Development and Validation of Animation-Based Science Learning Media in the STEM-PBL Model to Improve Students Critical Thinking and Digital Literacy

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Abstract: This study aims to produce an animation technology-based learning media product with the STEM-PBL model to improve critical thinking and digital literacy that is feasible and valid. The research uses a 4-D model. The research subjects were 27 MTsN, 1 Blitar City student, two expert lecturers, and one science teacher. The instruments used were validation sheets, readability, and practicality questionnaires with a 5-level Likert scale. The data analysis technique is descriptive and uses the ideal standard deviation value. The research results show that the product is in a very valid and feasible category, with a percentage of 94% material experts and 92% media experts. The readability and practicality tests are in a very good variety with rates of 85% and 99%. So that the product is very feasible and valid to use in learning. The recommendation for further research is to test the effectiveness of media when learning to improve student's critical thinking and digital literacy.

Keywords: Animation; Critical Thinking; Digital Literacy; Learning Media; STEM-PBL

Introduction

Science learning aims to develop students' understanding of scientific concepts, critical thinking skills, and digital literacy. Critical thinking and digital literacy are 21st-century skills that students must possess as provisions for the future (Fitriyani & Nugroho, 2022; Haryana, Cobern, Pleasants, & Fetters, 2021; Yunianto, Suyadi, & Suherman, 2020). Critical thinking is very important for students because critical thinking will train students' abilities to analyze and find solutions to problems, especially in everyday life (Mardhiyah, Aldriani, Chitta, & Zulfikar, 2021; Zubaidah, 2016). Critical thinking is an effective skill that allows students to develop their thinking (Aktoprakac & Hursen, 2022).

Digital literacy is a capability that students must have in the current era of technological development (Muhali, 2019). Digital literacy is very important for students to help them hone their skills in using digital technology and information and compete in the environment (Mardhiyah et al., 2021; R. Rahayu, Iskandar, & Abidin, 2022). Digital literacy is one of the provisions for students' personal, academic and professional development in a digital world that continues to grow (Hasibuan & Prastowo, 2019). Digital literacy involves various abilities, including understanding, analyzing, evaluating different information received, and evaluating information (Tristiana & Kayyis, 2022). Digital literacy is the ability to understand and use data in various forms from various sources widely accessed via computers (Gilster, 1997). Hague & Payton (2013) revealed that digital literacy is an individual skill in using digital-based devices to achieve goals in personal life situations. This shows that digital literacy activities are not only reading and writing skills but also include other skills.

Critical thinking and digital literacy have a close relationship because both complement and support each other in the information and technology era that
continues to develop, especially in 21st-century skills. Building a literacy culture can improve students' critical thinking because students will face some of the problems they find after they read and listen to stories or information so that they can analyze and form critical thinking skills (Kim, 2019; Tugtekin & Koc, 2020). In the entire learning process, both critical thinking and digital literacy must be strengthened and expanded so that students are ready to face the demands of today's digital society.

However, the fact that is happening in the field is that there are problems in teaching complex and abstract science concepts to junior high school students. One of these problems is about techniques or methods of delivering material. Teachers still often practice teaching centring with the lecture method without creative aids (ER Dewi, 2018; N. Dewi & Riandi, 2016). So learning in class becomes monotonous and passive because students only listen to explanations from the teacher. This causes students' critical thinking skills and digital literacy to be classified as low.

Based on initial observations made by researchers at MTsN 1, Kota Blitar, students' digital literacy abilities can be categorized as still varying in processing information obtained from digital media. This is due to the limited capacity of educators, limited time, facilities and infrastructure that have not been able to support digital literacy-based learning optimally, and many students still need to understand the benefits of digital literacy fully. Some students indicated that digital literacy skills were not used to assist their learning activities. Teachers still use conventional learning models with lectures so that learning occurs less effectively and monotonously. Not all students pay attention to the teacher's explanation and are still passive in the learning process. This causes very few students who dare to answer the problems posed. So, students' critical thinking skills are still relatively low. In addition, students' digital literacy in understanding and conveying material information still needs improvement.

Based on Intelligence data (2020), Indonesia is ranked 61st out of 100 countries for the level of education and readiness to use the Internet, so students' digital literacy is still low. The low critical thinking of students in Indonesia can be seen from the scores on the results of solving PISA questions. Based on the 2018 Program for International Student Assessment (PISA) results, Indonesia's scientific literacy score was 396, which has decreased compared to 2015, which was 403 (Schleicher, 2019). This shows that the ability of Indonesian students to answer questions that refer to the ability to think critically and logically and solve problems still needs to improve.

The development of the times causes digital technology to develop more and impact education. One of them is to overcome problems in learning by using innovative digital learning media in the digital era. This aims to make the delivery of material from the teacher to students more meaningful and conveyed clearly (Puspitari & Hanif, 2019). In this case, using innovative and relevant learning media is very important to increase science learning effectiveness in junior high schools so that students' critical thinking skills and digital literacy can increase.

In interesting learning, you can use one of the models, namely the animation-based STEM-PBL (Science, Technology, Engineering, Mathematics - Problem-Based Learning) model. This model integrates science concepts with STEM elements and a problem-based learning approach. It is intended that students can connect the material they get with their surroundings (Murray-Harvey, Santos Reyes, & Pourshafie, 2013). In addition, problem-based learning will also train students' critical thinking skills in analyzing and overcoming a problem in everyday life. The combined STEM approach aims to improve students' ability to think critically, creatively and innovatively, be able to solve problems, and train literacy because STEM connects learning from various aspects in the surrounding environment (Simeon et al., 2022; Ziatdinov & Valles, 2022). The STEM approach aims for students to have STEM Literacy, master 21st-century competencies, and be actively involved in learning (Mulyani, 2019).

An animation is an interesting form of media that can facilitate understanding complex scientific concepts such as abstract science. The animation aims to visualize the subject being taught as a model so that it is easier for students to understand the material and student's learning outcomes increase (Höffler & Leutner, 2007). Animation in learning media has benefits. Namely, learning becomes more interesting, motivates students, presents information, and provides clear explanations of material (Weiss et al., 2002). However, there is still limited development and use of animation-based science learning media in the STEM-PBL model at the junior high school level.

Based on research conducted by Wahyuaji & Suparman (2018) regarding analyzing media needs with a STEM approach in learning science. The study results show that the learning media used in schools have yet to help students develop critical thinking skills, the STEM approach can train critical thinking skills, and teachers need innovative learning media. In addition, Anisa, Ala, & Suffanah (2021) in their research suggested that low literacy and critical thinking skills will impact education in Indonesia.
Based on the background described above, this study aims to develop and produce an animation-based learning media with the PBL-STEM model to improve the critical thinking and digital literacy of junior high school students that is valid and feasible. The results of this study are expected to contribute to the development of innovative learning approaches and provide practical recommendations for educators in improving the quality of science learning at the junior high school level.

Method

The type of research is Research & Development, which aims to produce a decent product (Sugiyono, 2015). This study uses a 4-D model, which seeks to build a feasible and effective product with four stages: define, design, develop, and disseminate (Thiaragajan, Sivasailam, & Others, 1974). The research sample was 27 MTsN 1 Kota Blitar class VIII students, one science teacher, and two expert lecturers at Yogyakarta State University. The research results are animation-based learning applications with the PBL STEM model that can be operated via an Android smartphone. The instruments used were validation sheets and media legibility and practicality questionnaires using a 5-level Likert scale which can be seen in Table 1.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strongly Disagree/Very Unfavorable</td>
</tr>
<tr>
<td>2</td>
<td>Disagree/Not Good</td>
</tr>
<tr>
<td>3</td>
<td>Fairly Agree/Fairly Good</td>
</tr>
<tr>
<td>4</td>
<td>Agree/Fine</td>
</tr>
<tr>
<td>5</td>
<td>Strongly Agree/Very Good</td>
</tr>
</tbody>
</table>

Data were analyzed descriptively by recapitulating all statement items in the assessment sheet and then calculating the average score using the Formula 1.

\[ \bar{X} = \frac{\sum X}{n} \]  

(i)

Information:

\( \bar{X} \) = average score of each aspect  
\( \sum X \) = total score for each aspect  
\( n \) = number of appraisers

Next, change the average score into a category value. The feasibility of the developed media was obtained from the results of the validator using a Likert scale of 5, where the initial data in the form of a score was converted into qualitative data with a scale of 5. On the Likert scale, the highest score was 5, and the lowest was 1. The formula used was with standard deviation referring to (Mardapi, 2008) in Table 2.

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Category</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X \geq \bar{X} + 1.8 \text{SBi} )</td>
<td>Very Worth it</td>
<td>A</td>
</tr>
<tr>
<td>( \bar{X} + 0.6 \text{SBi} &lt; X \leq \bar{X} + 1.8 \text{SBi} )</td>
<td>Worthy</td>
<td>B</td>
</tr>
<tr>
<td>( \bar{X} - 0.6 \text{SBi} &lt; X \leq \bar{X} + 0.6 \text{SBi} )</td>
<td>Decent Enough</td>
<td>C</td>
</tr>
<tr>
<td>( \bar{X} - 1.8 \text{SBi} &lt; X \leq \bar{X} - 0.6 \text{SBi} )</td>
<td>Less Kayaking</td>
<td>D</td>
</tr>
<tr>
<td>( X \leq \bar{X} - 1.8 \text{SBi} )</td>
<td>Very Inadequate</td>
<td>E</td>
</tr>
</tbody>
</table>

Result and Discussion

Product Results

Media is developed concerning indicators of critical thinking, digital literacy, and steps in learning using the PBL STEM model. The resulting media is a learning application operated via an Android smartphone so students can learn independently and flexibly. The media was developed with the help of Adobe Animate CC software. The results of the developed media can be described as Figure 1 and 2.

![Figure 1. Opening](image1)

![Figure 2. Frontpage](image2)

Figures 1 and 2 are the initial appearance when the application is opened. This opening section displays the title as well as the start button. Then there is an identity page that serves as the student’s identity in the form of the name, email, and absent number when using the media. This is so that the answers done by students can go directly to the teacher’s email. So that the value of students will automatically appear.

![Figure 3. Home page](image3)

On the home page, several buttons and menus will appear. There is a sound button related to the background on or off. Power off the button to exit the application. Furthermore, at the top, there is the user’s identity. Then there are six menus: menu instructions, basic competencies, learning, evaluation, references, and developers. Each menu has an image icon that represents the menu. The background on the homepage is an animated rotating earth.
Figure 4. Help Menu

Figure 4 displays the instructions menu page. Instructions guide users on how to operate the media. This contains the use of each button found on the media.

Figure 5. Basic Competency Menu

Figure 5 displays the basic competency menu page. In basic competence, there are sub-menus, namely indicators, objectives, and concept maps. The basic competency used is KD 3.9 class VII SMP material on global warming. In the indicator sub-menu, several indicators will be achieved in learning. The objective sub-menu contains learning objectives to be achieved through learning activities with this media. The concept map sub-menu includes a concept map of global warming material.

Figure 6. Evaluation Menu

Figure 6 displays the evaluation menu. The evaluation consists of 3: critical thinking evaluation, digital literacy evaluation, and digital literacy attitude questionnaire. This evaluation serves as a measuring tool for students' necessary thinking skills and digital literacy after using media. Evaluation 1 contains ten multiple-choice questions with critical thinking indicators. Evaluation 2 includes 7 multiple choice questions with indicators of digital literacy. The questionnaire contains a questionnaire to measure students' digital literacy attitudes. Questions and questionnaires have been validated by expert lecturers and tested for reliability.

Figure 7. Reference Menu

The reference menu page contains a list of books that are used as references in preparing global warming material.

Figure 8. Developer Menu

Figure 8 displays the developer profile menu. This page contains the identity of the researcher in developing the media.

Figure 9. Study Menu

Figure number 9 displays learning activities while using the media. There are two sub-menus, namely Activity Menu 1 in the form of material on the greenhouse effect and Activity two on global warming material. Each activity is structured based on the STEM-PBL syntax and critical thinking and digital literacy indicators. At the end of each activity, there is a learning evaluation in the form of practice questions. Each material displayed is presented in the form of an
animated video. Video in the application attracts students to learn (Putri, Bakri, & Permana, 2016; Syaparuddin & Elihami, 2020). Media in the form of videos can facilitate the delivery of material (Sofyan, Gusniawati, & Buhairah, 2021). Animation can make it easier to present abstract material (Kurniati, Andra, & Wayan District, 2021; Thiagarajan, 1974). In addition to animated videos, the narrator shows explanations through narration and audio.

The STEM-PBL syntax used is Orientation (Science), Organizing (Science), Assisting investigations (Science), Developing and presenting results (Technology and Engineering), Analyzing and evaluating (Science, Mathematic) (Banawi, 2019; Reeve, 2015; Rusmono, 2012). The synthesized aspects of critical thinking are categorizing, giving reasons, concluding, stating results, and providing solutions (Ennis, 1989; Facione, 2011; Fisher, 2009). The synthesized aspects of digital literacy are internet search, hypertext navigation, critical thinking and content evaluation, knowledge building, communication, and security (Bawden, 2008; Eshet-Alkali & Amichai-Hamburger, 2004; Gilster, 1997; Hague & Payton, 2013; UNESCO, 2018).

Figure 10 displays Activity 1, while Figure 11 displays Activity 2. The page displays a video. This page contains learning activities in the form of apperception by observing videos. The video is shown to motivate and orient students to identify the problem of the greenhouse effect. This is syntax 1 of PBL, namely the orientation of students to issues. The STEM aspect is observing phenomena related to the greenhouse effect and global warming based on video (Science).

Figures 12 and 13 show the activities of organizing students to learn by asking questions and identifying the formulation of the problem by analyzing activities based on information obtained from the video. The PBL syntax is organizing students to learn. The STEM aspect is formulating the problem of scientific phenomena (Science). Digital literacy is the aspect of Internet searching in the form of gathering information. Characteristics of critical thinking categorize by formulating questions.

Figures 14 and 15 show the activities of guiding investigations to obtain information from problems and seek explanations and solutions with observation activities through simulations. The PBL syntax is to conduct investigations by making observations. Aspects of STEM observing experiment (Science). Digital Literacy Aspect evaluates information content by presenting valid information. Characteristics of Critical Thinking provide reasons for a decision with a credible source of information.

Figures 16 and 17 show the activities of developing and presenting results by writing information related to the analysis that has been carried out. Analyzing and evaluating the problem-solving process is a reflection activity by concluding problems and investigating how to reduce the impact of the greenhouse effect and global warming. The PBL syntax develops and presents works by analyzing, processing data, and giving. The Digital Literacy Aspect of compiling knowledge by building knowledge from media information content. Aspects of Critical Thinking by concluding, stating results, and providing solutions.

Figure 18 displays an information page at the end of each activity. This information contains reinforcement material for students. So that students can understand without any misconceptions. Figure 19 displays the practice questions page. Practice questions are given at
the end of each learning activity for each menu. So that students can measure their understanding through this exercise.

Results Validity and Practicality

The validation results from material and media experts can be seen in Tables 3 and 4.

Table 3. Media Expert Validation Results

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Score</th>
<th>Mark</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>84</td>
<td>A</td>
<td>Very Worth it</td>
</tr>
<tr>
<td>Presentation</td>
<td>14.5</td>
<td>A</td>
<td>Very Worth it</td>
</tr>
<tr>
<td>Navigation</td>
<td>10</td>
<td>A</td>
<td>Very Worth it</td>
</tr>
<tr>
<td>Instructional</td>
<td>76</td>
<td>A</td>
<td>Very Worth it</td>
</tr>
<tr>
<td>Total</td>
<td>184.5</td>
<td>A</td>
<td>Very Worth it</td>
</tr>
</tbody>
</table>

Table 4. Material Expert Validation Results

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Score</th>
<th>Mark</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material/Content</td>
<td>106</td>
<td>A</td>
<td>Very Valid</td>
</tr>
<tr>
<td>Language</td>
<td>27.5</td>
<td>A</td>
<td>Very Valid</td>
</tr>
<tr>
<td>Content</td>
<td>53.5</td>
<td>A</td>
<td>Very Valid</td>
</tr>
<tr>
<td>Total</td>
<td>187</td>
<td>A</td>
<td>Very Valid</td>
</tr>
</tbody>
</table>

Table 5. Results of Teacher Practicality

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Score</th>
<th>Mark</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>effectiveness</td>
<td>30</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Appearance</td>
<td>54</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Content/Material</td>
<td>19</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Instructional</td>
<td>20</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Programming</td>
<td>20</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>13</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Digital Literacy</td>
<td>18</td>
<td>A</td>
<td>Very Practical</td>
</tr>
<tr>
<td>Total</td>
<td>174</td>
<td>A</td>
<td>Very Practical</td>
</tr>
</tbody>
</table>

Table 6. Media Readability Test Results

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Score</th>
<th>Mark</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic</td>
<td>50.9</td>
<td>A</td>
<td>Very Good</td>
</tr>
<tr>
<td>Content / Material</td>
<td>17</td>
<td>A</td>
<td>Very Good</td>
</tr>
<tr>
<td>Programming</td>
<td>17</td>
<td>A</td>
<td>Very Good</td>
</tr>
<tr>
<td>Total</td>
<td>84.9</td>
<td>A</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Based on the results of the research, it shows that the media developed is very valid and appropriate for use in learning. This media can be used to train and improve students' critical thinking and digital literacy. Using the STEM-PBL model in media has the principle that the teacher’s role is only as a facilitator because the teacher facilitates students' learning. Meanwhile, students find understanding and knowledge through STEM PBL-based animated science media. This is by Amir (2009), who argued that the PBL model aims for students to have the ability to process and seek information, critical thinking, teamwork, interpersonal skills and active communication with other students. By combining the STEM approach, students become more trained in the critical thinking skills and digital literacy because the media presents problems relevant to everyday life related to STEM aspects. This is consistent with research that the STEM approach is an approach that refers to teaching, learning, and integrating the disciplines and abilities of science, technology, mathematics, and engineering in STEM topics, with an emphasis on solving real-world problems and can improve critical thinking (Cameron & Craig, 2016; Wahono, Lin, & Chang, 2020; Yildirim & Turk, 2018).

The existence of animation in the media can make students interested in learning. Material presented in animated form can make abstract material concrete. This will make it easier for students to understand the material so that the abilities and skills of students can increase. Animation aims to visualize the subject being taught to make the material easier to understand (Höffler & Leutner, 2007). Animation in learning media has benefits. Namely, learning becomes more interesting, motivates students, presents information, and provides clear explanations of material (Weiss, Knowltonb, & Morrison, 2002).

Material presented in animated form and packaged in a digital-based learning application will facilitate learning. Learning becomes more effective and efficient. In addition, with digital media, students will practice their digital skills using media. Digital literacy is a skill in using digital-based devices, analyzing and processing information to obtain information (Gilster, 1997; Hague & Payton, 2013). So the results of this study align with research conducted by S. Rahayu, Isnaeni, & Masturi (2022) that STEM media can improve students' critical thinking and digital literacy. Critical thinking will make it easier for students to solve problems (Kurniawan & Husna, 2023). Media is part of learning that contains messages, people, and devices, which keep up with technological developments (Aprilia, Anggereini, & Ahda, 2023). Building literacy awareness can help advance the world of education (Sangaji & Pribadi, 2023).
Conclision

Based on the study's results, the developed product is an android application of animation-based learning media with the PBL STEM model to improve student's critical thinking and digital literacy. Products designed are in very feasible and valid categories, with a percentage of 92% media experts and 94% material experts. Readability and practicality tests for teachers and students are in the very good category, namely 85% and 99%. The media can be feasible and valid for science learning to improve students' critical thinking and digital literacy. Recommendations for further research are to test the effectiveness of using STEM PBL animation media in education.

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Author Contributions

Fitria, Conceptualizing research ideas, designing methodologies, analyzing data, discussing, and managing. Dadan Rosana reviewed the literature and criticized the manuscript.

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Conflicts of Interest

The funders had no role in the study's design, in the collection, analysis, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

References


Reeve, E. M. (2015). STEM Education is Here To Stay. ITEEA.


