BIO-INOVED
Jurnal Biologi-Inovasi Pendidikan
Volume 6, Issue 3, October 2024 page. 342-352

P-ISSN : 2684-9062 | E-ISSN : 2714-9803
https://ppjp.ulm.ac.id/journal/index.php/bino
DOI: 10.20527/bino.v6i3.19525

Development of interactive multimedia on environmental pollution topics with STEM approach for junior high school students

Zusje Wiesje Merry Warouw [(1)] *, Elcia Romarta Purba [(2)], Widya Anjelia Tumewu [(2)], Ester Caroline Wowor [(2)], Brian Ricard Wola [(3)]

[(1)] Study Program of Biology Education, Faculty of Mathematics, Natural and Earth Science, Universitas Negeri Manado, Minahasa, North Sulawesi, Indonesia, 95618
[(2)] Study Program of Science Education, Faculty of Mathematics, Natural and Earth Science, Universitas Negeri Manado, Minahasa, North Sulawesi, Indonesia, 95618
[(3)] Study Program of Elementary Teacher Edcation, Sekolah Tinggi Keguruan dan Ilmu Pendidikan Persada Evav Tual, Tual, Maluku, Indonesia, 97611

** Corresponding Author Email: zusyewarouw@unima.ac.id*

Article Information

Keyword:
Environmental pollution; Development; Interactive multimedia; Science education; STEM

Kata Kunci:
Pencemaran lingkungan; Pengembangan; Multimedia interaktif; Pendidikan IPA; STEM

History:
Received : 12/06/2024
Revised : 02/08/2024
Accepted : 04/10/2024
Published : 11/10/2024

Abstract

The 21st century is known as the digital age, in which teachers' and students' ability to access and utilize technology is essential. This study aims to develop feasible and practical interactive multimedia on environmental pollution topics with a STEM approach for junior high school students. The research type we use is development research using the ADDIE model. The data collection techniques used were interviews and questionnaires. The research instruments used were interview sheets and questionnaires. Quantitative and qualitative data analysis techniques were used in this study. The results showed that the validation of subject matter experts was 93%, learning media experts was 94%, and peer assessment was 94%. All three were included in the very feasible category and did not require revision. In addition, the small group evaluation obtained an average score of 4.50 with a percentage of 90%. Based on these findings, interactive multimedia on environmental pollution topics with a STEM approach for junior high school students was declared feasible and practical for science learning. The STEM-based teaching material we have successfully produced can support and answer some of today's science learning challenges.

Abstrak. *Abad ke-21 dikenal sebagai era digital, dimana kemampuan guru dan siswa dalam mengakses dan memanfaatkan teknologi menjadi sangat penting. Penelitian ini bertujuan untuk mengembangan multimedia interaktif berbasis STEM pada topik pencemaran lingkungan untuk siswa SMP yang layak dan praktis digunakan. Jenis penelitian yang kami gunakan adalah penelitian pengembangan menggunakan model ADDIE. Teknik pengumpulan data yang kami gunakan adalah wawancara dan kuisioner. Instrumen penelitian yang kami gunakan adalah lembar wawancara dan angket. Teknik analisis data kuantitatif dan kualitatif digunakan dalam penelitian ini. Hasil penelitian menunjukkan bahwa validasi ahli materi pelajaran 93%, ahli media pembelajaran 94%, dan penilaian teman sejawat 94% yang mana ketiganya termasuk pada kategori sangat layak dan tidak memerlukan revisi. Selain itu, hasil penilaian siswa dalam small group evaluation memperoleh skor rata-rata 4.50 dengan persentase 90%. Berdasarkan temuan tersebut, multimedia interaktif berbasis STEM pada topik pencemaran lingkungan untuk siswa SMP dinyatakan layak dan praktis dimanfaatkan dalam pembelajaran IPA. Bahan ajar berbasis STEM yang berhasil kami produksi diharapkan mendukung dan menjawab sebagian tantangan pembelajaran IPA masa kini.*

A. Introduction

The 21st century is known as the digital age, where almost all areas of human life are rapidly affected by the development and advancement of information and communication technology (Balyer & Öz, 2018; Ginting et al., 2023). This situation challenges teachers to design learning integrating technology, information, and communication (Wu & Tai, 2016). That is why teachers' and students' ability to access and utilize technology is important (Wola, 2023). Teachers are expected to design flexible learning that allows students to easily reach learning subjects (Huang et al., 2020). How teachers design teaching materials, adopt new technologies, and adapt to the whole digital transformation are key factors in education services in the 21st century.

Learning media is defined as physical and non-physical tools teachers use to deliver material to students to make it more effective and efficient (Lumintang et al., 2023; Pondoki et al., 2023; Puspitarini & Hanif, 2019). Several technology-based learning media can be used to support the learning process. Based on the technology used, Depdiknas (2010) classifies teaching materials into four categories, namely printed teaching materials, including handouts, books, modules, student activity sheets, brochures, leaflets, wallcharts, photos/ pictures, and models/packets; audio teaching materials including cassettes, radios, vinyl records, and audio compact disks; audio-visual teaching materials such as video compact disks, and films; and interactive multimedia teachings materials such as computer-assisted instruction, interactive learning multimedia compact disks, and web-based learning materials. This technology-based learning media facilitates the learning process in terms of effectiveness and efficiency.

Nowadays, multimedia-based learning is increasingly popular in various fields of learning and training because it stimulates new ways of delivering information (Leow & Neo, 2014). Multimedia combines more than one type of media, such as text, symbols, images, pictures, audio, video, and animation, usually with the help of technology, intending to improve understanding (Guan et al., 2018). Multimedia is interpreted as computer-assisted instruction/ learning (CAI/CAL) or computer-assisted learning presentation that combines text, graphics, video, and audio (Rahmat, 2015; Xie et al., 2020). CAI mechanizes independent learning, guidance availability, and interaction. CAI programs are one way to improve student learning outcomes (De Witte et al., 2015). On the other hand, interactive is defined as the ability to control or determine the order of learning materials following the wishes or needs of the user. Interactive multimedia allows interaction between students and learning materials (Manurung, 2020). Research conducted by Dinçer (2015) reported that research in Turkey on using computer-assisted learning is mostly conducted in the science field and shows a better impact than traditional learning.

Science, technology, engineering, and mathematics (STEM) education is one of the most important themes that is intensively researched and practiced in science education today (Park et al., 2020; Rungkat et al., 2023; Warouw et al., 2024). The STEM approach explores and integrates teaching and learning between two or more STEM disciplines (English, 2016; Martín-Páez et al., 2019). The STEM approach aims to increase students' understanding of how things work, increase students' utilization of technology, and introduce engineering before college (Marsya et al., 2022). Through STEM education, students are trained to become individuals who can handle problems and learn new things, produce creative solutions, become someone who can organize themselves, be able to think logically, and be technologically literate (Widya et al., 2019). Applying STEM to learning can encourage students to design, develop, and utilize technology, hone cognitive, manipulative, and affective, and apply knowledge (Kapila & Iskander, 2014). The results of a literature review by Muttaqiin (2023) showed that the STEM approach to science learning positively impacts 21st-century skills and is often paired with various learning models.

Based on interviews with science teachers conducted at SMP Negeri 3 Tondano, it is known that science teachers in the learning process only use simple media and learning resources such as textbooks and simple power points and have never used interactive multimedia in learning. This condition causes students to be bored and passive when learning. A more in-depth interview revealed that teachers' lack of ability to create interactive learning multimedia and unsupportive school facilities were factors in this concern. In the formative assessment results, we also found that students' learning outcomes on environmental pollution topics were not maximized. In fact, this topic is very important to be fully understood by students while studying at school, considering that learning science is one of the ways humans understand natural phenomena that occur in the surrounding environment (Masloman et al., 2023; Ruitan et al., 2023; Suriani et al., 2022). Science teaching is challenging because it often requires changing students' misconceptions about nature (Suriani et al., 2023).

One of the benefits of learning about environmental pollution for students is to foster their environmental literacy. Environmental literacy for junior high school students is important (Siddiq et al., 2020). This goal can be achieved through seventh-grade science learning on environmental pollution topics stated in Basic Competency 3.8: "analyzing the occurrence of environmental pollution and its impact on ecosystems" (Republik Indonesia, 2018). Good

environmental literacy skills make students carry positive changes in their environment (Drake et al., 2024).

Previous studies reported on the development of STEM-based interactive multimedia on various topics(Arianti et al., 2022; Basri & Adlini, 2023; Hidayati & Irmawati, 2019; Khairani et al., 2023; Pramuji et al., 2018; Putri et al., 2023; Sumawati et al., 2021). We found that interactive multimedia developed with the STEM approach is still limited. However, research that successfully develops interactive multimedia about environmental pollution with a STEM approach for junior high school students is rarely reported. On the other hand, research by Rosalina & Suhardi (2020) is still limited to analyzing the need for developing interactive multimedia on environmental pollution. Furthermore, they found that the learning media used by science teachers when presenting the topic of environmental pollution is still limited to textbooks and student worksheet, and there is no use of interactive multimedia. Widayanti et al. (2019) stated that there is a need for the development of STEM-based teaching materials to support today's learning. Based on these facts and the various learning problems revealed in the previous interviews, it is necessary to present interactive multimedia based on the STEM approach to environmental pollution topics for students. Therefore, this study aims to develop feasible and practical interactive multimedia on environmental pollution topics with a STEM approach for junior high school students. The STEM-based teaching material we have successfully produced is wished to support and answer some of the science learning challenges today.

B. Material and method

The type of research we used was development research with the ADDIE model design (see Figure 1). Its acronym depicts the five steps: analysis, design, development, implementation, and evaluation (Spatioti et al., 2022). The ADDIE instructional design model provides a structure for planning, developing, and adapting instruction to focus on learner needs and content requirements (Siew & Chin, 2018). It is an iterative instructional design method in which the instructional designer may return to any previous step based on the formative evaluation undertaken during the process (Shakeel et al., 2023). This model is an approach that helps learning designers, content developers, or even teachers create efficient and effective instructional designs on any learning product (Aldoobie, 2015).

At the analysis stage, we reviewed the curriculum used, reviewed the basic competencies, analyzed the science subject matter, analyzed the learning process, set the objectives to be achieved, and determined the media to be developed. At the design stage, we determine and design the product developed in the form of STEM-based interactive multimedia. The development stage is the translation of the predetermined design. We used Autoplay Media Studio application software to produce interactive multimedia. The components contained in the interactive multimedia are adjusted to the description contained in the storyboard. The STEM-based interactive multimedia produced is then validated by subject matter expert lecturers and learning media experts. This activity aims to assess the feasibility of STEM-based interactive multimedia from the angle of the underlying theoretical constructs. In addition, ten peers were also validated to determine the readability of the product. The validators provided various suggestions and input as improvement materials for product improvement.

The implementation stage was carried out by organizing the learning process using the STEM-based interactive multimedia that had been developed. This activity was carried out in a limited class of six students. The evaluation stage is the last process that has actually been carried out at each stage of ADDIE. In particular, the evaluation was carried out in a limited small group evaluation, where students were asked to fill out a questionnaire to obtain data on the practicality of using the product.

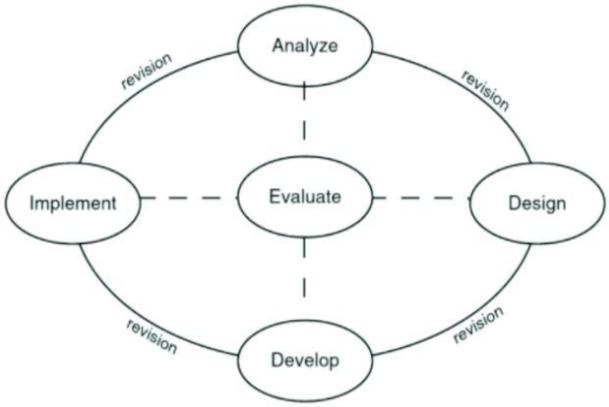

Figure 1
ADDIE model development steps (Source: Branch, 2009)

The research subjects consisted of a lecturer as subject matter expert, a lecturer as learning media expert, ten students of the science education undergraduate program at Universitas Negeri Manado as peers, and six students at SMP Negeri 3 Tondano. The data collection techniques we used were interviews and questionnaires. The research instruments we used were interview sheets and validation questionnaires. We conducted a semi-structured interview with a science teacher at SMP Negeri 3 Tondano to get data about science learning in the classroom. Also, an expert validation questionnaire was used to obtain data about the feasibility, a peer questionnaire was used to obtain data about the product's readability, and a student response test questionnaire was used to obtain data about the practicality of using the product.

Quantitative and qualitative data analysis techniques were used in this study. Quantitative data analysis techniques are used to analyze the scores from the expert validation questionnaire, peer validation, and student responses. The calculation of the average score of the questionnaire answers uses a Likert scale consisting of five categories. The scoring categories are available in Table 1. Validators and students assessed the questionnaire and obtained a score that was summed up and percented to determine the feasibility and attractiveness of the media made. The percentage results are then interpreted in the feasibility criteria which can be seen in Table 2.

Based on Table 2, the STEM-based interactive multimedia developed is declared feasible and practical to use if it obtains a minimum percentage of 61%. Qualitative data analysis was carried out to analyze subject matter and media experts' validation questionnaires using validators' suggestions, criticisms, and responses. The results of this analysis are then used to consider improvements or revisions to STEM-based interactive multimedia.

Table 1 Scoring categories

Score	Category
5	Very Good / Strongly Agree
4	Good / Agree
3	Quite Good / Doubtful
2	Less Good / Less Agree
1	Not Good / Disagree

Table 2 Percentage of media feasibility criteria

Achievement level	Category
81% - 100%	Very feasible, no need for revision / Very practical
61% - 80%	Feasible, needs minor revisions / Practical
41% - 60%	Quite feasible, needs moderate revision / Quite practical
21% - 40%	Less feasible, needs major revisions / Less practical
< 21%	Not feasible, cannot be used / Not practical

C. Results and discussion

The research was conducted to develop interactive multimedia on environmental pollution topics with a STEM approach. The development model uses the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The following presents the results of the research sequentially at each stage.

Analysis

The results of our analysis show that: (1) the curriculum being used is Curriculum 2013; (2) basic competencies and learning objectives can be seen in Table 3; (3) environmental pollution is the subject matter we chose, which consists of sub-topics of water pollution, air pollution, and soil pollution; (4) the goal we want to achieve is the presence of a media that supports learning; (5) STEM-based interactive multimedia is the learning media we set to develop.

In the analysis of the learning process, we found that the learning process is still teacher-centered. The learning resources and learning media that teachers use are only textbooks and simple power points. The teacher stated that she had never used interactive multimedia. This situation causes students to be bored and passive when learning. Teachers' lack of ability to create interactive learning multimedia and unsupportive school facilities are known to be the causes. Besides, environmental literacy for junior high school students is important (Siddiq et al., 2020).

In accordance with the analysis of potentials and problems, researchers concluded that STEM-based interactive multimedia needs to be developed to assist students and teachers in learning. Students can be more active because they operate the media directly. The components in this interactive multimedia such as text, animation, video, images, and audio make it easier for students to understand environmental pollution topics.

Table 3 Basic competencies and learning objectives on environmental pollution topics

Basic competencies (Knowledge)	Learning objectives
Analyze the occurrence of environmental pollution and its impact on the ecosystem	After following the learning process: 1. Students can explain the definition of environmental pollution 2. Students can mention the types of environmental pollution 3. Students can explain the factors that cause and impact water pollution 4. Students can explain the causes and effects of air pollution 5. Students can explain the causes and effects of soil pollution 6. Students can mention examples of types of environmental pollution 7. Students can mention technology and daily activities to reduce environmental pollution.

Design

The design stage requires careful and mature planning as well as understanding the learning objectives to be achieved and how the material will be designed to achieve these objectives (Adeoye et al., 2024). At this stage, we determine and design the product developed in the form of STEM-based interactive multimedia. This stage includes creating flowcharts and storyboards. The flowchart is made to determine the relationship and flow between the subject matter content and the multimedia components. Storyboard includes the design of learning multimedia in terms of subject matter content, interactive multimedia principles, and multimedia components in animation, video, audio, text, and images.

Development

We produce STEM-based interactive multimedia using Autoplay Media Studio application software. The background and quiz questions were designed using Photoshop software. The background display made using Photoshop software can be seen in Figure 2.

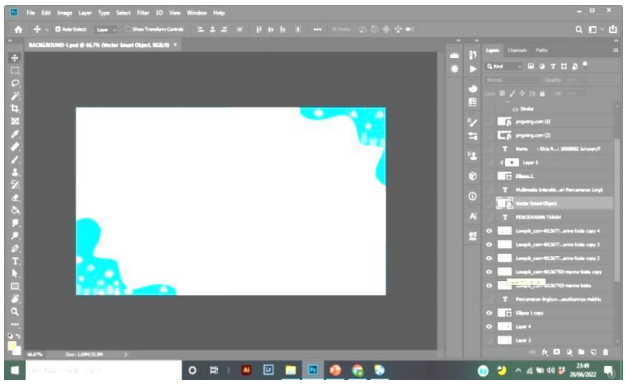

Figure 2
Display of background creation using Photoshop

Figure 2 shows the background creation using images and elements adapted to environmental pollution topics. After making the background, continue making quiz questions. The display of making quiz questions using Photoshop software can be seen in Figure 3.

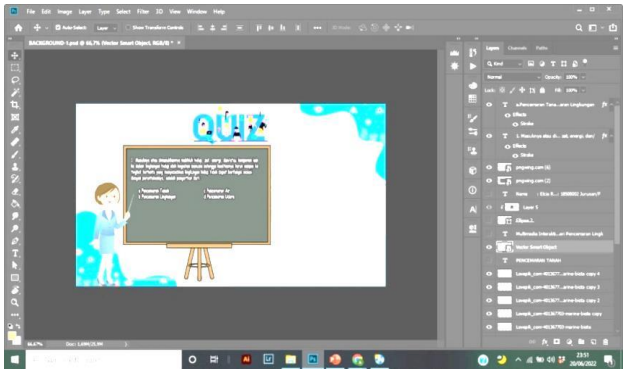

Figure 3
Display of quiz question creation using Photoshop

Figure 3 displays the quiz questions designed attractively and easy to read. After creating the background and quiz questions in Photoshop, the next step was to finalize the interactive multimedia. The display of interactive multimedia creation using autoplay software can be seen in Figure 4. Figure 4 displays the creation of interactive multimedia made slide by slide and connected through the appropriate menus and buttons.

Figure 4
Display of product creation using Autoplay Media Studio (in Indonesian)

The STEM-based interactive multimedia that has been completed was then validated by subject matter experts and learning media experts to determine its feasibility. In addition, ten peers were also validated to determine its readability. The results of validation by subject matter experts are shown in Figure 5, the results of validation by learning media experts are shown in Figure 6, and validation by peers is shown in Figure 7.

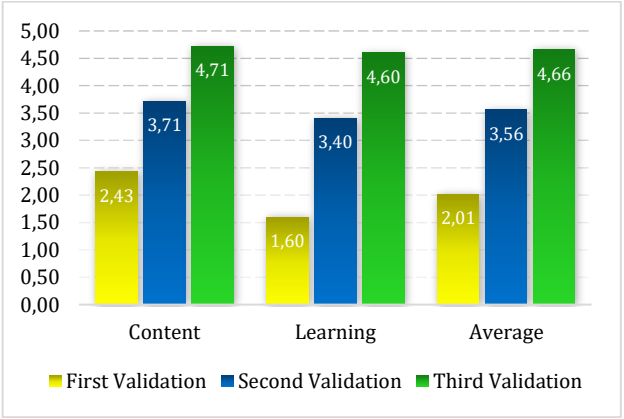

Figure 5
Subject matter expert validation results

Based on Figure 5, it can be seen that the validation activities by subject matter experts were carried out three times. In the first validation, the content aspect received an average score of 2.43, and the learning aspect received an average score of 1.60, so the overall average score was 2.01 with a percentage of 40%. When referring to Table 2, these results indicate that STEM-based interactive

multimedia is included in the category of less feasible and needs major revisions. Furthermore, in the second validation, the content aspect received an average score of 3.71, and the learning aspect received an average score of 3.40, so the overall average score was 3.56, with a percentage of 71%. Regarding Table 2, these results indicate that STEM-based interactive multimedia is included in the feasible category and needs minor revisions. Finally, in the third validation, the content aspect received an average score of 4.71, and the learning aspect received an average score of 4.60, so the average score overall was 4.66, with a percentage of 93%. Regarding Table 2, these results indicate that STEM-based interactive multimedia has entered the very feasible and does not require revision category. The results of the assessment by subject matter experts above are in line with research by Hidayati & Irmawati (2019), who reported that the assessment by subject matter experts of the anatomy of human physiology multimedia based on STEM education they developed received an 89% rating which is included in the very valid and does not need revision category. In addition, our findings also support research by Basri & Adlini (2023), who reported that the assessment by subject matter experts of the STEM-Based Interactive Multimedia they developed received a 96% rating, which is included in the highly valid and no revision category.

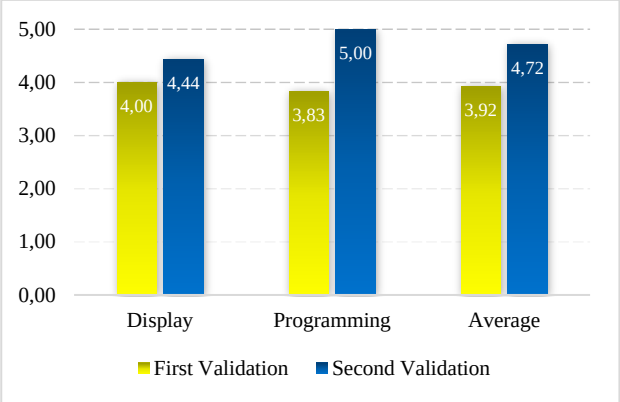

Figure 6
Learning media expert validation results

Based on Figure 6, it can be seen that the validation activities by learning media experts were carried out twice. In the first validation, the display aspect received an average score of 4.00, and the programming aspect received an average score of 3.83, so the overall average score was 3.92, with a percentage of 78%. Table 2 shows that STEM-based interactive multimedia is included in the feasible category and needs minor revisions. Finally, in the second validation, the display aspect received an average score of 4.44, and the programming aspect received an average score of 5.00, so the overall average score was 4.72, with a percentage of 94%. When referring to Table 2, these results indicate that STEM-based interactive multimedia is included in the very feasible category and does not require revision. The results of the assessment by learning media experts above are in line with research by Hidayati & Irmawati (2019), who reported that the assessment by learning media experts of the multimedia anatomy of human physiology based on STEM education they developed received a 97% assessment which was included in the very valid and does not need revision category. In addition, our findings also support research by Arianti et al. (2022), who reported that the assessment by learning media experts of the interactive multimedia based on STEM they developed was in the very valid category.

The assessment of STEM-based interactive multimedia by subject matter and learning media experts indicates that there are still parts that need to be improved. The experts' comments and recommendations were used as a standard for revision. After we completed product improvements, the validation was carried out again, and we finally reached the maximum score. It is clear that evaluation and revision are needed to improve the quality of the learning multimedia products developed so as to produce good-quality.

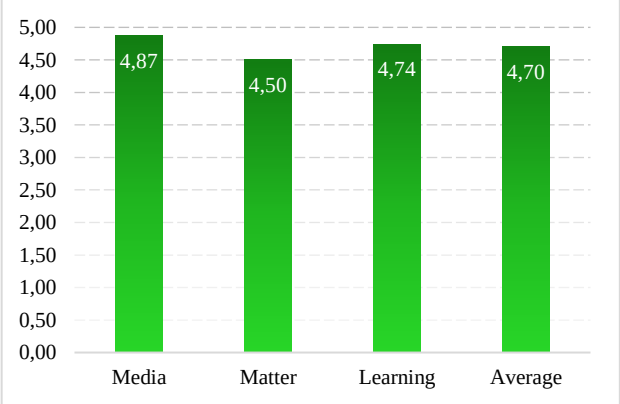

Figure 7
Peer validation results

Based on Figure 7, it can be seen that the assessment of product readability by peers is carried out in three aspects. The media aspect gets an average score of 4.87, the matter aspect gets an average score of 4.50, and the learning aspect gets an average score of 4.74, so the overall average score is 4.70, with a percentage of 94%. When referring to Table 2, these results indicate that STEM-based interactive multimedia is included in the very feasible category and does not require revision. The peer assessment results above align with research by Zalukhu et al. (2022), who reported that peer assessment of the web-based interactive multimedia they developed was in the good category. In addition, our findings also support research by Triyanti (2015), who reported that peer assessment of the interactive multimedia she developed was in the very good category.

Implementation & Evaluation

After the product meets the eligibility criteria, the next step is implementation. This activity was conducted in a limited class of six seventh graders at SMP Negeri 3 Tondano. The students were first introduced and given directions on how to use the product. At the end of the lesson, students were given a questionnaire consisting of 10 items to determine their response and obtain data on the practicality of using the product. This student response test is part of the evaluation stage. The results of the limited trial in the small group evaluation are shown in Table 4.

Table 4 Limited trial in small group evaluation

No.	Statement	Student code						Total
		1	2	3	4	5	6	
1	I am interested in learning about environmental pollution using STEM-based interactive multimedia.	5	5	5	5	4	5	29
2	I can learn according to the speed and intensity of my independent learning	5	4	5	5	5	5	29
3	STEM-based interactive multimedia is easy to operate/use	4	5	4	3	3	4	23
4	STEM-based interactive multimedia can help my understanding of environmental pollution topics	5	5	5	4	4	5	28
5	The display of animated images in this STEM-based interactive multimedia is interesting	4	5	5	5	4	5	28
6	I am happy to be given the opportunity to practice questions and gain new knowledge	5	4	4	5	5	3	26
7	I am more motivated to learn using STEM-based interactive multimedia	4	4	4	3	4	5	24
8	The video and audio in STEM-based interactive multimedia are interesting	4	5	4	5	4	4	26
9	I can read the text easily because the type and size of the font used are appropriate	5	5	4	5	5	5	29
10	I am more interested in learning using STEM-based interactive multimedia than just using a textbook.	5	4	5	5	5	4	28
Average								**4,50**
%								**90**

Based on Table 4, the student assessment results in the small group evaluation comprising ten items obtained an overall average score of 4.50 with a percentage of 90%. When referring to Table 2, these results indicate that STEM-based interactive multimedia is included in the very practical category. Thus, the product that has been developed is ready to be implemented in real classes. The assessment results by the students mentioned above align with the research by Basri & Adlini (2023), who reported that the STEM-Based Interactive Multimedia they developed received an assessment of 78%, including the very practical category. In addition, our findings also support research by Khairani et al. (2023), who reported that the results of a limited trial of the STEM-based interactive multimedia they developed fell into the very good category.

After the implementation stage, the next stage is the evaluation stage. Evaluation has been carried out at each stage, starting with the analysis, design, development, and implementation processes. Expert and peer validation results show that STEM-based interactive multimedia is very feasible. In addition, the results of the student response trials were very practical. Thus, we state that this research has answered the objectives, successfully developing interactive multimedia on environmental pollution topics with a STEM approach for junior high school students that is feasible and practical to use.

Media development is also progressing rapidly in this era of technology and information. The use of technology and information as learning media is a demand for learning to be more interesting and not only fixated on the teacher. The reason is that students must be taught how knowledge is acquired and processed (Wola et al., 2023). In its use, technology and information media do require special skills to operate. However, we cannot deny that technology and information-based learning media are indispensable in learning this century. This type of learning media greatly facilitates teachers in teaching and learning activities because there is no need to re-explain the topic discussed. Devices that can operate technology-based learning media are also very broad, making it easy for students to reach.

The introduction of information technology into the educational process significantly changes and ultimately improves teaching effectiveness (Medetbayeva & Akhmetov, 2021). Interactive multimedia is one of the learning media that can help the computer-based teaching and learning process (Septiani et al., 2020). With interactive multimedia, learning that was originally teacher-centered becomes fun and more acceptable to students (Ariandini & Ramly, 2023). That is in line with the cognitive theory of learning multimedia, which states that the use of multimedia in learning can create an active process that requires five cognitive processes, namely word

selection, image selection, word organization, image organization, and the process of connecting with existing knowledge (Mayer, 2014). There are many benefits obtained when using multimedia in a teaching and learning process, namely student interaction, increasing student interest in learning, and making it easier to deliver content where it is more efficient and effective. Teaching practices combined with technology not only improve the quality of teaching but also allow students to develop their skills, increase their motivation, and increase their knowledge and information efficiently (Akram et al., 2022; Gani et al., 2022).

The media selection must be tailored to the subject matter needs of today's students, who depend on technology and are less interested in books. Students also often feel bored because they only listen to subject matter delivered by the teacher. Through interactive multimedia on environmental pollution topics with a STEM approach, students can more easily understand the subject matter and solve problems related to everyday life. That is because STEM education uses a student-centered approach to develop problem-solving skills and uses real-world challenges as entry points for integrating STEM disciplines (Margot & Kettler, 2019; Stehle & Peters-Burton, 2019). STEM education equips students with the knowledge and skills they need to succeed in the twenty-first century (Kennedy & Odell, 2023).

D. Conclusion

Based on our research, we have successfully developed interactive multimedia about interactive multimedia on environmental pollution topics with a STEM approach for junior high school students that is feasible and practical to use. The data support this finding: subject matter expert validation, learning media expert, and peer assessment are all included in the very feasible and do not require revision category. In addition, the small group evaluation results indicate that interactive multimedia on environmental pollution topics with a STEM approach is included in the very practical category. Future research is recommended to test the effectiveness of using this media in a broader real class, assess student learning motivation, and evaluate its use on various 21st-century skills.

E. References

Adeoye, M. A., Wirawan, K. A. S. I., Pradnyani, M. S. S., & Septiarini, N. I. (2024). Revolutionizing education: Unleashing the power of the ADDIE Model for effective teaching and learning. *Jurnal Pendidikan Indonesia*, *13*(1), 202–209. DOI: https://doi.org/10.23887/jpiundiksha.v13i1.68624

Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' perceptions of technology integration in teaching-learning practices: a systematic review. *Frontiers in Psychology*, *13*, 920317. DOI: https://doi.org/10.3389/fpsyg.2022.920317

Aldoobie, N. (2015). ADDIE model. *American International Journal of Contemporary Research*, *5*(6), 68–72. Retrieved from https://aijcrnet.com/journal/index/969

Ariandini, N., & Ramly, R. A. (2023). Penggunaan multimedia pembelajaran interaktif dalam meningkatkan hasil belajar siswa. *Jurnal Kependidikan Media*, *12*(2), 107–116. DOI: https://doi.org/10.26618/jkm.v12i2.11943

Arianti, A., Marlina, L., & Sriyanti, I. (2022). Development of interactive multimedia based on STEM wave material for high school students. *Berkala Ilmiah Pendidikan Fisika*, *10*(2), 163–170. DOI: https://doi.org/10.20527/bipf.v10i2.12215

Balyer, A., & Öz, Ö. (2018). Academicians' views on digital transformation in education. *International Online Journal of Education and Teaching*, *5*(4), 809–830. Retrieved from https://iojet.org/index.php/IOJET/article/view/441

Basri, R., & Adlini, M. N. (2023). Development of STEM-based interactive multimedia as an effort to increase student learning motivation in biology learning. *Jurnal Pendidikan MIPA*, *24*(1), 384–392. DOI: https://doi.org/10.23960/jpmipa/v24i1.pp384-392

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Boston, MA: Springer. DOI: https://doi.org/10.1007/978-0-387-09506-6_1

De Witte, K., Haelermans, C., & Rogge, N. (2015). The effectiveness of a computer-assisted math learning program. *Journal of Computer Assisted Learning*, *31*(4), 314–329. DOI: https://doi.org/10.1111/jcal.12090

Depdiknas. (2010). *Juknis Pengembangan bahan ajar*. Jakarta: Direktorat Pembinaan Sekolah Menengah Atas.

Dinçer, S. (2015). Effects of computer assisted learning on students achievements in Turkey: A meta-analysis. *Journal of Turkish Science Education*, *12*(1), 99–118. DOI: https://doi.org/10.12973/tused.10136a

Drake, K. C., Speer, J. H., Stachewicz, M. L., Newsham, T. M. K., & Sheets, V. L. (2024). Environmental literacy differences based on gender identity and race: A social justice concern. *Sustainability*, *16*(1), 282. DOI: https://doi.org/10.3390/su16010282

English, L. D. (2016). STEM education K-12: perspectives on integration. *International Journal of STEM Education*, *3*(3), 1-8. DOI: https://doi.org/10.1186/s40594-016-0036-1

Gani, M. A., Tumewu, W. A., & Wola, B. R. (2022). Motivasi belajar siswa kelas VII SMP Anugerah Tondano pada pembelajaran IPA di era pandemi covid-19. *SCIENING : Science Learning Journal*, *3*(1), 8–13. DOI: https://doi.org/10.53682/slj.v3i1.1845

Ginting, G. P., Ogi, N. L. I. M., Warouw, Z. W. M., &

Rampengan, M. M. F. (2023). Pengaruh media pembelajaran berbasis aplikasi android terhadap hasil belajar peserta didik pada materi sistem gerak di SMA Negeri 1 Lembean Timur. *JSPB BIOEDUSAINS*, *4*(1), 89–96. Retrieved from https://ejurnal.unima.ac.id/index.php/bioedusains/article/view/7719

Guan, N., Song, J., & Li, D. (2018). On the advantages of computer multimedia-aided English teaching. *Procedia Computer Science*, *131*, 727–732. DOI: https://doi.org/10.1016/j.procs.2018.04.317

Hidayati, N., & Irmawati, F. (2019). Developing digital multimedia of human anatomy and physiology material based on STEM education. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *5*(3), 497–510. DOI: https://doi.org/10.22219/jpbi.v5i3.8584

Huang, R. H., Liu, D. J., Tlili, A., Yang, J. F., Wang, H. H., Jemni, M., & Burgos, D. (2020). *Handbook on facilitating flexible learning during educational disruption: The Chinese experience in maintaining undisrupted learning in COVID-19 outbreak*. Beijing: Smart Learning Institute of Beijing Normal University.

Kapila, V., & Iskander, M. (2014). Lessons learned from conducting a K-12 project to revitalize achievement by using instrumentation in science education. *Journal of STEM Education*, *15*(1), 46–51. Retrieved from https://www.learntechlib.org/p/148286/

Kennedy, T. J., & Odell, M. R. L. (2023). STEM education as a meta-discipline. In B. Akpan, B. Cavas, & T. Kennedy (Eds.), *Contemporary Issues in Science and Technology Education* (pp. 37–51). Springer, Cham. DOI: https://doi.org/10.1007/978-3-031-24259-5_4

Khairani, L. A., Djulia, E., & Bunawan, W. (2023). Development of STEM-based interactive multimedia on human digestive system for elementary school. *Elementary School Journal PGSD FIP UNIMED*, *13*(2), 205–212. DOI: https://doi.org/10.24114/esjpgsd.v13i2.46189

Leow, F. T., & Neo, M. (2014). Interactive multimedia learning: innovating classroom education in a Malaysian university. *Turkish Online Journal of Educational Technology*, *13*(2), 99–110. Retrieved from https://eric.ed.gov/?id=EJ1022913

Lumintang, B., Repi, R. A., & Warouw, Z. W. M. (2023). Pengembangan media video pembelajaran biologi berbasis STEAM pada siswa Kelas XI IPA materi sistem ekskresi di SMA Negeri 1 Dumoga Timur. *SOSCIED*, *6*(2), 538–547. DOI: https://doi.org/10.32531/jsoscied.v6i2.720

Manurung, P. (2020). Multimedia interaktif sebagai media pembelajaran pada masa pandemi Covid 19. *Al-Fikru: Jurnal Ilmiah*, *14*(1), 1–12. DOI: https://doi.org/10.51672/alfikru.v14i1.33

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(2), 1-16. DOI: https://doi.org/10.1186/s40594-018-0151-2

Marsya, A., Syafi'i, A., & Wulandari, A. Y. R. (2022). Efektivitas pendekatan STEM pada materi pesawat sederhana terhadap hasil belajar peserta didik. *Natural Science Education Research (NSER)*, *5*(1), 135–141. DOI: https://doi.org/10.21107/nser.v5i1.15760

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799–822. DOI: https://doi.org/10.1002/sce.21522

Masloman, F., Suriani, N. W., Rungkat, J. A., Komansilan, A., & Wola, B. R. (2023). Keterampilan Proses sains mahasiswa dalam pembelajaran eksploratif fenomena lokal-global mengenai perubahan gelombang air dan kecepatan angin di Danau Tondano. *Jurnal Pendidikan MIPA*, *13*(3), 717–728. DOI: https://doi.org/10.37630/jpm.v13i3.1158

Mayer, R. E. (2014). Multimedia instruction. In J. Spector, M. Merrill, J. Elen, & M. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 385–399). New York: Springer. DOI: https://doi.org/10.1007/978-1-4614-3185-5_31

Medetbayeva, S., & Akhmetov, N. (2021). Psychological and pedagogical problems of computer-aided teaching of natural sciences. *International Journal of Emerging Technologies in Learning (IJET)*, *16*(20), 208–222. Retrieved from https://www.learntechlib.org/p/220545/

Muttaqiin, A. (2023). Pendekatan STEM (science, technology, engineering, mathematics) pada pembelajaran IPA untuk melatih keterampilan abad 21. *JURNAL PENDIDIKAN MIPA*, *13*(1), 34–45. DOI: https://doi.org/10.37630/jpm.v13i1.819

Park, W., Wu, J.-Y., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the USA, Korea and Taiwan. *Science & Education*, *29*, 899–927. DOI: https://doi.org/10.1007/s11191-020-00139-1

Pondoki, P. H., Warouw, Z. W. M., & Rungkat, J. A. (2023). Pengaruh penggunaan media animasi berbasis STEAM terhadap hasil belajar IPA materi pencemaran lingkungan pada siswa kelas VII SMP Negeri 6 Tondano. *SOSCIED*, *6*(1), 154–171. DOI: https://doi.org/10.32531/jsoscied.v6i1.623

Pramuji, L., Permanasari, A., & Ardianto, D. (2018). Multimedia interaktif berbasis STEM pada konsep pencemaran lingkungan untuk meningkatkan kemampuan berpikir kritis siswa. *JSEP (Journal of Science Education and Practice)*, *2*(1), 1–15. DOI: https://doi.org/10.33751/jsep.v2i1.1699

Puspitarini, Y. D., & Hanif, M. (2019). Using learning media to increase learning motivation in elementary school. *Anatolian Journal of Education*, *4*(2), 53–60. DOI: https://doi.org/10.29333/aje.2019.426a

Putri, J. A., Parno, P., Marsuki, M. F., Hamimi, E., &

Fitriyah, I. J. (2023). Development of STEM-based animation interactive multimedia with feedback to improve students' creative thinking ability on motion topic. In A. Doyan, S. Hadisaputra, A. Ramdani, L. R. T. Savalas, & S. Susilawati (Eds.), *The 1st International Conference on Science Education and Sciences* (p. 110002). Mataram, Indonesia: AIP Publishing. DOI: https://doi.org/10.1063/5.0122527

Rahmat, S. T. (2015). Pemanfaatan multimedia interaktif berbasis komputer dalam pembelajaran. *Jurnal Pendidikan dan Kebudayaan Missio*, *7*(2), 196–208. DOI: https://doi.org/10.36928/jpkm.v7i2.35

Republik Indonesia. (2018). *Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nomor 37 Tahun 2018 tentang Perubahan Atas Peraturan Menteri Pendidikan dan Kebudayaan Nomor 24 Tahun 2016 tentang Kompetensi Inti dan Kompetensi Dasar Pelajaran Pada Kurikulum 2013.* Indonesia: Kementerian Pendidikan dan Kebudayaan.

Rosalina, S. S., & Suhardi, A. (2020). Need analysis of interactive multimedia development with contextual approach on pollution material. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *1*(1), 93–108. DOI: https://doi.org/10.21154/insecta.v1i1.2107

Ruitan, A. J. A., Suriani, N. W., Rondonuwu, A. T., Komansilan, A., Wola, B. R., Rogahang, M. K., & Mirontoneng, G. I. Z. (2023). Keterampilan kolaborasi mahasiswa dalam pembelajaran eksploratif fenomena lokal dan global mengenai radiasi cahaya matahari dan suhu di Danau Tondano. *Journal on Teacher Education*, *4*(4), 419–430. DOI: https://doi.org/10.31004/jote.v4i4.15247

Rungkat, J. A., Jeujanan, A., Wola, B. R., & Warouw, Z. W. M. (2023). Development of STEM-based science e-module on the human excretory system topic. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6548–6556. DOI: https://doi.org/10.29303/jppipa.v9i8.4437

Septiani, A. N. N. S. I., Rejekiningsih, T., Triyanto, T., & Rusnaini, R. (2020). Development of interactive multimedia learning courseware to strengthen students' character. *Journal of Educational Research*, *9*(3), 1267–1280. DOI: https://doi.org/10.12973/eu-jer.9.3.1267

Shakeel, S. I., Al Mamun, M. A., & Haolader, M. F. A. (2023). Instructional design with ADDIE and rapid prototyping for blended learning: Validation and its acceptance in the context of TVET Bangladesh. *Education and Information Technologies*, *28*(6), 7601–7630. DOI: https://doi.org/10.1007/s10639-022-11471-0

Siddiq, M. N., Supriatno, B., & Saefudin, S. (2020). Pengaruh penerapan problem based learning terhadap literasi lingkungan siswa SMP pada materi pencemaran lingkungan. *Assimilation: Indonesian Journal of Biology Education*, *3*(1), 18–24. DOI: https://doi.org/10.17509/aijbe.v3i1.23369

Siew, N. M., & Chin, M. K. (2018). Design, development and evaluation of a problem-based with cooperative module on scientific creativity of pre-schoolers. *Journal of Baltic Science Education*, *17*(2), 215–228. DOI: https://doi.org/10.33225/jbse/18.17.215

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. *Information*, *13*(9), 1-20. DOI: https://doi.org/10.3390/info13090402

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, *6*(39), 1-15. DOI: https://doi.org/10.1186/s40594-019-0192-1

Sumawati, R. A., Pramita, M., Santanapurba, H., Wiranda, N., & Utami, B. (2021). STEM-based interactive learning media to improve student's critical thinking skills on number system materials. In *2021 Universitas Riau International Conference on Education Technology (URICET)* (pp. 425–430). IEEE. DOI: https://doi.org/10.1109/URICET53378.2021.9865952

Suriani, N. W., Wola, B. R., & Komansilan, A. (2022). Development of biological macromolecules three-tier test (BM-3T) to identify misconceptions of prospective science teachers. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2093–2100. DOI: https://doi.org/10.29303/jppipa.v8i4.1297

Suriani, N. W., Wola, B. R., Komansilan, R., Komansilan, A., & Susilawati, A. (2023). Do prospective science teachers experience misconceptions? identification using a digital biological macromolecules three-tier test (BM-3T). *Journal of Engineering Science and Technology (JESTEC)*, *18*(6), 51–60. Retrieved from https://jestec.taylors.edu.my/Special Issue ISCoE 2022_4/ISCoE 4_07.pdf

Triyanti, M. (2015). Pengembangan multimedia interaktif pada materi sistem saraf untuk meningkatkan motivasi dan hasil belajar siswa SMA kelas XI. *Jurnal Bioedukatika*, *3*(2), 9–14. DOI: https://doi.org/10.26555/bioedukatika.v3i2.4148

Warouw, Z. W. M., Wekes, W. C. A., Harahap, F., Tumewu, W. A., & Wola, B. R. (2024). Development of STEM-based virtual laboratory on global warming topic for junior high school student. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2309–2321. DOI: https://doi.org/10.29303/jppipa.v10i5.6403

Widayanti, W., Abdurrahman, A., & Suyatna, A. (2019). Future physics learning materials based on STEM education: Analysis of teachers and students perceptions. In A. Saefuddin, M. E. Toriman, D. Y. Ibrahim, P. J. Wanner, J. Colliste, K. Robinson, … K. M. Nasir (Eds.), *Young Scholar Symposium on Transdisciplinary in Education and Environment*

(YSSTEE) (p. 012021). Lampung, Indonesia: IOP Publishing. DOI: https://doi.org/10.1088/1742-6596/1155/1/012021

Widya, W., Rifandi, R., & Rahmi, Y. L. (2019). STEM education to fulfil the 21st century demand: a literature review. In R. Ramli, M. Khair, A. Alizar, R. Sumarmin, D. H. Putri, Y. Yohandri, … D. Permana (Eds.), *The 3rd International Conference on Mathematics, Sciences, Education, and Technology* (p. 012208). IOP Publishing. DOI: https://doi.org/10.1088/1742-6596/1317/1/012208

Wola, B. R. (2023). Literasi digital calon guru sekolah dasar di STKIP Persada Evav Tual pasca pandemi COVID-19. *PEDAGOGIKA: Jurnal Pedagogik dan Dinamika Pendidikan*, *11*(2), 244–255. DOI: https://doi.org/10.30598/pedagogikavol11issue2page244-255

Wola, B. R., Rungkat, J. A., & Harindah, G. M. D. (2023). Science process skills of prospective science teachers' in practicum activity at the laboratory. *Jurnal Inovasi Pendidikan IPA*, *9*(1), 50–61. DOI: https://doi.org/10.21831/jipi.v9i1.52974

Wu, T.-J., & Tai, Y.-N. (2016). Effects of multimedia information technology integrated multi-sensory instruction on students' learning motivation and outcome. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(4), 1065–1074. DOI: https://doi.org/10.12973/eurasia.2016.1552a

Xie, C., Cheung, A. C. K., Lau, W. W. F., & Slavin, R. E. (2020). The effects of computer-assisted instruction on mathematics achievement in mainland China: a meta-analysis. *International Journal of Educational Research*, *102*, 101565. DOI: https://doi.org/10.1016/j.ijer.2020.101565

Zalukhu, J. J., Telaumbanua, D., & Ziliwu, D. (2022). Pengembangan multimedia interaktif berbasis web pada materi sistem ekskresi pada manusia. *Educativo: Jurnal Pendidikan*, *1*(2), 473–485. DOI: https://doi.org/10.56248/educativo.v1i2.62