Bioedukasi
Jurnal Biologi dan Pembelajarannya
Vol. 21 No 3, October 2023, page 241-250
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v21i3.41512
jurnal.unej.ac.id/index.php/BIOED

Development of Interactive Digital Textbook Based on STEM to Enhance Junior High School Students' Critical Thinking Skills in Environmental Pollution Subject

Nor Indriyanti[1], Imam Mudakir[2], Sulifah Aprilya Haryani[3]
[1,2,3] Master of Science Education, University of Jember, Indonesia

Article Info

Article history:
Received July 16, 2023
Revised September 27, 2023
Accepted October 02, 2023

Keywords:
Critical thinking,
Interactive digital textbook,
STEM.

ABSTRACT

The purpose of this research is to describe the stages of developing an interactive digital textbook based on STEM for the subject of environmental pollution, and to test the effectiveness of the interactive digital textbook based on STEM in enhancing the critical thinking skills of junior high school students in the subject of environmental pollution. This research is development research that adopts the 4 D model from Thiagarajan's, which consists of four stages, namely define, design, developed, and disseminate (Mutia, 2020). The research subjects were junior high school students who had never received environmental pollution material. Limited-scale trials and single-class trial were conducted at Ma'arif 08 Junior High School in Wuluhan Jember. Dissemination was carried out at Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School This research used qualitative and quantitative approaches. STEM-based interactive digital textbooks on environmental pollution material are effective in improving critical thinking skills with an average score of 89.03 based on indicators of providing simple explanations, providing further explanations, developing strategies and tactics, and students' ability to draw conclusions.

Corresponding Author:
Nor Indriyanti,
Magister Pendidikan IPA, University of Jember
Kalimantan Street 37 Sumbersari, Jember 68121, Indonesia
Email: norindriyanti91@gmail.com

1. INTRODUCTION

The rapid development in the era of globalization, especially in the fields of technology, information, and communication, has had an impact on human life. These impacts include high competition and changes in the order of life in the education and non-education sectors (Mayawati et al., 2020). The shifts and changes in life demand that all parties be able to adapt well, including the education sector.

Education in Indonesia must be able to utilize technological advancements. Technological developments enable the facilitation of the learning process by creating new learning spaces (Marta, 2019). With technology, students can access learning resources even outside the school (Motamedi, 2019), making learning more flexible (Shatri, 2020). Education in Indonesia will advance if it adopts technology-based learning.

Technology-based learning aims to equip students with the necessary skills in the era of globalization. With technology-based learning, students become accustomed to the 21st-century skills (Widodo et al., 2021). One approach that can be used to develop students' 21st-century skills is STEM. The STEM approach integrates various disciplines to develop critical, logical, and systematic thinking skills. By integrating more than two disciplines, STEM prepares students to face the developments and challenges of the 21st century (Gulen & Yaman, 2019).

To address the challenges of the 21st century, 21st-century skills are required. The 21st-century skills are known as the 4Cs, which include creative thinking, critical thinking and problem-solving, communication, and collaboration (Haviz et al., 2018; Zubaidah, 2019; Lubis & Lubis, 2021; Partono et al., 2021). Critical thinking is an aspect in which students practice seeking the truth in every piece of information they encounter (Bustami et al., 2018). 21st-century skills develop all types of thinking skills, from basic to critical thinking skills (Dasgupta et al., 2018; Khoiriyah & Husamah, 2018; Setambah et al., 2019).

Critical thinking skills can be sharpened by using interactive STEM-based learning media. This is because the determinant factor in the success of the learning process is the application of interactive learning media (Tafonao, 2018; Faqih et al., 2021). The need for learning media is an integral part of the learning process (Nursyahidah et al., 2020). Educators can utilize smartphone technology in learning by using engaging and practical features and applications (Afriansyah et al., 2020). Learning media that utilizes STEM-based smartphone technology is capable of meeting the demands of the 21st century and developing students' intellect by integrating technology with various scientific knowledge and skills in science, technology, engineering, and mathematics (Thahir et al., 2020). Technological advancements have played a significant role in the integral process of life, both in schools and in society. Teachers are expected to effectively utilize digital technology to develop students' competencies (Tondeur et al., 2017; Starkey, 2020). The integration of education and technology allows students to experience a different learning experience.

Science education is the study of the universe and its contents, as well as the events that occur within it. It is carried out by experts through a series of scientific processes (Suroso et al., 2021). Science education enables students to independently discover ideas, provides direct experiences, and helps them understand the surrounding world scientifically (Sutarto et al., 2021). The environment, as one of the objects of science, encompasses various issues, including environmental pollution.

Environmental pollution is a science subject taught in 7th grade, and it is a complex subject as it involves environmental pollution and management. Based on interviews with teachers in Jember, Banyuwangi, and Situbondo, it was found that students did not show significant changes in their environmental awareness behavior after learning about environmental pollution. The behavioral changes that showed environmental concern were limited to separating organic and inorganic waste, disposing of trash properly, recycling waste into decorations or more useful items. However, these behaviors have not significantly reduced the quantity of waste.

The results of a questionnaire distributed to science teachers in Banyuwangi, Jember, and Situbondo showed that the learning resources used by teachers in the classroom were 43.8% printed textbooks, 31.3% worksheets, package books, and natural materials, and only 12.5% of teachers used digital textbooks. The need for digital textbooks among teachers reached 68.8%. With the media used by teachers, 62.5% of students' critical thinking skills were categorized as moderate, and 75% of teachers stated that they did not use STEM textbooks to teach environmental pollution. 93.3% of teachers agreed that the development of a textbook on environmental pollution that can improve students' critical thinking skills and learning outcomes in junior high school should be conducted.

The results of the questionnaire distributed to students in Jember, Banyuwangi, and Situbondo showed that 64.5% of students highly needed user-friendly learning media. 50% of students expressed a need for electronic learning media. Students faced some difficulties in understanding the subject of environmental pollution, with a percentage of 40.8%. 60.5% of students were not familiar with STEM learning. 67.1% of students did not use digital textbooks for the subject of environmental pollution. 96.1% of students agreed that the development of an interactive digital textbook based on STEM to enhance their critical thinking skills and learning outcomes should be conducted. Based on the analysis of students' needs, the developed interactive digital textbook based on STEM should consider the following suggestions: being easy, practical, and engaging; facilitating students' understanding of the content and learning process; providing concise yet detailed explanations; being interactive to increase students' enthusiasm for learning; not overburdening students; and including more practical activities.

Based on the described information, it is deemed necessary to develop a textbook that utilizes the STEM approach, particularly for the subject of environmental pollution. The objectives of this research include: 1) describing the stages of developing an interactive digital textbook based on STEM for the subject of environmental pollution, and 2) testing the effectiveness of the interactive digital textbook based on STEM in enhancing the critical thinking skills of junior high school students in the subject of environmental pollution.

2. RESEARCH METHOD

This type of research is a Research and Development study. The research aims to develop an interactive digital textbook based on STEM. This research is a development research that adopts the 4 D model from Thiagarajan's, which consists of four stages, namely define, design, develope, and disseminate (Mutia, 2020).

The research subjects are junior high school students who have not received any instruction on environmental pollution during their time in junior high school. A limited-scale pilot test and a single-class trial were conducted at Ma'arif 08 Junior High School Wuluhan Jember. The wider dissemination was conducted at two different schools, namely Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School. This research was conducted in the second semester of the 2022/2023 academic year.

In this research, data analysis was conducted using both qualitative and quantitative approaches. Suggestions and critiques from experts and students were analyzed using a qualitative approach, while data on effectiveness were processed using a quantitative approach.

The analysis of critical thinking skills was calculated based on each indicator of Ennis' critical thinking skills. The measurement of critical thinking skills was obtained from the analysis of students' answers according

to the developed indicators. The students' final scores were calculated by summing up all the scores for each indicator (Sugiyono, 2015). Using the formula:

$$Cs = JS \times \frac{100}{N}$$

Information:
Cs : Assess student's critical thinking skills
JS : The number of scores obtaine by student
N : Score sum

Table 2.1 Criteria for Student's Critical Thinking Ability

No	Criteria	Score sum
1	Very low	0-39,99
2	Low	40,00-54,99
3	High enough	55,00-69,99
4	High	70,00-84,99
5	Very high	85,00-100

Nuraini (2017)

3. RESULT AND DISCUSSION

Based on the 4D stages conducted (define, design, develop, disseminate), the following results were obtained:

a. Define Stage: In the defining stage, the activities conducted included: a) survey results on teachers' needs; b) survey results on students' needs analysis; c) concept analysis results.

b. Design Stage: The design of the textbook includes the development of test criteria, media selection, format selection, and initial design. The design of the interactive digital textbook based on STEM is divided into three main parts: introduction, content, and conclusion. Each section can be seen in Table 3.1.

Table 3.1 Design of Interactive Digital Textbook Based on STEM

No.	Book component	Textbook design
1.	Introduction	a. Textbook cover b. Coverpage c. Foreword d. List of contents e. Concept maps f. Introduction g. Core competencies and basic competencies h. Study guide i. The role of teachers and parents
2.	Content	a. Learning objectives b. Learning materials: definition of pollution, factors that cause pollution, impacts arising from pollution, strategies to overcome pollution. The scope ofmaterial includes water, air, soil and soun pollution. c. Components supporting learning matterials: Let's think critically in the formof exposure to pollution problems in the surrounding environment, critical thinking questions, STEM mega projects, questions to measure learningoutcomes, learning videos, learning animations, summaries, formative test.
3.	Closing	a. Glossary b. Bibliography c. About the author

Figure 3.1 Design of STEM-Based Interactive Digital Textbooks

Furthermore, the development of research instruments and supporting learning tools needs to be adjusted to the characteristics of the interactive digital textbook based on STEM.

d. Develop Stage: The activities carried out in this stage include expert validation, user validation, and testing of the interactive digital textbook. The validation process consists of validating the interactive digital textbook based on STEM to measure the validity of the developed textbook, validation of learning tools (syllabus, lesson plans, pretest-posttest questions on critical thinking skills), small-group testing, and single-class testing. The small-group

testing aims to determine whether the interactive digital textbook based on STEM for the subject of environmental pollution can be read, worked on, and completed according to the planned timeline. The research subjects used in this testing were 9 students from class VII B of Ma'arif 08 Junior High School Wuluhan Jember, consisting of 3 high-ability students, 3 moderate-ability students, and 3 low-ability students. There are 4 indicators for analyzing critical thinking skills based on the theory proposed by Ennis, which was modified by Apiati and Hermanto. These indicators are presented in table 3.2.

Table 3.2 Ennis Critical Thinking Indicators (Apiati & Hermanto, 2020)

No	Indicator	Activity
1	Elementary clarification	Identify problems by focusing on questions and elements contained in the problem
2	Advance clarification	Identify the relationship between the concepts in the problemby creating an IPA model and appropriate explanations
3	Strategy and tactics	Using the right strategy in solving problems, as well ascomplete and correct
4	Inference	Make the right conclusions

The assessment of critical thinking skills was obtained from the average scores of the pretest and posttest on critical thinking conducted in class VII B of Ma'arif 08. The pretest and posttest on critical thinking consisted of 4 essay questions. The average scores of the pretest and posttest can be seen in Table 3.3.

Table 3.3 Results of Critical Thinking Skills in Small-Group Testing

	Mean Score of Critical Thinking Pretest	Mean Score of Critical Thinking Posttest
	33,89	99,44
Category	Very low	Very high

Table 3.3 shows an improvement in students' critical thinking abilities in the learning process. This improvement is indicated by the average score for critical thinking, which increased from 33.89 in the pretest, categorized as very low, to 99.44 in the posttest, categorized as very high.

There are four indicators of critical thinking abilities measured in this study, which include providing elementary clarification, providing advanced clarification, formulating strategies and tactics, and drawing inferences. The average results of each indicator calculation are listed in Figure 3.1.

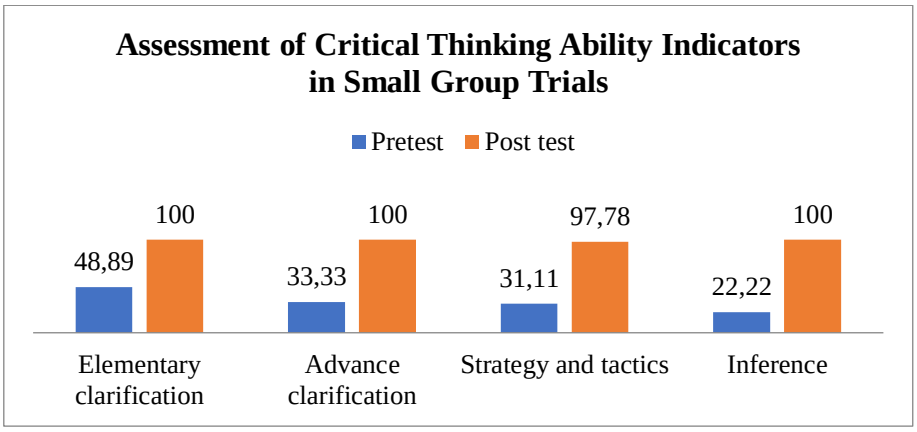

Figure 3.1 Assessment of Critical Thinking Ability Indicators in Small Group Trials

Figure 3.1 shows an improvement in students' critical thinking abilities as observed from each indicator. In the indicator of providing elementary clarification, the average score was 48.89 in the pretest and increased to 100 in the posttest. In the indicator of providing advanced clarification, the average score was 33.33 in the pretest and increased to 100 in the posttest. In the indicator of formulating strategies and tactics, the average score was 31.11 in the pretest and increased to 97.78 in the posttest. In the indicator of drawing inferences, the average score was 22.22 in the pretest and increased to 100 in the posttest. This indicates that the interactive digital STEM-based textbook is effective in improving students' critical thinking abilities.

A single-class trial was conducted after revising the interactive digital STEM-based textbook based on feedback received during a small-group trial. The research subjects in the single-class trial were 36 students from class VIIA of Ma'arif 08 Junior High School. The single-class trial consisted of 5 learning sessions.

The assessment of critical thinking abilities was obtained from the average scores of the pretest and posttest on critical thinking conducted in class VIIA of Ma'arif 08 Junior High School. The pretest and posttest on critical thinking consisted of 4 essay questions. The results of the pretest and posttest scores can be seen in Table 3.4.

Table 3.4 Results of Critical Thinking Abilities in the Single-Class Trial

	Mean Score of Critical Thinking Pretest	**Mean Score of Critical Thinking Posttest**
	45,42	89,03
Category	Low	Very High

Table 3.4 shows an improvement in students' critical thinking abilities in the learning process. This indicates that the interactive digital STEM-based textbook is effective in enhancing students' critical thinking skills.

The average results of the calculations for each of the four indicators of critical thinking abilities in the single-class trial stage, measured in this study, are listed in Figure 3.2.

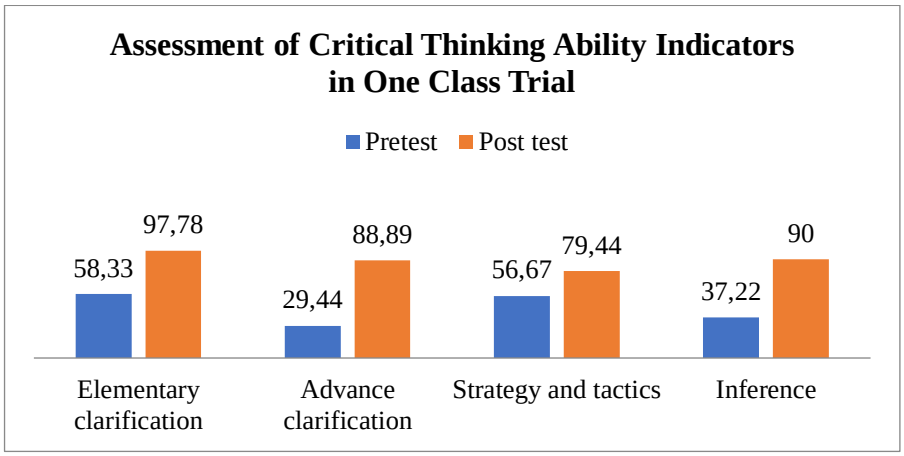

Figure 3.2 Assessment of Critical Thinking Ability Indicators in One Class Trial

Figure 3.2 shows an improvement in students' critical thinking abilities as observed from each indicator. In the indicator of providing elementary clarification, the average score was 58.33 in the pretest and increased to the indicator of providing advanced clarification, the average score was 29.44 in the pretest and increased to 88.89 in the posttest. In the indicator of formulating strategies and tactics, the average score was 56.67 in the pretest and increased to 79.44 in the posttest. In the indicator of drawing inferences, the average score was 37.22 in the pretest and increased to 90 in the posttest. This indicates that the STEM-based interactive digital textbook is effective in enhancing students' critical thinking skills.

d. Dissemination Phase.

The dissemination phase aims to determine the effectiveness of the STEM-based interactive digital textbook when implemented in other schools with different student characteristics. Dissemination was conducted at two schools, Ma'arif Ambulu Islamic Junior High School and Darul Hikam Jenggawah Islamic Junior High School. Dissemination at Ma'arif Ambulu Islamic Junior High School was carried out in class VII B with 30 students, while at Darul Hikam Jenggawah Islamic Junior High School, it was conducted in class VII A with 21 students. The assessment of critical thinking abilities was obtained from the average scores of the pretest and posttest on critical thinking. The results of the pretest and posttest scores can be seen in Table 3.5.

Table 3.5 Results of Critical Thinking Abilities in the Dissemination Phase

No	**School**	**Mean Score of Critical Thinking Pretest**	**Mean Score of Critical Thinking Posttest**
1	Ma'arif Ambulu Islamic Junior High School	42,50	94,50
	Category	Low	Very High
2	Darul Hikam Islamic Junior High School	41,67	94,29
	Category	Low	Very High

Table 3.5 shows that in both schools, there is an improvement in students' critical thinking abilities in the learning process. The improvement at Ma'arif Ambulu Islamic Junior High School is demonstrated by the average score

for critical thinking, which increased from 42.50 in the pretest, categorized as low, to 94.50 in the posttest, categorized as very high. The improvement at Darul Hikam Jenggawah Islamic Junior High School is indicated by the average score for critical thinking, which increased from 41.67 in the pretest, categorized as low, to 94.29 in the posttest, categorized as very high. This indicates that the STEM-based interactive digital textbook is effective in enhancing students' critical thinking abilities in both Ma'arif Ambulu Islamic Junior High School and Darul Hikam Jenggawah Islamic Junior High School. As for the average results of the calculations for each of the four indicators of critical thinking abilities in the single-class trial stage, measured in this study, they are listed in Table 3.6.

Table 3.6 Assessment of Critical Thinking Ability Indicators in the Dissemination Phase

Indicator	**School**			
	Ma'arif Ambulu Islamic Junior High School		**Darul Hikam Islamic Junior High School**	
	Pretest Average	**Posttest Average**	**Pretest Average**	**Posttest Average**
Elementary clarification	45,33	97,33	58,10	100
Advance clarification	30,67	86,67	36,19	94,29
Strategy and tactics	55,33	98,00	34,29	98,10
Inference	38,67	96,00	38,10	84,76
Average	42,50	94,50	41,67	94,29
Category	Low	Very high	Low	Very high

Table 3.6 shows the overall average of students' critical thinking abilities at Ma'arif Ambulu Islamic Junior High School and Darul Hikam Jenggawah Islamic Junior High School, as observed from each indicator. The overall results of students' critical thinking abilities at Ma'arif Ambulu Islamic Junior High School indicate an improvement from a pretest score of 42.50, categorized as low, to a posttest score of 94.50, categorized as very high. This improvement is also evident at Darul Hikam Jenggawah Islamic Junior High School, where the average pretest score increased from 41.67, categorized as low, to 94.29 in the posttest, categorized as high. This indicates that the STEM-based interactive digital textbook is effective in enhancing students' critical thinking skills.

Effectiveness of STEM-Based Interactive Digital Textbook on Environmental Pollution Topic

Textbooks, in general, can be considered effective when learning objectives are achieved. Three main factors that can be used to assess the effectiveness of a textbook are its implementation in classroom learning, utilization of instructional media during class, and continuity of its utilization in students' self-learning and teaching (Situmorang, 2013). The effectiveness of the interactive digital STEM-based textbook in this research is determined by the average N-gain scores of student learning outcomes and the average critical thinking abilities measured through several stages, including small-group trials, single-class trials, and dissemination.

Small-group trials and single-class trials were conducted at Ma'arif 08 Junior High School. The small-group trial involved 9 students from class VIIB, while the single-class trial involved 36 students from class VIIA. The dissemination stage was conducted at two schools, namely Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School. In this study, the pretest was administered in the first meeting, and the posttest was given in the final meeting. The learning activities began by connecting the learning material to students' prior experiences and asking questions to recall and relate them to the subsequent material. Furthermore, literacy activities were conducted using the STEM-based interactive digital textbook, along with video presentations and activities for students to argue about the given problems, aiming to encourage critical thinking. In the final meeting, students were assigned a STEM mega-project, which included making an ecobrick chair, a simple air filter device, and producing biogas from organic waste.

This improvement occurred because the researcher made efforts to address the weaknesses that arose in each meeting, minimizing the potential errors in subsequent meetings. Another factor that influenced the improvement in the small-group trials and single-class trials was the interactive nature of the developed textbook, which provided various features that made the learning activities enjoyable. This advantage is in line with the findings of Perdana et al. (2021) and Jannah & Atmojo (2022) that interactive digital textbooks support the creation of a learning environment that facilitates students, with interactive content, fun elements, and a contextually relevant approach to everyday life (learning videos, concrete images, quizzes), which effectively enhance students' self-learning skills.

The features included in the textbook were also tailored to optimize brain performance, as the brain generally functions better when processing colorful images and videos. The use of color images can stimulate students' thought processes and help them understand concepts accurately (Stefanikova & Prokop, 2015). Additionally, the inclusion of instructional videos in the textbook provides students with new learning experiences by presenting phenomena that are difficult to observe directly (Novita et al., 2019).

The effectiveness of the STEM-based interactive digital textbook in this research is also determined by the criteria of students' critical thinking abilities. The applied indicators of critical thinking abilities consist of providing elementary clarification, providing advanced clarification, formulating strategies and tactics, and

drawing inferences. The researcher measured students' critical thinking abilities by providing 4 critical thinking skill questions. Data in Table 3.3 on critical thinking abilities in the small-group trials indicate an improvement in students' critical thinking abilities in the learning process. This improvement is demonstrated by the average score for critical thinking, which increased from 33.89 in the pretest, categorized as very low, to 99.44 in the posttest, categorized as very high. As for the results in the single-class trials, data in Table 3.4 show an improvement in students' critical thinking abilities, with the average score increasing from 45.42 in the pretest, categorized as low, to 89.03 in the posttest, categorized as very high. This improvement indicates that the STEM-based interactive digital textbook is effective in enhancing students' critical thinking abilities. The observed improvement aligns with the theory of digital textbooks. Prasetyono & Hariyono (2020) stated that digital textbooks effectively achieve learning objectives, thus improving students' cognitive, affective, and psychomotor skills, as well as enhancing logical thinking and critical thinking abilities.

The final stage of this research is the dissemination phase, which is conducted after the textbook has been deemed effective based on the trial results. Dissemination activities were carried out at two schools, Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School. The steps taken in this stage are similar to the previous stages.

Table 4.27 on students' learning comprehension in both schools show an improvement. The improvement is demonstrated by the average N-gain of 0.85 at Ma'arif Ambulu Islamic Junior High School and 0.82 at Darul Hikam Islamic Junior High School, both falling into the high category. This indicates that the STEM-based interactive digital textbook is effective in enhancing students' learning outcomes at both Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School. Meanwhile, the assessment of students' critical thinking abilities in table 4.28 also shows an improvement in their understanding of the learning outcomes during the learning process at both schools. The improvement at Ma'arif Ambulu Islamic Junior High School is indicated by the average score for critical thinking, which increased from 42.50 in the pretest, categorized as low, to 94.50 in the posttest, categorized as very high. The improvement at Darul Hikam Islamic Junior High School is demonstrated by the average score for critical thinking, which increased from 41.67 in the pretest, categorized as low, to 94.29 in the posttest, categorized as very high. Thus, it can be concluded that the STEM-based interactive digital textbook is effective in enhancing students' critical thinking abilities at both Ma'arif Ambulu Islamic Junior High School and Darul Hikam Islamic Junior High School.

4. CONCLUSION

Based on the data analysis of this research, it can be concluded that interactive digital STEM-based textbooks on environmental pollution are effective in enhancing critical thinking skills. These results were obtained from an average score of 89.03 in critical thinking ability, as measured by indicators such as providing simple explanations, providing further explanations, devising strategies and tactics, and students' ability to draw conclusions.

5. ACKNOWLEDGEMENT

Thank you is conveyed to Ma’arif 08 Junior High School Wuluhan, Ma’arif Ambulu Islamic Junior High School, and Darul Hikam Islamic Junior High School for their support, which has contributed to the successful implementation of this research.

3. REFERENCES

Afriansyah, E. A., Madio, S. S., Sumartini, T. S., Mardiani, D., Nurulhaq, C., Sritresna, T., & Nuraeni, R. (2020). Pelatihan Aplikasi Jotform untuk Pembuatan Form Kuesioner dan Presensi. *Jurnal PEKEMAS*, *3*(2), 26–32.

Apiati, V., & Hermanto, R. (2020). Kemampuan Berpikir Kritis Peserta Didik dalam Memecahkan Masalah Matematik Berdasarkan Gaya Belajar. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(1), 167–178. https://doi.org/10.31980/mosharafa.v9i1.630

Bustami, Y., Syafruddin, D., & Afriani, R. (2018). The implementation of contextual learning to enhance biology students’ critical thinking skills. *Jurnal Pendidikan IPA Indonesia*, *7*(4), 451–457. https://doi.org/10.15294/jpii.v7i4.11721

Dasgupta, C., Magana, A. J., & Vieira, C. M. (2018). *Title: Investigating the Affordances of a CAD Enabled Learning Environment for Promoting Integrated STEM Learning Author names and affiliations: Investigating the Affordances of a CAD Enabled Learning Environment for Promoting Integrated STEM Learning*.Gulen, S., & Yaman, S. (2019). The Effect of Integration of STEM Disciplines into Toulmin’s Argumentation Model on Students’ Academic Achievement, Reflective Thinking, and Psychomotor Skills*. *Journal of Turkish Science Education*, *16*(2), 216–230. https://doi.org/10.12973/tused.10276a

Faqih, A., Nurdiawan, O., & Setiawan, A. (2021). Pengembangan Media pembelajaran Multimedia Interaktif Alat Masak Tradisional Berbasis Etnomatematika. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(2), 301–310. https://doi.org/10.31980/mosharafa.v10i2.876

Haviz, M., Karomah, H., Delfita, R., Umar, M. I. A., & Maris, I. M. (2018). Revisiting generic science skills as 21st century skills on biology learning. *Jurnal Pendidikan IPA Indonesia*, *7*(3), 355–363. https://doi.org/10.15294/jpii.v7i3.12438

Jannah, D. R. N., & Atmojo, I. R. W. (2022). Media Digital dalam Memberdayakan Kemampuan Berpikir Kritis Abad 21 pada Pembelajaran IPA di Sekolah Dasar. Jurnal Basicedu, 6(1), 1064–1074. https://doi.org/10.31004/basicedu.v6i1.2124

Khoiriyah, A. J., & Husamah, H. (2018). Problem-based learning: Creative thinking skills, problem-solving skills, and learning outcome of seventh grade students. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *4*(2), 151–160. https://doi.org/10.22219/jpbi.v4i2.5804

Lubis, N., & Lubis, A. (2021). Pembelajaran Abad 21 Dengan Implementasi Experiential-Based Learning Bagi Guru Sd Negeri 101789 Marindal I Kabupaten Deli Serdang. *Amaliah: Jurnal Pengabdian Kepada Masyarakat*, *5*(1), 1–6. https://doi.org/10.32696/ajpkm.v5i1.686

Marta, L. C. (2019). The Integration of digital devices into learning spaces according to the needs of primary and secondary teachers. *TEM Journal*, *8*(4), 1351–1358. https://doi.org/10.18421/TEM84-36

Mayawati, C. I., Evalin, N., & Anggreinie, S. (2020). Jurnal Lentera. *Jurnal Lentera, Kajian Keagaaan, Kelilmuwan Dan Teknologi, Vol 19 No. 1 Maret 2020, E-ISSN : 2540 -7767*, *2*, 2013–2015.

Motamedi, V. (2019). The promises of presentational technology for teaching and learning. *Journal of Education and Learning (EduLearn)*, *13*(3), 416–419. https://doi.org/10.11591/edulearn.v13i3.13175

Mutia, L., Gimin, & Mahdum (2020). Development of Blog-Based Audio Visual Learning Media to Improve Student Learning Interests in Money and Banking Topic. *Journal of Educational Science* Vol. 4 No. 2 (April, 2020) 436-448. https://doi.org/10.31258/jes.4.2.p.436-448

Nuraini, Nita. 2017. Critical Thinking Profile of Student of Biological Teacher Candidate as Efforts to Prepare 21 st Century Generatio. *Jurnal Penelitian Pendidikan Biologi.* Vol 1 (2) http://jurnal.umpalembang.ac.id/indexphp/dikbio

Nursyahidah, F., Saputro, B. A., Albab, I. U., & Aisyah, F. (2020). Pengembangan Learning Trajectory Based Instruction Materi Kerucut Menggunakan Konteks Megono Gunungan. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(1), 47–58. https://doi.org/10.31980/mosharafa.v9i1.560

Partono, P., Wardhani, H. N., Setyowati, N. I., Tsalitsa, A., & Putri, S. N. (2021). Strategi Meningkatkan Kompetensi 4C (Critical Thinking, Creativity, Communication, & Collaborative). *Jurnal Penelitian Ilmu Pendidikan*, *14*(1), 41–52. https://doi.org/10.21831/jpipfip.v14i1.35810

Prasetyono, R. N., & Hariyono, R. C. S. (2020). Development of flipbook using web learning to improve logical thinking ability in logic gate. *International Journal of Advanced Computer Science and Applications*, *11*(1), 342–348. https://doi.org/10.14569/ijacsa.2020.0110143

Setambah, M. A. B., Tajudin, N. M., Yaakob, M. F. M., & Saad, M. I. M. (2019). Adventure learning in basics statistics: Impact on students critical thinking. *International Journal of Instruction*, *12*(3), 151–166. https://doi.org/10.29333/iji.2019.12310a

Shatri, Z. G. (2020). Advantages and disadvantages of using information technology in learning process of students. *Journal of Turkish Science Education*, *17*(3), 420–428. https://doi.org/10.36681/tused.2020.36

Situmorang, M. 2013. Pengembangan Buku Ajar Kimia SMA Melalui Inovasi Pembelajaran dan Integrasi Pendidikan Karakter untuk Meningkatkan Hasil Belajar Siswa. *Jurnal FMIPA Kimia. Prosiding*.

Starkey, L. (2020). A review of research exploring teacher preparation for the digital age. *Cambridge Journal of Education*, *50*(1), 37–56. https://doi.org/10.1080/0305764X.2019.1625867

Stefanikova, S., and P. Prokop. 2015. Do We Believe Pictures More or Spoken Words? How Specific Information Affects How Students Learn about Animals. *Eurasia Journal of Mathematics, Science, and Technology Education*. 11(4): 725-733. doi: 10.12973/Eurasia.2015.1380a.

Suroso, J., Indrawati, Sutarto, S., Mudakir, I., & Chotib, M. (2021). Analysis of high school students' skills in solving science problems in the environment. *AIP Conference Proceedings*, *2330*(March). https://doi.org/10.1063/5.0044038

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

Sutarto, Prihatin, J., Hariyadi, S., & Wicaksono, I. (2021). Development of student worksheets based on STEM approach to improve students' critical thinking skills. *Journal of Physics: Conference Series*, *2104*(1). https://doi.org/10.1088/1742-6596/2104/1/012009

Tafonao, T. (2018). Peranan Media Pembelajaran Dalam Meningkatkan Minat Belajar Mahasiswa. *Jurnal Komunikasi Pendidikan*, *2*(2), 103. https://doi.org/10.32585/jkp.v2i2.113

Thahir, A., Anwar, C., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding. *Journal of Physics: Conference Series*, *1467*(1). https://doi.org/10.1088/1742-6596/1467/1/012008Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children: a sourcebook. Virginia: The Council for Exceptional Children.

Tondeur, J., Aesaert, K., Pynoo, B., van Braak, J., Fraeyman, N., & Erstad, O. (2017). Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century. *British Journal of Educational Technology*, *48*(2), 462–472. https://doi.org/10.1111/bjet.12380

Widodo, C. A., Sukendra, I. K., & Sumandya, I. W. (2021). Pengembangan Bahan Ajar DIgital Matematika SMA Kelas X Berbasis STEM. *WIDYADARI Jurnal Pendidikan*, *22*(2), 478–486. https://doi.org/10.5281/zenodo.5550400

Zubaidah, S. (2019). STEAM (Science, Technology, Engineering, Arts, and Mathematics): Pembelajaran untuk Memberdayakan Keterampilan Abad ke-21. *Seminar Nasional Matematika Dan Sains*, *September*, 1–18.