JPPIPA 9(9) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

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

Fitria Lafifa[1*], Dadan Rosana[1]

[1] Master of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

Received: June 25, 2023
Revised: August 18, 2023
Accepted: September 25, 2023
Published: September 30, 2023

Corresponding Author:
Fitria Lafifa
fitrialafifa.2021@student.uny.ac.id

DOI: 10.29303/jppipa.v9i9.4448

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

How to Cite:
Lafifa, F., & Rosana, D. (2023). Development and Validation of Animation-Based Science Learning Media in the STEM-PBL Model to Improve Students Critical Thinking and Digital Literacy. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7445–7453. https://doi.org/10.29303/jppipa.v9i9.4448

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 teacher 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 (Puspitarini & 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 things in 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 1. Likert Scale Category

Scale	Category
1	Strongly Disagree/Very Unfavorable
2	Disagree/Not Good
3	Fairly Agree/ Fairly Good
4	Agree/ Fine
5	Strongly Agree/ Very Good

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

$$\ddot{X} = \frac{\Sigma X}{n} \quad \text{(i)}$$

Information:

$\ddot{X}$ = 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 2. Ideal Media Assessment Category

intervals	Category	Mark
$X \geq \ddot{X}i + 1.8$ SBi	Very Worth it	A
$\ddot{X}i + 0.6$ SBi $< X \leq \ddot{X}i + 1.8$ SBi	Worthy	B
$\ddot{X}i - 0.6$ SBi $< X \leq \ddot{X}i + 0.6$ SBi	Decent Enough	C
$\ddot{X}i - 1.8$ SBi $< X \leq \ddot{X}i - 0.6$ SBi	Less kayaking	D
$X \leq \ddot{X}i - 1.8$ SBi	Very Inadequate	E

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

Figure 2. Frontpage

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

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.

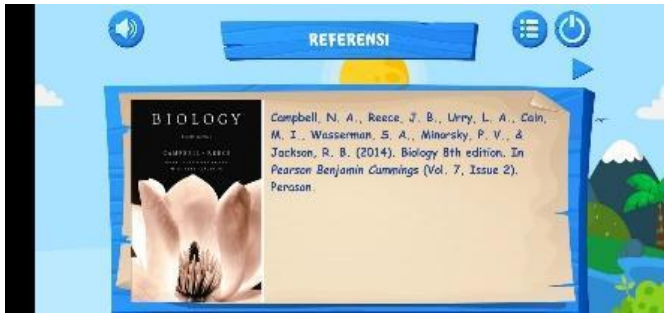

Figure 7. Reference Menu

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, & Buhaerah, 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. Activity 1

Figure 11. Activity 2

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).

Figure 12. Activity 1

Figure 13. Activity 2

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.

Figure 14. Activity 1

Figure 15. Activity 2

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.

Figure 16. Activity 1

Figure 17. Activity 2

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. Information Page

Figure 19. Exercise Page

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

Aspect	Score	Mark	Category
Appearance	84	A	Very Worth it
Presentation	14.5	A	Very Worth it
Navigation	10	A	Very Worth it
Instructional	76	A	Very Worth it
Total	184.5	A	Very Worth it

Table 4. Material Expert Validation Results

Aspect	Score	Mark	Category
Material/Content	106	A	Very Valid
language	27.5	A	Very Valid
Content	53.5	A	Very Valid
Total	187	A	Very Valid

Tables 3 and 4 are the results of media validation assessed by two expert lecturers at Yogyakarta State University. Based on the assessment, it was found that the media was in a very valid and feasible category at an A value. The results of the media validation got a score of 184.5, with a percentage of 92%. The results of the material validation get a score of 187 with a rate of 94%. At the same time, the results of the media practicality test have a score of 174 with a very practical category with a percentage of 99%. The result of the students' readability test was 85% with a score of 84.9. This practicality test was carried out by a science teacher while the readability test was given to 27 grade VIII students. The results of the practicality and readability test of the media can be seen in Tables 5 and 6.

Table 5. Results of Teacher Practicality

Aspect	Score	Mark	Category
effectiveness	30	A	Very Practical
Appearance	54	A	Very Practical
Content/Material	19	A	Very Practical
Instructional	20	A	Very Practical
Programming	20	A	Very Practical
Critical thinking	13	A	Very Practical
Digital Literacy	18	A	Very Practical
Total	174	A	Very Practical

Table 6. Media Readability Test Results

Aspect	Score	Mark	Category
Garphic	50.9	A	Very Good
Content / Material	17	A	Very Good
Programming	17	A	Very Good
Total	84.9	A	Very Good

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 their 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).

Conclsion

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.

Acknowledgments
Researchers would like to thank the Directorate General of Higher Education, Research and Technology through the Directorate of Research, Technology and Community Service (DRTPM) for grants.

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

Funding
This research was funded through the Research and Community Service Program by the Directorate General of Higher Education, Research and Technology the Directorate of Research, Technology and Community Service (DRTPM)

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

Aktoprakac, A., & Hursen, C. (2022). A Bibliometric And Content Analysis Of Critical Thinking In Primary Education. *Thinking Skills and Creavity*, *4*.

Amir, M. (2009). *Inovasi Pendidikan Melalui Problem Based Learning: Bagaimana Pendidik Memberdayakan Pemelajar di Era Penetahuan*. Jakarta: Kencana Prenada Media Group.

Anisa, A. R., Ala, A. I., & Suffanah, K. N. (2021). Pengaruh Kurangnya Literasi serta Kemampuan dalam Berpikir Kritis yang Masih Rendah dalam Pendidikan di Indonesia. *Conference Series Journal*, *01*(01), 1–12.

Aprilia, C., Anggereini, E., & Ahda, Y. (2023). *The Development of Web-Based Learning Media (Glideapps) to Improve Digital Literacy and Science Literacy About Materials Human Digestive Systems*. *9*(3), 1112–1117. https://doi.org/10.29303/jppipa.v9i3.2618

Banawi, A. (2019). Implementasi Pendekatan Saintifik Pada Sintaks Discovery/Inquiry Learning, Based Learning, Project Based Learning. *Biosel: Biology Science and Education*, *8*(1), 90. https://doi.org/10.33477/bs.v8i1.850

Bawden, D. (2008). *Origins and Concepts of Digital Literacy dalam Lankshear, C. dan Knobel, M., Editors (Eds.), Digital Literacies: Concepts, Policies and Practices*. New York: Peter Lang Publishing Inc.

Cameron, S., & Craig, C. (2016). *STEM labs for middle grades, grades 5-8*. Illinois: Mark Twain Media.

Dewi, E. R. (2018). Metode Pembelajaran Modern Dan Konvensional Pada Sekolah Menengah Atas. *PEMBELAJAR: Jurnal Ilmu Pendidikan, Keguruan, Dan Pembelajaran*, *2*(1), 44. https://doi.org/10.26858/pembelajar.v2i1.5442

Dewi, N., & Riandi, R. (2016). Analisis Kemampuan Berpikir Kompleks Siswa Melalui Pembelajaran Berbasis Masalah Berbantuan Mind Mapping. *Edusains*, *8*(1). https://doi.org/10.15408/es.v8i1.1805

Ennis, R. (1989). *Evaluating Critical Thinking*. California: Midwest Publications.

Eshet-Alkali, Y., & Amichai-Hamburger, Y. (2004). Experiments in digital literacy. *Cyberpsychology and Behavior*, *7*(4), 421–429. https://doi.org/10.1089/cpb.2004.7.421

Facione, P. a. (2011). Critical Thinking : What It Is and Why It Counts. In *Insight assessment*. Retrieved from https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and-Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF

Fisher, A. (2009). *Berpikir Kritis (Sebuah pengantar)*. Jakarta: Erlangga.

Fitriyani , F., & Nugroho, A. T. (2022). Literasi Digital di Era Pembelajaran Abad 21. *El-Mujtama: Jurnal Pengabdian Masyarakat*, *2*(3), 213–220. https://doi.org/10.47467/elmujtama.v2i3.1088

Gilster, P. (1997). *Digital Literacy*. New York: Willy.

Hague, C., & Payton, S. (2013). Digital Literacy across the Curriculum. In *Literacy across the Curriculum*. https://doi.org/10.18848/978-1-61229-143-7/cgp

Haryani, E., Cobern, W. W., Pleasants, B. A. S., & Fetters, M. K. (2021). Analysis of teachers' resources for integrating the skills of creativity and innovation, critical thinking and problem solving, collaboration, and communication in science classroom. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 92–102. https://doi.org/10.15294/jpii.v10i1.27084

Hasibuan, A. T., & Prastowo, A. (2019). Konsep Pendidikan Abad 21: Kepemimpinan Dan Pengembangan Sumber Daya Manusia Sd/Mi.

MAGISTRA: Media Pengembangan Ilmu Pendidikan Dasar Dan Keislaman, *10*(1), 26–50. https://doi.org/10.31942/mgs.v10i1.2714

Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction*, *17*(6), 722–738. https://doi.org/10.1016/j.learninstruc.2007.09.013

Intelligence, E. (2020). *Economist Intelligence Unit*. Retrieved from https://theinclusiveinternet.eiu.com/explore/countries/ID/%0Aperformance/indicators/readiness/literacy

Kim, K. T. (2019). The structural relationship among digital literacy, learning strategies, and core competencies among south korean college students. *Educational Sciences: Theory and Practice*, *19*(2), 3–21. https://doi.org/10.12738/estp.2019.2.001

Kurniati, R. D., Andra, D., & Wayan Distrik, I. (2021). E-module development based on PBL integrated STEM assisted by social media to improve critical thinking skill: A preliminary study. *IOP Conference Series: Earth and Environmental Science*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012077

Kurniawan, D. A., & Husna, S. M. (2023). *A Study of Critical Thinking Skills , Science Process Skills and Digital Literacy : Reviewed Based on the Gender*. *9*(4), 1741–1752. https://doi.org/10.29303/jppipa.v9i4.1644

Mardapi, D. (2012). *Pengukuran Penilaian & Evaluasi Pendidikan*. Yogyakarta: Nuha Medika.

Mardhiyah, R. H., Aldriani, S. N., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya Keterampilan Belajar di Abad 21 sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia. *Jurnal Pendidikan*, *12*(1), 29–40. Retrieved from https://kns.cnki.net/kcms/detail/11.1991.n.20210906.1730.014.html

Muhali, M. (2019). Pembelajaran Inovatif Abad Ke-21. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *3*(2), 25. https://doi.org/10.36312/e-saintika.v3i2.126

Mulyani, T. (2019). Pendekatan Pembelajaran STEM untuk menghadapi Revolusi. *Seminar Nasional Pascasarjana 2019*, *7*(1), 455.

Murray-Harvey, R., Santos Reyes, W., & Pourshafie, T. (2013). What teacher education students learn about collaboration from problem-based learning. *Journal of Problem Based Learning in Higher Education*, *1*(1), 114–134.

Puspitarini, Y. D., & Hanif, M. (2019). Using Learning Media to Increase Learning Motivation in Elementary School. *Anatolian Journal of Education*, *4*(2), 53–60. https://doi.org/10.29333/aje.2019.426a

Putri, W. M., Bakri, F., & Permana, A. H. (2016). *Pengembangan Media Pembelajaran Berbasis Multimedia Augmented Reality Pada Pokok Bahasan Alat Optik*. *V*, SNF2016-RND-83-SNF2016-RND-88. https://doi.org/10.21009/0305010218

Rahayu, R., Iskandar, S., & Abidin, Y. (2022). Inovasi Pembelajaran Abad 21 Dan Penerapannya Di Indonesia. *Jurnal Basicedu*, *6*(2), 2099–2104. Retrieved from https://jbasic.org/index.php/basicedu/article/view/2082/pdf

Rahayu, S., Isnaeni, W., & Masturi, M. (2022). Critical Thinking Skills and Digital Literacy of High School Students in Science Learning Using E-Learning with STEM Vision. *Journal of Innovative Science …*, *11*(37), 354–367. Retrieved from https://journal.unnes.ac.id/sju/index.php/jise/article/view/57281

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

Rusmono. (2012). *Strategi Pembelajaran dengan Problem Based Learning itu. Perlu: untuk meningkatkan Profesionalitas Guru*. Bogor: Ghalia.

Sangaji, A. C., & Pribadi, I. A. (2023). Effect of Digital Literacy and Educational Technology on School Quality: Case Study of The Tiara Bangsa School. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 721–728. https://doi.org/10.29303/jppipa.v9i2.2827

Schleicher, A. (2019). PISA 2018. In *OECD: Insight and Interpretations*.

Simeon, M. I., Samsudin, M. A., & Yakob, N. (2022). Effect of design thinking approach on students' achievement in some selected physics concepts in the context of STEM learning. *International Journal of Technology and Design Education*, *32*(1), 185–212. https://doi.org/10.1007/s10798-020-09601-1

Sofyan, E., Gusniawati, & Buhaerah. (2021). Meningkatkan Motivasi Belajar Menggunakan Media Pembelajaran Metode Sydw Pada Pelajaran Matematika Di Smpn 3 Pare. *Mathematics Education Journal*, *4*(2), 6–10.

Sugiyono. (2015). *Metode Penelitian Pendidikan* (22nd ed.). Bandung: Alfabeta.

Syaparuddin, S., & Elihami, E. (2020). Peningkatan Motivasi Belajar Siswa Melalui Video pada Pembelajaran PKn di Sekolah Paket C. *Jurnal Edukasi Nonformal*, *1*(1), 187–200.

Thiagarajan, S. (1974). *Instructional Development for Training Teacher of Exceptional Cheldren*. Indiana: A Sourcebook, indiana Univ, Blomington Center for Inovation in Indiana University.

Thiaragajan, Sivasailam, & Others. (1974). Instructional development for training teachers of exceptional children: A sourcebook. In *Journal of School*

Psychology (Vol. 14). https://doi.org/10.1016/0022-4405(76)90066-2

Tristiana, N. E., & Kayyis, R. (2022). the Students Response of Using Google Classroom for Online Class. *Journal of English Language Teaching and Applied Linguistics*, *8*(1), 19–27.

Tugtekin, E. B., & Koc, M. (2020). Understanding the relationship between new media literacy, communication skills, and democratic tendency: Model development and testing. *New Media and Society*, *22*(10), 1922–1941. https://doi.org/10.1177/1461444819887705

UNESCO. (2018). A Global Framework of Reference on Digital Literacy. In *UNESCO Institute for Statistics*. Canada.

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, *7*(1), 1–18. https://doi.org/10.1186/s40594-020-00236-1

Wahyuaji, N. R., & Suparman. (2018). Deskripsi Kebutuhan Media Pembelajaran E-Learning Berpendekatan STEM untuk Mengembangkan Kemampuan Berfikir Kritis dan Kreatif Siswa SMA Kelas XI. *Seminar Nasional Pendidikan Matematika Ahmad Dahlan*, (May), 194–199.

Weiss, R. E., Knowltonb, D. S., & Morrisonc, G. R. (2002). Principles for using animation in computer- based instruction: theoretical heuristics for effective design. *Computers in Human Behaviour*, *18*(18), 465–477.

Yildirim, B., & Turk, C. (2018). The effectiveness of argumentation-assisted STEM practices. *Cypriot Journal of Educational Sciences*, *13*(3), 259–274. https://doi.org/10.18844/cjes.v13i3.3457

Yunianto, T., Suyadi, S., & Suherman, S. (2020). Pembelajaran abad 21: Pengaruhnya terhadap pembentukan karakter akhlak melalui pembelajaran STAD dan PBL dalam kurikulum 2013. *Premiere Educandum : Jurnal Pendidikan Dasar Dan Pembelajaran*, *10*(2), 203. https://doi.org/10.25273/pe.v10i2.6339

Ziatdinov, R., & Valles, J. R. (2022). Synthesis of Modeling, Visualization, and Programming in GeoGebra as an Effective Approach for Teaching and Learning STEM Topics. *Mathematics*, *10*(3). https://doi.org/10.3390/math10030398

Zubaidah, S. (2016). Keterampilan Abad Ke-21: Keterampilan Yang Diajarkan Melalui Pembelajaran. *Isu-Isu Strategis Pembelajaran MIPA Abad 21*, *2*(2), 1–17.