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Development Of Science Literacy Based Digital Teaching Materials To Improve Students Critical Thinking On The Sub Matter Of Energy Flow And Biogeochemical Cycles

Fayca Febi Tiara, Ibnul Mubarok[1]✉

[1]Biology Department, FMIPA, Universitas Negeri Semarang, Indonesia

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Abstract

This study aims to develop science literacy-based digital teaching materials that are feasible, practical, and effective for improving students' critical thinking on the sub-materials of energy flow and biogeochemical cycles. This type of research is research and development (RnD). The method used in research and development refers to the ADDIE development model. The population in this study were students in grades XI Mipa and X SMA Negeri 15 Semarang in the 2022/2023 academic year. MIPA 7 for small-scale trials and 60 students from each of 30 students X-1 and X-2. The data collection techniques used were interviews, questionnaires and tests. Based on data analysis, the feasibility test results of science literacy-based digital teaching materials by material experts amounted to 85% and media experts amounted to 82%. The results of the practicality test analysis by teachers in both scale trials were 90% and the results of the practicality test analysis by students in both scale trials were 84%. From all the results of the analysis, it is included in the category of very feasible and practical. To determine the effectiveness of science literacy-based digital teaching materials, pretests and posttests in classes X-1 and X-2 were conducted and then calculated using the N-Gain test based on aspects. The results of the N-Gain test for the science literacy aspect in both classes were 0.64% and the N-Gain test for the critical thinking ability aspect in both classes was 0.62%. This shows that classes X-1 and X-2 on improving science literacy and critical thinking skills are at moderate criteria. It can be concluded that the use of science literacy-based digital teaching materials is effective for improving students critical thinking skills in the sub-materials of energy flow and biogeochemical cycles.

✉ Correspondence Address:
D6 Building 1st Floor Jl Raya Sekaran Gunungpati Semarang
E-mail: ibnulmubarok@mail.unnes.ac.id

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INTRODUCTION

Educational ability regarding technology is a basic skill that must be possessed by a teacher. The utilization that can be done by teachers from technological developments is to combine the learning process with technological tools. According to Supriadi's research (2017), the success of the learning process using information technology media is higher than the conventional method.

To achieve the success of the learning process, teachers in planning learning must be able to cover all the elements needed to facilitate understanding and achievement of learning objectives, one of which is planning learning on teaching materials. Teachers in developing good teaching materials need to adjust the characteristics of today's students, namely the generation of students who are often referred to as "Generation Z". One of the characteristics of genZ is digital natives (Karina, 2019). Digital natives are generation Z who were born in the midst of the development of digital technology and have a great dependence on technology (Adityara, 2019). Students who belong to generation Z have a natural understanding of technological devices such as smartphones, tablets, and computers. This statement is in accordance with the results of interviews with several students at SMA Negeri 15 Semarang, students are accustomed to learning activities through smartphones.

In accordance with the reality in the field in the learning process, one of the steps that teachers need to take is to develop teaching materials in digital form. Digital teaching materials are learning materials presented in digital format including various types of content such as text, images, videos, animations, and interactivity designed to support the learning and teaching process through electronic devices (Farhana et al., 2021). The advantages possessed by digital teaching materials in terms of using materials are more flexible, easily accessible, and able to provide a more diverse learning experience.

The development of digital teaching materials has the potential to provide students and teachers with insights into learning designs that utilize technology. The core components of digital learning materials involve objectives, content, activities, evaluation, and feedback and reflection (Kosasih, 2021). In developing digital teaching materials, teachers need to pay attention to other components needed, namely digital teaching materials that are aligned with the abilities needed by students to have skills in accordance with the 21st century called 4C skills.

4C skills include critical thinking, creativity, collaboration, and communication skills. Based on an interview with one of the teachers at SMA Negeri 15 Semarang, teachers are in a strategic position to help students develop 4C skills. However, in reality, the 4C skills have not been developed optimally, one of which is critical thinking skills. Critical thinking ability is a thinking process that focuses on making decisions according to what is believed or done (Zakiah et al., 2019). The lack of students' critical thinking skills such as student activeness in discussion and decision making, students only tend to remember the content of the material without feeling motivated to argue or find solutions in the learning process.

Critical thinking skills play an important role in the implementation of an independent curriculum. In the independent curriculum approach, students not only act as proactive individuals in seeking knowledge but are encouraged to develop critical thinking skills (Kemendikbud, 2022). The independent curriculum is a curriculum with diverse intracurricular learning, where content is provided more optimally, so that students can explore concepts and strengthen the competence of learning objectives (Kemendikbud, 2022). In the independent curriculum, students are also equipped with basic skills, namely literacy skills. Literacy skills are not just reading and writing, but involve thinking skills that make students literate in learning, including in science learning.

Science literacy according to PISA (2015), is an ability to engage with issues related to science and scientific ideas. Students' science literacy skills are closely related to the demands of reading skills that lead to the ability to understand information critically. This is in accordance with Septiani's research (2019) that science literacy is one of the factors that influence critical thinking skills. Thus, in the independent curriculum, science literacy and critical thinking skills complement each other in the process of scientific understanding and the development of strong thinking skills.

The independent curriculum uses the concept of phases as an indicator of the level of learning ability.

The phase that will be focused on in this study is phase E which is intended for grade X SMA. Grade X students are presented with all science specialization materials to learn until phase E ends. One of the science specialization materials is biology which in its achievement is directed at the goal of sustainable development. Energy flow and biogeochemical cycles are sub-materials that have important concepts in maintaining environmental sustainability and achieving several sustainable development goals (Widodo et al., 2021). Energy flow and biogeochemical cycles involve the ability to analyze data, solve problems, explain complex ecological phenomena and formulate solutions to the ecological environmental challenges faced. With science literacy skills, students use scientific knowledge to formulate scientific problems. It requires students' critical thinking skills to be able to solve scientific problems and identify various solutions logically before reaching the right conclusion.

Given the importance of science literacy skills to be able to train students' critical thinking skills in learning energy flow and biogeochemical cycle sub-materials. Of course, the availability of digital teaching materials that have science literacy characteristics is needed to be able to improve students' critical thinking skills through the sub-materials of energy flow and biogeochemical cycles, so this research raises the research title, namely "Development of Science Literacy-Based Digital Teaching Materials to Improve Students' Critical Thinking in Energy Flow and Biogeochemical Sub-Materials".

RESEARCH METHOD

This type of research is research and development (RnD). This research was conducted at SMA Negeri 15 Semarang. The product developed in this research is science literacy-based digital teaching materials on the sub-materials of energy flow and biogeochemical cycles.

The method used in research and development refers to the ADDIE development model. According to Sugiyono's research (2015: 200) in full the ADDIE development model consists of five steps, namely analysis, design, development, implementation, and evaluation.

The subjects of this study were students in grades XI and X at SMA N 15 Semarang. The sample of this study consisted of students of class XI. MIPA 7 was used as a small-scale trial to determine the practicality of science literacy-based digital teaching materials. The number of students selected was 15, using purposive sampling technique. Consideration is based on academic ability. Large-scale trials conducted in classes X-1 and X-2 were used to determine the effectiveness of increasing students' critical thinking skills after using science literacy-based digital teaching materials.

Data obtained through the distribution of questionnaires that have been validated and practicality and test questions used to determine the effectiveness of digital teaching materials. The effectiveness of digital teaching materials can be seen from the results of student learning tests. The test questions were in the form of descriptions consisting of pre-test and post-test questions. The research data were analyzed quantitatively. The effectiveness test results were analyzed using the N-gain calculation.

RESULTS AND DISCUSSION

The results of research on the development of science literacy-based digital teaching materials to improve students' critical thinking on the sub-matter of energy flow and Android-based mobile learning media on virus material to improve student learning outcomes are as follows.

1. Feasibility of Science Literacy Based Digital Teaching Materials

The feasibility of digital teaching materials is analyzed based on the results of research by material experts and media experts. Feasibility assessment by material experts using a Likert scale of 1 - 4. The results of the feasibility analysis of digital teaching materials are presented in Table 1.

Table 1. Analysis of the Feasibility Results of Digital Teaching Materials by Material Experts

Material Feasibility Aspect	Percentage (%)	Criteria
Feasibility of content	79	worth
Presentation feasibility Language feasibility	86	very feasible
Characteristics	81	very feasible
Science literacy	90	very feasible
Critical thinking	90	very feasible
Average	86	very feasible
	85	very feasible

The feasibility assessment of science literacy-based digital teaching materials was also assessed by media experts. The results of the feasibility assessment of digital teaching materials by media experts are presented in Table 2.

Table 2. Analysis of the Feasibility Results of Digital Teaching Materials by Media Experts

Media Feasibility Aspects	Percentage (%)	Criteria
Graphics	82	very feasible
Language	81	very feasible
Average	82	very feasible

The percentage analysis of the feasibility research results of digital teaching materials from material experts obtained an average of 85%, while the media experts obtained an average of 82%, both of which were on very feasible criteria. From the results of the feasibility assessment by material experts and material experts, it can be concluded that science literacy-based digital teaching materials in terms of feasibility have improvements in order to achieve a product that is very feasible to be applied to learning. In accordance with the research of Charlina et al. (2019) validated products require improvement until the developed product is said to be suitable for use in the next stage. The feasibility validation results have a significant influence in improving the products developed (Setiawan et al., 2020).

2. Practicality of Science Literacy Based Digital Teaching Materials

The practicality test aims to determine the practicality of the digital teaching materials developed as far as the feasibility of content, presentation, language, graphics, characteristics, science literacy aspects and critical thinking aspects for teacher use. The results of practicality by teachers on small and large scale trials are presented in Table 3.

Table 3. Practicality Results by Teacher

Practicality Aspect	Percentage (%)	
	Small Scale Trial	Large Scale Trial
Feasibility of content	89	89
Presentation feasibility Language feasibility	89	93
Characteristics	89	92
Science literacy	85	95
Critical thinking	90	92
Feasibility of content	86	93
Graphics	90	90
Average	88	92

From the results of the teacher's practicality in the small-scale trial, it obtained an average of 88%, but there were still suggestions to improve the shortcomings in the digital teaching materials, namely by adding animated videos supporting the material on the discussion of differences in food webs and biogeochemical cycles. After making improvements to the practicality of digital teaching materials, large-scale trials can obtain practicality with an average of 92%. It can be concluded that the average results of practicality by teachers in small and large scale trials of digital teaching materials obtained a percentage of 90% which was in very practical criteria. The practicality test aims to determine the practicality of digital teaching materials developed in terms of interest, material, language for use by students. The results of

practicality by students on small and large scale trials are presented in Table 4.

Table 4. Practicality Results by Students

Assessment Indicators	Percentage (%)	
	Small Scale Trial	Large Scale Trial
Attraction	81	86
Material	80	85
Language	86	87
Average	82	86

From the results of student practicality in small-scale trials, an average of 82% was obtained, but there were still suggestions to improve the shortcomings in digital teaching materials, namely adding games to digital teaching materials. The game contained in digital teaching materials is an educational game that aims to attract students' attention so that they are not easily bored to study digital teaching materials. After making improvements to the practicality of digital teaching materials, large-scale trials can obtain practicality with an average of 86%. It can be concluded that the average results of practicality by students in small and large scale trials of digital teaching materials obtained a percentage of 84% which is in very practical criteria. From the results of the practicality assessment, it shows that digital teaching material products based on science literacy are very practical to use in learning energy flow sub-materials and biogeochemical cycles. Good teaching materials can be used easily and practically (Setiawan et al., 2020).

3. Effectiveness of Science Literacy Based Digital Teaching Materials

The results of the assessment of the effectiveness of science literacy based digital teaching materials on improving students' critical thinking skills on the subject of energy flow and biogeochemical cycles can be obtained from pretest-posttest scores integrated in the domain of science literacy aspects and aspects of critical thinking skills. Furthermore, the N-gain test was conducted to determine the improvement of students' critical thinking skills on the subject of energy flow and biogeochemical cycles. A recapitulation of the calculation of the N-gain test for science literacy aspects and critical thinking skills aspects in both classes is presented in Tables 5 and 6.

Table 5. Recapitulation of N-gain test Calculation of Science Literacy Aspects

Aspects of Science Literacy	N-Gain		Average N-gain	Criteria
	X-1	X-2		
Context Aspect	0,50	0,66	0,58	Medium
Knowledge Aspect	0,67	0,53	0,60	Medium
Competency Aspect	0,77	0,76	0,76	High

Table 6. Recapitulation of N-gain test Calculation of Critical Thinking Aspects

Critical Thinking Indicators	N-Gain		Average N-gain	Criteria
	X-1	X-2		
Elementary Clarification	0,83	0,64	0,73	High
Basic Support	0,64	0,60	0,62	Medium
Inference	0,67	0,59	0,63	Medium
Advanced Clarification	0,67	0,53	0,60	Medium
Strategies and tactics	0,53	0,51	0,52	Medium

Based on the calculation of the N-gain test, the increase in science literacy shown in Table 5 has an average of 0.64 with a medium category. The use of science literacy into digital teaching materials on energy flow and biogeochemical cycles has a positive effect on improving students' critical thinking skills. Supported by the opinion of Karademir et al. (2016) that individuals who have critical thinking skills have a positive effect on science literacy skills because through this ability the attitude towards science literacy becomes

meaningful. Meanwhile, based on the calculation of the N-gain test, the increase in critical thinking skills shown in Table 6 has an average of 0.62 with a medium category. This means showing that science literacy-based digital teaching materials can improve students' critical thinking skills. The use of science literacy into science literacy-based digital teaching materials has a positive effect on improving students' critical thinking skills. this is in accordance with the research of Yuriza et al. (2018)

The use of science literacy into digital teaching materials on energy flow and biogeochemical cycles has a positive effect on improving students' critical thinking skills. Supported by the opinion of Karademir et al. (2016) that individuals who have critical thinking skills have a positive effect on science literacy skills because through this ability the attitude towards science literacy becomes meaningful. Science literacy implemented in digital teaching materials serves as a foundation for understanding, evaluation, and scientific information. In accordance with the opinion of Rohmi (2015), science literacy is defined as an understanding of science content and scientific practices. In the context of energy flow and biogeochemical cycles, science literacy can help students to understand fundamental concepts such as energy flow, cycles in biogeochemistry and interactions between organisms. This is in accordance with the research of Diana et al. (2015) students who have science literacy skills have the skills to solve problems using the science concepts they have acquired.

Science literacy also includes an understanding of the scientific method and the use of evidence to support scientific statements. It interprets scientific research related to energy flow and biogeochemical cycles. With critical thinking skills, students can analyze scientific information in depth, identifying underlying assumptions. In this context, critical thinking skills help in evaluating complex scientific concepts. For example, when students understand how climate change affects the biogeochemical cycling of carbon, science literacy helps students understand the concept of increasing carbon dioxide concentrations in the atmosphere, while critical thinking skills help students examine current scientific data and question its implications. In accordance with the research of Singh et al. (2017) students who have good literacy indicate that students are able to use their knowledge to think critically in solving a problem well.

The relationship between science literacy and critical thinking indicates that to understand science thoroughly requires good thinking skills. This shows that increasing scientific literacy skills affects students' critical thinking skills. This is supported by the opinion of Rahayuni (2016) which states that critical thinking skills are directly proportional to science literacy skills. Then reinforced by Davies (2013) statement that critical thinking skills can be built through discovery-based learning using a science literacy approach. If a student's critical thinking skills are good, then his scientific knowledge is also good. When students have a good foundation in science, their critical thinking increases and students can confidently respond to problems that arise in their environment. This statement is also in line with the research of Dayelma et al. (2019) which states that there is a significant relationship between science literacy and critical thinking skills. So it can be concluded that digital teaching materials based on science literacy are effective because they can improve students' critical thinking skills.

CONCLUSION

The conclusions obtained from the results of the research on the development of science literacy based digital teaching materials on the subject of energy flow and biogeochemical cycles to improve students' critical thinking skills are as follows.

1. The feasibility of digital teaching materials based on the assessment by material experts and media experts is very feasible.
2. The practicality of digital teaching materials based on small trials and large-scale trials of teachers and students is very practical.
3. Science literacy based digital teaching materials on the subject of energy flow and biogeochemical cycles are effective for improving the critical thinking skills of class X students at SMA Negeri 15 Semarang on medium criteria.

REFERENCES

Adityara, S., & Rakhman, R. T. (2019). Karakteristik Generasi Z dalam Perkembangan Diri Anak melalui Visual.*Seminar Nasional Seni dan Desain "Reinvensi Budaya Visual Nusantara" Jurusan Seni Rupa dan Jurusan Desain Universitas Negeri Surabaya*,1(1), 401-406.

Charlina, & Septyanti, E. (2019). Development of Work Sheets for Students (LKPD) in Writing Explanation Text ELS. *Journal on Interdisciplinary Studies on Humanities,* 2(4), 515–528.

Davies, M. (2013). Critical Thinking and The Disciplines Reconsidered. *Higher Education Research & Development*, 32(4), 529-544. https://doi.org/10.1080/07294360.2012.697878

Dayelma, Y., Octarya, Z., Refelita. (2019). Materi Ikatan Kimia. *Journal Education and Chemistry,* 1(2),2.

Diana, S., Rachmatulloh, A., & Rahmawati, E. S. (2015). Profil Kemampuan Literasi Sains Siswa SMA Berdasarkan Instrumen Scientific Literacy Assesments (SLA). *Prosiding Seminar Nasional Pendidikan Biologi FKIP UNS,* 1(201).

Farhana, F., Suryadi, A., & Wicaksono, D. (2021). Pengembangan Bahan Ajar Berbasis Digital Pada Mata Pelajaran Bahasa Inggris Di SMK Atlantis Plus Depok. *Journal Instruksional*, 3(1),1-17.

Karademir, E., & Ulucinar, U. (2016). Examining The Relationship Between Middle School Students' Critical Reading Skills, Science Literacy Skills and Attitudes: A structural Equation Modeling. *Journal of Education in Science, Environment and Health*, 3(1), 29–29. https://doi.org/10.21891/jeseh.275669.

Karina, Mercia. (2019). *Gen Z Insights: Perspective on Education*. Surakarta : UNISRI Press.

Kemendikbud. (2017). *Panduan Praktis Penyusunan E-modul*. Jakarta : Direktorat Pembinaan SMA

Kosasih, E. (2021). *Pengembangan Bahan Ajar*. Jakarta: PT. Bumi Aksara

Rahayuni, G. (2016). Hubungan Keterampilan Berpikir Kritis dan Literasi Sains pada Pembelajaran IPA Terpadu dengan Model PBM dan STM. *Jurnal penelitian dan Pembelajaran IPA*, *2*(2), 131-146.

Rohmi, P. (2015). *Penerapan Levels of Inquiry untuk Meningkatkan Domain Kompetensi dan Pengetahuan Sains Siswa SMP pada Tema Pencemaran Lingkungan*. Bandung : Universitas Pendidikan Indonesia.

Setiawan, M. E., Sastria, E., Haryanto, T., Novinovrita, M., Angela, L., Lardiman, H., Bukhari, A., Habibi, M. (2020). The Practicality and Validity of The Popular Scientific Book Development Survival Plants. *Journal Bioedusiana*, 9(02), 4997–5001.

Singh, B., Kaur, A., & Brar, K. S. (2017). Information Literacy and Learning Styles: An Overview of Resource-Based Student Centred Learning. *Journal of Management Research and Analysis,* 4(3), 84–86. https://doi.org/10.18231/2394-2770.2017.0012.

Sugiyono. (2015). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif dan R&D).* Bandung : Alfabeta.

Supriadi, F. (2017). Efektivitas Pembelajaran Media E-Learning Berbasis Web Dan Konvensional Terhadap Tingkat Keberhasilan Belajar Mahasiswa (Studi Kasus Mahasiswa Program Studi Manajemen Fakultas Ekonomi Universitas Muhammadiyah Pontianak. *Jurnal Manajemen Motivasi*, *12*(2), 722-726.

Widodo, D., Kristianto, S., Susilawaty, A., Armus, R., Sari, M., Chaerul, M., ... & Mastutie, F. (2021). *Ekologi dan Ilmu Lingkungan*. Jakarta : Yayasan Kita Menulis.

Yuriza, P. E., Adisyahputra, dan Sigit, D. V. (2018). Hubungan Antara Kemampuan Berpikir Tingkat Tinggi dan Tingkat Kecerdasan dengan Kemampuan Literasi sains pada Siswa SMP. *Jurnal Pendidikan Biologi*, 11(1), 13-20

Zakiah, Linda & Lestari, Ika. (2019). *Berpikir Kritis Dalam Konteks Pembelajaran*. Bogor: Erzatama Karya Abadi.