning is developed. The product specifications developed include the following:

The developed product can be run using a computer or an Android OS smartphone.

The product contains material and summaries, sample questions and evaluations, games, guides, product information, and developer profiles.

The developed product integrates the CT components adopted by Dagienè et al. (2017), such as abstraction, decomposition, algorithm, evaluation, and generalization.

Meanwhile, the stages carried out in this design process start from 1) planning storyboards and flowcharts, 2) developing product prototypes with software help, and 3) publishing prototypes in the form of .exe or URL links.

3.2. Creating GBL media products

3.2.1. Development phase
At this stage, validation and testing of the developed product prototype are carried out. Several experts tested the feasibility of product development with two media experts, two materials, and one instructional design person. A rating scale of 1–5 was used in the study for each item of the questionnaire. Media assessment aspects consist of the display, navigation, and language. The material assessment consists of the material concept, the quality of the questions, language, and benefits. Meanwhile, the instructional design assessment aspect consists of learning design, navigation, and language.

Table 1
Results of Expert Assessment

<table>
<thead>
<tr>
<th>Experts</th>
<th>Score</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media I</td>
<td>4.14</td>
<td>Very good</td>
</tr>
<tr>
<td>Media II</td>
<td>4.78</td>
<td>Very good</td>
</tr>
<tr>
<td>Material I</td>
<td>4.26</td>
<td>Very good</td>
</tr>
<tr>
<td>Material II</td>
<td>4.32</td>
<td>Very good</td>
</tr>
<tr>
<td>Instructional design</td>
<td>4.39</td>
<td>Very good</td>
</tr>
<tr>
<td>Average</td>
<td>4.38</td>
<td>Very good</td>
</tr>
</tbody>
</table>

Based on Table 1, all experts rated it as ‘very good’ and concluded that the developed GBL media can be tested on students. The ADDIE model has three trial processes: individual, small group, and field trials. The trial was conducted by providing a product feasibility questionnaire with aspects of media content assessment, language, navigation, and usability. The results of the product feasibility assessment, when tested by students, can be seen in Table 2.

After each product trial, there will be a revision so that this leads to an increase in value for the subsequent trial. The final result of the assessment shows that each aspect gets an average score in the ‘good’ category. The three stages of testing carried out on these students also achieved an average result of 3.92, which was classified as ‘good’. Thus, we demonstrate that the developed media can be tested extensively to determine product efficacy.

Table 2
Results of Product Trial Assessment

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Individual trials</th>
<th>Small group trials</th>
<th>Field trials</th>
<th>Average</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media content</td>
<td>3.78</td>
<td>3.83</td>
<td>3.89</td>
<td>3.83</td>
<td>Good</td>
</tr>
<tr>
<td>Language</td>
<td>3.83</td>
<td>4.00</td>
<td>4.03</td>
<td>3.95</td>
<td>Good</td>
</tr>
<tr>
<td>Navigation</td>
<td>3.83</td>
<td>3.89</td>
<td>4.05</td>
<td>3.92</td>
<td>Good</td>
</tr>
<tr>
<td>Usefulness</td>
<td>3.94</td>
<td>3.96</td>
<td>4.01</td>
<td>3.97</td>
<td>Good</td>
</tr>
<tr>
<td>Average</td>
<td>3.85</td>
<td>3.92</td>
<td>4.00</td>
<td>3.92</td>
<td>Good</td>
</tr>
</tbody>
</table>

3.2.2. Implementation and evaluation phase

At the implementation stage, preparations will be made for educators and students. Educators will receive guidance from researchers. Meanwhile, students will be selected as participants who will
evaluate the developed GBL media. The control and experimental classes are research class designs used in the evaluation phase.

At the evaluation stage, the research began when control and experimental group students with conventional learning conditions were given pre-test questions. The pre-test determines the students’ initial CT ability. Furthermore, the control group students were not given any treatment, while the experimental group received a different learning treatment using the GBL media that had been developed. The final assessment of learning was based on the post-test.

Before statistical tests, pre-and post-test scores were valid for normality and homogeneity. The statistical test is a paired t-test for finding mean comparisons between two paired samples. The results of the CT assessment for each class can be seen in Table 3. The control class did not show any change in the mean scores before and after the test. On the other hand, in the experimental class, the mean before and after changed significantly from 64.70 to 83.51. The value of the experimental class increased by 18.81. This shows that giving treatment using the developed GBL media affects students’ CT.

<table>
<thead>
<tr>
<th>Variations</th>
<th>Control group</th>
<th>Experiment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average pre-test</td>
<td>66.966</td>
<td>64.695</td>
</tr>
<tr>
<td>Average post-test</td>
<td>70.983</td>
<td>83.509</td>
</tr>
<tr>
<td>t-test [Sig (2-tailed)]</td>
<td>0.051</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sig (2-tailed) &gt; 0.050</td>
<td>There is an average difference</td>
<td></td>
</tr>
<tr>
<td>Sig (2-tailed) &lt; 0.000</td>
<td>No difference in the average</td>
<td></td>
</tr>
</tbody>
</table>

4. Discussion

CT has become one of the mandatory competencies learned at the junior high school level in Indonesia, but many still have not implemented it optimally optimal (Yuliana et al., 2021). This is due to the lack of educators’ knowledge of the concept of CT and media that can help them implement it in the classroom (Yadav et al., 2017b). At the same time, CT is seen as one of the necessary skills to adapt to the future of rapid technological development (Hsu et al., 2018).

Educators as lesson planners play an important role. This leads to the need to provide teachers with experience in integrating CT into their learning process (Yadav et al., 2017a). This makes the government in Indonesia to continue to disseminate information to educators in all regions to be able to implement CT (Dagienė et al., 2021). Indonesia collaborates with the Bebras community to spread the concept of CT at all levels of education through the Bebras Challenge or Bebas Task. Then, it is also known that the assessment by adopting the Bebras Task has been introduced to train CT in games (Asbell-Clarke et al., 2021; Kuo & Hsu, 2020).

The findings in the UK Bebras (2017) and the research of Aslina et al. (2020) succeeded in developing a Bebras Task-based game to practice CT skills. Research by Lawanto et al. (2017), Utesch et al. (2020), Chan et al. (2021), Israel-Fishelson et al. (2021), and Guenaga et al. (2021) showed that the type of game that can improve CT is maze game. By following previous findings, the developed GBL media offer questions integrated into CT components while paying attention to the type of game...
or game element. The results of this research lead to decisions by media, materials, instructional design professionals, and students that the developed GBL media are proper. Expert evaluation results reached an average score of 4.38 in the ‘very good’ category. When the experiment was conducted on students, they received an average overall score of 3.92 in the ‘good’ category. After analyzing the effectiveness, it is known that treatment is affected between the two classes used. The benefit of GBL that has been developed is that materials, questions, and games have been integrated with CT. The integration of CT in GBL can make the media’s potential in building students’ CT knowledge fun.

The developed GBL also does not require any programming experience. Many studies have linked digital GBL to block-based (Deng et al., 2020; Lawanto et al., 2017) or text-based programming (Grizioti & Kynigos, 2021). Meanwhile, research by Jagušt et al. (2018) and Gresse von Wangenheim et al. (2019) used pen–paper or board games associated with coding. As a result, students can improve their CT but face many obstacles. Educators (An & Cao, 2017) and students (Kynigos & Grizioti, 2020) have difficulty understanding programming. However, it can also be a concern that researchers can start with an unplugged play approach before carrying out GBL or combine it with digital (Caeli & Yadav, 2020; Sun et al., 2022).

In this study, students have shown that the GBL media experimental class can improve CT compared to the control class. The positive response shown by students during GBL can occur because students tend to master technology more than educators (Buss & Gamboa, 2017). This happens because GBL uses various literacies, such as digital literacy, technological literacy, and game literacy (Wu, 2018). Moreover, digital literacy has many similarities with the components of CT (Juškevičienė & Dagienė, 2018). Troiano et al. (2019) also found that CT is a key skill supporting digital literacy and problem-solving development. Hsu et al. (2018) stated that training CT is not only digital literacy but also must take advantage of new technology. Thus, developing GBL media in this study is one of the new technology alternatives that can improve CT.

5. Conclusion

CT is a mandatory skill for everyone in this computing age. CT is a concern worldwide, including in Indonesia, one of the countries in Southeast Asia that continues to spread students’ CT. This study experimented with GBL’s media development on middle school students. Product development is carried out through several processes, including analysing learning conditions, planning, prototyping, implementing, and evaluating effectiveness. Experts in media, materials, instructional design, and students assessed that the media developed as feasible. After the effectiveness test was carried out on junior high school students, it was found that there were differences in results between the two classes used. The experimental class showed more learning outcomes after being given treatment compared to the control class. GBL structured in such a way is not only concerned with the fun aspect but can also improve students’ skills, especially CT. Therefore, developing GBL media is a feasible media innovation to encourage students’ CT in the classroom.

Although the GBL media developed showed that it could support the CT of junior high school students compared to conventional classes. This study has limitations, such as games that are only used on specific operating systems, subjects, grade levels, and development research models are encountered. Suggestions for further research can change the CT components used and the role of students in becoming game designers and examine how students behave when playing more deeply.
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References


