Jurnal Penelitian dan Pembelajaran IPA JPPI
Vol.10, No.2, 2024, p. 270-296 p-ISSN 2477-1422 e-ISSN 2477-2038

Development of Problem-Based Electronic Comics on Environmental Pollution Subject

(Received 20 May 2024 Revised 30 November 2024 Accepted 30 November 2024)

Sisean Baga[1*], Uswatun Hasanah[2], I Made Astra[3]

[1,2,3]Doctoral Program in Population and Environmental Education,
Universitas Negeri Jakarta, Jakarta, Indonesia
Corresponding Author: *siseanbaga_9908921006@mhs.unj.ac.id

DOI: 10.30870/jppi.v10i2.25422

Abstract

This study aimed to measure the eligibility of problem-based electronic comics that have been developed. The method used is research and development, with the 4-D model development by Thiagarajan (1974). The process consisted of three stages: define, design, and develop, concluding with the limited testing stage. The dissemination stage, however, is not covered in this paper. Product eligibility was evaluated using a validation questionnaire, assessed by 12 experts with a minimum educational background of a doctoral degree and more than 3 years of teaching experience at a university. The development of teaching materials in problem-based electronic comics was conducted in two trials: a small group trial of 12 students, which scored 95.7%, and a large group trial of 34 students, which scored 96.6%. These two results showed that the trial is highly eligible. Therefore, the problem-based electronic comics developed can be utilized as a learning resource on environmental pollution and can proceed to field tests or experiments. The urgency of this teaching material development was due to the limited resource of teaching materials in the form of electronic comics with the syntax of the Problem-Based Learning (PBL) model. This study revealed that problem-based electronic comics on environmental pollution subjects in this study are highly eligible to proceed to the dissemination stage.

Keywords: Electronic Comic, Environmental Pollution Subject, Problem-Based Learning

INTRODUCTION

Junior High School is currently dominated by the alpha generation, who are primarily interested in technology-based media as they grew up with information technology as a significant part of their lifestyle (Rasyid, et.al., 2019; Boileau, et.al., 2022; Japar et al., 2023). The educational model that suits the interests of the alpha generation is digital technology-based education (Pratiwi, et.al., 2019; Karlimah et al., 2021).

Digital technology can be integrated into learning media that accommodates students to understand subjects more easily (Baga et al., 2021; Erol, 2021; Pal, et.al., 2022; Karimova et al., 2023). In addition, technology-based media is easily accessible anytime and anywhere (Gutiérrez-Martín, et.al., 2022; Ahmadi et al., 2023). Digital technology for learning has a positive effect on increasing students' learning motivation (Jang et al., 2021).

Currently, many digital technology-based learning media have been developed, such as e-modules, interactive media, interactive games, and electronic comics (Purwanto, et al., 2020; Irma, et al., 2021; Tuma, 2021; Prasetyaning, et.al., 2022; Kudubes, et.al., 2023).

These media have proven their validity, and various variables have been improved. However, combining learning media with model syntax that can be applied in junior high school must be further developed (Ichsan, et al., 2020; Laksmi & Suniasih, 2021; Ramdani, et al., 2021).

Junior high school students, typically aged 12 to 16, are transitioning toward the formal operational stage, the final phase in cognitive development (Santrock, 2008; Babakr, et.al., 2019). However, as their abstract thinking skills are not yet fully developed, they benefit significantly from using visual media to support their learning process. Students of this age can use symbols related to abstract concepts, such as science.

This is in accordance with the or Learning Outcomes in Independent Curriculum Phase D in science class, which consists of 2 LO elements: science understanding and processing skills (Ministry of Education, Culture, Research, and Technology, 2022). The hope is that teachers will be able to develop both elements so that students can apply these abilities to solve daily life problems (Hasanah et al., 2023; Hodijah et al., 2023).

However, in reality, teachers still need to be able to help students develop science understanding and processing skills. The needs analysis involved 31 respondents from two schools taken randomly in West Jakarta. It was found that teachers tend to focus on memorizing

concepts or procedures taught in a lecture setting. The media displayed are still in the form of ppt, or youtube has not optimized digital technology in forming learning media.

The limited combination of media and learning models that attract attention to developing these two elements is still an obstacle. One of the media that can attract students' attention with interesting pictures and dialog is comics. (Robbani & Khoirotunnisa, 2021; Udayani, et.al., 2021; Topkaya, et al., 2023).

However, comics cannot be used efficiently both in terms of access and related to time and space if not in electronic form or mobile/android-based (Hussein, 2020; Rina, et al., 2020; Priyadi & Kuswanto, 2023). In addition, electronic comics are only limited to teaching materials if not combined with a relevant learning model for now (Nasrulloh, et.al., 2020; Dewi, et.al., 2022). Appropriate means that it can accommodate students' ability to solve science problems in everyday life.

This is also in accordance with the result of research (Radeswandri, et al., 2021), which states that junior high school students are still fond of reading, which attracts attention to support the process of integrating the information they have with abstract concepts. Moreover, integrating concepts requires a learning model syntax that demands students to solve daily life problems (Koh et al., 2019; Liu, 2021; Hertlein et al., 2023).

In the D Phase of science, as outlined in the learning outcomes of the Merdeka Curriculum, students explore material on environmental pollution and climate change. The learning outcomes aim to enable students to identify interactions between living things and their environment and to design strategies for preventing and addressing environmental pollution {Formatting Citation}. Efforts to teach science, specifically on environmental pollution material, to students who are Problem-Based Learning (PBL) oriented need to be carried out in an integrated and simultaneous manner that involves educators from various levels (Amin, et al., 2020; Fita, et.al., 2021; Sajidan, et al., 2022; Suciati, et al., 2023).

PBL (Problem-Based Learning) should not be viewed solely as a teaching method or model but as a comprehensive approach to organizing student learning around real-world problems (Bancong & Song, 2020; Khoiri, et.al., 2020; Yani, et al., 2021; Hodijah, et al., 2023). Combining comic electronic media and PBL can help students form new knowledge and experiences through problem-solving (Wajdi, et al., 2022; Indriyani, et.al., 2024). The ability to solve problems will allow students to

develop themselves and continue learning.

DKI Jakarta is Indonesia's capital and an autonomous region at the provincial level. DKI Jakarta is essential in various aspects of national life, including economy, politics, culture, and society. Nevertheless, DKI Jakarta still has shortcomings in terms of environmental aspects.

Based on the Environmental Indifference Behavior Index, DKI Jakarta citizens are still categorized as indifferent toward the environment (BPS, 2019). In addition, according to the National and Provincial Environmental Quality Index in 2020, DKI Jakarta is nationally classified as very poor based on the assessment. These two data illustrate that DKI Jakarta, which has a vital role in various aspects of life, has an emergency on how to view the environment.

Environmental education learning in science subjects, especially on environmental pollution material, can be strengthened. Thus, it is cognitively developed and has an attitude toward protecting the environment. The topic of environmental pollution is closely related to environmental issues. Although these issues are sometimes relevant to the students' immediate surroundings, studying directly in a polluted environment may pose safety risks for them (Marnita et al., 2020; Ichsan, et.al., 2021; Sezgin, 2022). Using electronic comics as a Project-Based Learning (PBL) medium can minimize these risks. Polluted environmental conditions can be depicted in the electronic comics, and problem-solving strategies for pollution can be guided through the PBL framework.

These things led to research on the development of problem-based electronic comics on environmental pollution for class VII Junior High School.

METHOD

This study used Research and Development (R & D), which produces a problem-based electronic comic product design by validating the product's eligibility (Sugiyono, 2017; Cohen & Morrison, 2018; Putrawan, 2022). The development model used in this research is the 4D development model Thiagarajan, et.al (1974), which includes four stages: define, design, develop, and disseminate. This research only reached the development stage in small and large trials. This research was conducted in 2 public junior high schools in West Jakarta, which have relatively similar characteristics related to the condition of the school environment and the ability to provide mobile phones as a suggestion in implementing the developed learning media.

The first stage is collecting information through initial needs analysis, learner analysis, concept analysis, and specification of learning objectives. Data is obtained through interviews, observations, and data analysis through Google Forms, which are given to schools and used as research objects.

The second stage is design, which develops problem-based electronic comics, starting with making comics through format selection and preparing the initial draft. After that, the comics are designed according to the defined stage's needs. In addition, product validation instruments were prepared at this stage (Thiagarajan, et.al., 1974; Ramdani et al., 2021).

The third stage is development, which is the electronic testing of problem-based comics by twelve experts: three material experts, three media experts, three language experts, and three learning experts. The requirements to become an expert in this study are an educational background of at least a doctorate and a minimum of 3 years of experience teaching at a university or 5 years of experience working in a professional field. After obtaining the assessment results from the experts, the expert validation data was analyzed using the following formula:

$$P = \frac{\sum X}{\sum Xi} \text{ X } 100\%$$

Description:

P = Percentage of eligibility

X = Validator score answer (real value)

Xi = Maximum score

The results obtained are continued into the categories according to Table 1 (Gall, et.al., 2003; Riduwan, 2013; Cohen & Morrison, 2018):

Table 1. Qualification of Expert Eligibility Level

Level of Attainment	Qualification
91-100%	Very Good
81-90%	Good
60-79%	Enough
40-59 %	Not Good
0-39 %	Bad

If the results of the grouping according to Table 1 are classified as eligible, then proceed to the small group trial (12 students) and large group trial (34 students) to determine the readability and ease of problem-based comic electronic products on environmental pollution material. The response to the product includes the material eligibility category, presentation, language, application presentation category, comic display, usefulness, and ease of use of the application. The results obtained are continued into the category according to Table 2 (Riduwan, 2013):

Table 2. Qualification of Students' Respons

Level of Attainment	Qualification	Explanation
91-100%	Very Good	Highly Eligible for Trial
81-90%	Good	Eligible for Trial
60-79%	Enough	Eligible with Consideration
40-59 %	Not Good	Not Eligible
0-39 %	Bad	Not Eligible

This study uses two data, namely qualitative and quantitative data. Qualitative data is input from experts and students to validate problem-based comic electronics. At the same time, quantitative data is in the form of data on the results of expert and student assessments from questionnaires given regarding aspects/indicators of product validation. The instrument used for quantitative data collection is a checklist questionnaire with a Likert scale to experts (experts validation) and students (small and large trials).

RESULTS AND DISCUSSION

Learning media as a means of conveying messages in the form of lesson information from teachers to students (Rusydiyah, et.al., 2020; Sudjana & Rivai, 2020; Zein et al., 2023; Gürses & Girne, 2024). This research aims to develop electronic comic products based on materials about environmental pollution. The development process is described at each stage of development according to (Thiagarajan, et.al., 1974), namely Define, Design, and Development. The three stages of 4D are explained as follows:

1. Define

This is the initial stage of determining and finding problems or obstacles in integrated science courses. The define stage includes five main steps, namely:

a. Front-end analysis (Needs)

Front-end analysis identifies problems experienced in schools in the learning process (Yuntiaji, et.al., 2020; Prasetyaning, et.al., 2022; Suparman, et.al., 2022). These problems become the basis for the development of specific products. This analysis is the first step in 4D after the school is generally obtained as the research target. This stage seeks facts and alternative solutions (Thiagarajan, et.al., 1974). These facts and solutions are then processed to formulate appropriate and directed initial steps in the development.

This stage is carried out using two data collection methods: Focus Group Discussion (FGD) and direct observation in the classroom. Both types of data collection support each other. The FGD stage was conducted in 2 target schools in the West Jakarta area. Four teachers were interviewed. Meanwhile, one teacher in 1 meeting conducted the classroom observation stage. Indicators explored in FGDs are how teachers carry

out classroom learning on environmental pollution material, teacher expectations related to attitudes/competencies expected to emerge in environmental learning, and strategies that want to be developed but have not been implemented or achieved to develop the expected attitude and competencies.

Based on the FGD with the science teacher, several models were applied to environmental pollution in 2021/2022, namely discovery learning and jigsaw. However, the lecture method is also dominantly applied in class on this topic. Based on the interview, it was also found that one teacher had tried to implement PBL but had difficulties related to PBL syntax and preparing relevant problems for students. This is also reinforced by direct observation that the teaching module has PBL syntax but does not appear appropriately in learning, and the teacher looks confused in its implementation because the learning resources are only in the form of PPT, books, and student worksheets in the form of questions.

Teachers also stated that the dominant learning resources used in the classroom are materials from the ministry and books. The teacher stated that student worksheets emphasizes theory and that it is only in the form of questions, not environmental problems. Teachers also conveyed the difficulty of making and getting appropriate digital media (Miralles-Martínez, et al., 2019; Yani, et al., 2021; Cascolan, 2024). Digital teaching materials from the government or other media on the SIMPKB or PMM are still in standard form. Teachers find it not very interesting.

Teachers also stated that they want to strengthen students' sense of caring regarding environmental awareness. This is relevant to the topic of discussion, which is environmental pollution and the location of most students in the school. However, teachers find it challenging to design lessons that can strengthen this. Although there is already a waste sorting program in both Jakarta State Junior High Schools, it is not yet optimal.

b. Student Analysis

Student Analysis aims to characterize and identify students so that they can develop appropriate learning according to their needs and learning objectives (Thiagarajan, et al., 1974). The analysis was conducted to determine student responses to learning resources to analyze the obstacles faced in the learning process in the previous year's students (currently grade VIII) who had learned about environmental pollution and grade VII students for science learning in general. The analysis is done through Focus Group Discussion (FGD) with a team of science teachers, interviews, and questionnaires.

Based on the FGD analysis results with the science teacher while exploring the front-end analysis, the indicator at the student analysis stage is characterizing students to determine the appropriate product based on their needs. The results showed that students are interested and motivated by learning media that attracts attention. This is in accordance with research Udayani, et.al (2021), which states that using comics as a learning medium can attract students' attention and make it easier to understand.

The results of interviews with grade VIII students who had learned about environmental pollution in the previous semester and grade VII students related to science subjects stated that the teacher only used posters, books, and PDF books as media and homework in the form of questions. They stated that it was very difficult to understand the material because it was still dominated by theoretical writing, making it difficult to learn this topic. Students also stated they had difficulty learning independently because teaching materials were still limited. Students also feel that learning the topic has not motivated them to change their attitude toward protecting the environment.

The third data collection from the student analysis stage, namely the needs analysis questionnaire, was filled out by 72 students in grade VII in both schools. Through the questionnaire given to students, information was obtained that there were still students who did not understand the problem of environmental pollution in the surrounding environment. The results showed that 53% of students did not understand the topic of environmental pollution, and 43% did not know how to prevent and overcome environmental pollution in the form of garbage waste.

The questionnaire results also show that 83% of students have never learned creative media that can attract their attention. 94% of students need a different learning method than the usual process applied. This is in accordance with the conclusions and suggestions from the research of Angelita, et.al (2023) for further research that schools, including teachers, should develop the quality of Biology learning, such as the selection of learning methods and media so that it will increase knowledge of ecological concepts, environmental awareness, and ecological behavior of students.

c. Task Analysis

Task analysis is conducted to identify the main tasks that students do. This analysis helps teachers to determine the media to be used (Thiagarajan, et.al., 1974; Giordani, et al., 2024). This task analysis is carried out by analyzing the tasks given to students so that they can

analyze the types of main tasks that students must master in order to achieve the minimum competencies set.

The results of FGDs and questionnaires obtained from teacher assignments are still in the form of student worksheets and questions in books or online. In addition, there are still no integrated and interactive learning resources that can increase students' awareness.

Based on the task analysis, it is also known that there are no integrated, engaging, interactive textbooks that can increase students' independent learning motivation. Assignments and teaching materials teachers provide are still in the realm of knowledge in which they concentrate on cognitive abilities. In contrast, science subjects emphasize direct experience to develop scientific competencies to know the surrounding environment. Teaching materials and teacher assignments must also be able to accommodate these competencies.

d. Concept Analysis

The concept analysis stage involves identifying the main concepts, putting them hierarchically, and breaking down individual concepts into critical and irrelevant things (Thiagarajan, et.al., 1974; Ramdani, et al., 2021). In addition, the steps to be taken are also arranged rationally. This concept analysis includes an analysis of learning outcomes which aims to determine the number and type of teaching materials and analysis of learning resources, namely, identifying sources that support the preparation of teaching materials. The method of data collection at this stage is still in the form of interviews with teachers and an analysis of the current curriculum.

Based on interviews with the teachers of two schools, they were dissatisfied with the environmental pollution material in terms of maximizing learning media and the learning process. According to these teachers, environmental pollution material is not as difficult as other materials in grade VII. However, it demands output in the form of caring behavior or attitudes that can be raised in the learning process that impact the surrounding environment.

In the Independent Curriculum implemented in both schools, students in grades VII to IX are categorized under Phase D. Science subjects in Phase D include general learning outcomes and per-element learning outcomes. The general learning outcomes cover students' ability to explain how natural laws operate, from the micro to the macro scale, as well as to understand how elements within a system are interdependent.

In this phase, learners implement their understanding of the concepts by

making decisions and solving problems faced in everyday life. This concept analysis is also related to the applied curriculum. Through this concept analysis, the curriculum's objectives will be obtained and can be developed by the teacher. This analysis also allows learning media products or appropriate learning models to be obtained, not only according to the needs of students but in accordance with the latest curriculum (Erol, 2021; Gutiérrez-Martín, Pet.al., 2022; Japar et al., 2023). Based on this, the concept is analyzed in Table 3 (Ministry of Education, Culture, Research, and Technology, 2022; Ministry of Education, Culture, Research, and Technology, 2023):

Table 3. Curriculum Analysis

Learning Outcome	Material Distribu-tion	Expected Compe-tencies
Students can design efforts to prevent and overcome pollution and climate change.	Environmental pollution and climate change are related to examples, mechanisms, and ways to overcome them.	Understanding of science concepts, process skills, environmental awareness, and concern.

DKI Jakarta is the center of the Indonesian government and is located in the northwestern part of Java Island. It consists of five administrative cities: Central Jakarta, North Jakarta, East Jakarta, South Jakarta, and West Jakarta (BPS, 2022). DKI Jakarta is the province that has the fourth largest waste generation, and the administrative city of West Jakarta is the city in DKI Jakarta that contributes the largest, shabbiest, and dirtiest waste (BPS, 2020; Apsari et al., 2022).

Based on curriculum analysis, these facts are very relevant for environmental pollution material in Phase D of science subjects. It is also reinforced by information from teachers that students' understanding of environmental pollution material must be strengthened in order to raise environmental awareness. Environmental indifference in DKI Jakarta is high (BPS, 2022).

Strengthening environmental education in schools is a form of strengthening education in the family environment, which must be carried out consistently and continuously from early childhood to high school and even at university level (Ridwan et al., 2020; Urbańska et al., 2022). Forming environmental awareness requires the help of learning resources that can attract students' attention to create a willingness to read them (Abas, et.al., 2023; Knaus, 2023). Technology-supported environmental education must be combined with a learning model that can lead students to solve environmental

problems (Agustina & Astuti, 2020; Goodale, 2021).

e. Learning Objectives Analysis

The learning objectives analysis stage determines competencies to be achieved through learning objectives. The results of learning objectives analysis specifications are presented in Table 4 (Ministry of Education, Culture, Research, and Technology, 2022).

In this step, a few instructional purposes regarding relevant and necessary knowledge were obtained for students to achieve expected learning objectives. Students need to learn environmental pollution material in the natural science school subject at school. As per the very high questionnaire results, comics become a desirable medium for students.

As a result, comics are sought after to support the emergence of the skill process, which aims for learning objectives per element. Comics have exciting forms that can stimulate students to reread them. However, comics by themselves alone cannot reach the learning objectives which are stated in Table 4. Because of that, coherence with learning models that can stimulate students to solve problems is needed.

The PBL learning model can galvanize students to be active and to expand on a problem so that an alternative solution may be found to solve those problems (Ural & Dadli, 2020; Asli, et al., 2023). Apart from that, PBL syntax can train students to possess capabilities in solving current environmental challenges (Sumarmi, et al., 2020; Gök & Boncukçu, 2023). It is hoped that in such a process, environmental awareness is built.

Table 4. Learning Objectives Analysis Result

Learning Outcomes	Learning Objectives
Science Understanding: Students can design measures to prevent and address pollution and climate change. **Process Skills:** Consist of 6 stages: 1. Observing; 2. Questioning and predicting; 3. Planning and conducting an investigation; 4. Processing, analyzing data and information; 5. Evaluating and reflecting; 6. Communica-ting results.	1. Students can correctly relate pollutants, causes, and effects of land pollution; 2. Students can correctly relate pollutants, causes, and effects of water pollution; 3. Students can correctly relate pollutants, causes, and effects of air pollution; 4. Students can plan efforts to prevent and deal with environmental pollution and climate change.

2. Design

The design stage aims to plan and develop electronic comics based on problems in environmental pollution material. The design product's stages are as follows.

a. Media Selection

Under the define stage, it is determined that the learning media that will be developed is digital comics containing environmental pollution materials, which are also combined with PBL syntax. This combination is dubbed electronic comics based on problems in the environmental pollution material.

In the define stage, which is the analysis of students according to necessities, 93% of students feel that an appealing learning experience is essential in studying environmental education, and 77% percent of students wished that there is a learning media in the form of comics because they are exciting and seldom do teachers use such a media. Thus, the learning media used in this research is comics.

b. Format Selection

In this stage, electronic comics based on problems in the environmental pollution material's format are determined. The comic started with a manual sketch on A4 paper. After the initial sketch and speech bubbles were finished, a scan with the application CamScanner was done. Afterward, the comic was edited using the software PaintTool SAI and Manga Studio with the help of hardware Wacom. Both software used to complement each other. The feature in Manga Studio but not in PainTool SAI, which is the line art feature, eased managing lines and panels if the initial sketch needed correction.

As per the defined stage, a learning media, which can be accessed whenever and wherever without an internet connection, is also needed. Hence, this digital comic learning media was designed as application/electronics. The programming language of electronic comics based on problems in the environmental pollution material is Java, Android Studio, incorporating fragment and viewbinding.

This caused the learning media to become comics and incorporate many complementary features into the application. Features such as online student worksheets with the use of Live Worksheet, online questions using Google Forms, and videos from YouTube accompany electronic comics based on problems in the environmental pollution material.

c. Initial Design

The early design was presented in the storyboard. Storyboards are used to make valuable sketches, which are used to picture the plot of the product made by researchers so that it is easier to imagine the final product. In the PBL learning on electronic comics based on problems in the environmental pollution material context, researchers apply the PBL activity stages into core activities in the learning module, which includes 1)

student orientation on the problem, 2) organizing students to learn, 3) guiding individual or group research, 4) developing and presenting the product, 5) analyzing and evaluating the problem-solving process (A.Pribadi, 2010; Trianto, 2010). Here is Figure 1 and Figure 2, which shows the initial design of the manually drawn and digitally applied comic.

Figure 1. The initial design of the scanned comic after manual drawing

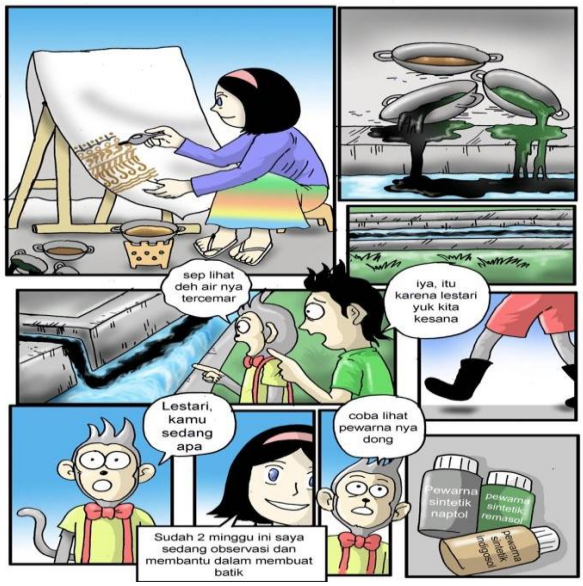

Figure 2. The edited image in the application or digitally.

d. Product Design

At this stage, the comic is converted into an electronic form using Java programming language, which can be seen in Figure 3.

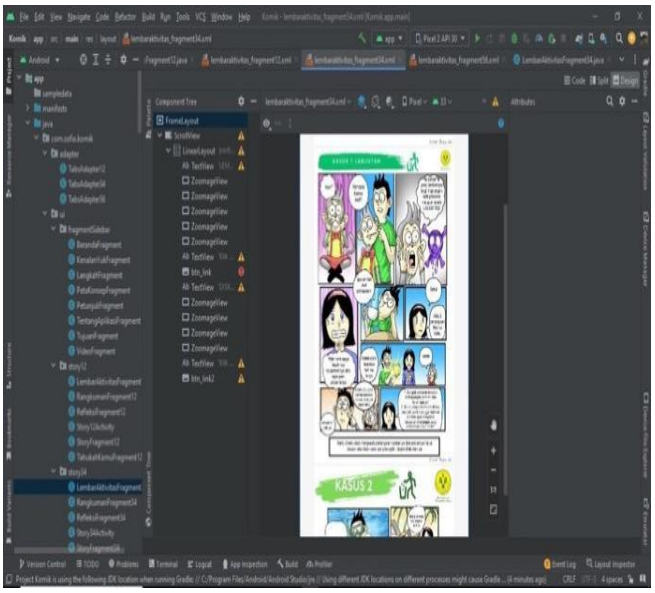

Figure 3. Inserting all the comics into the space provided

3. Develop Stage

a. Expert Validation

Expert validation is conducted to review the product. Experts validate problem-based electronic comics to determine whether the developed products are suitable for use as teaching materials in learning activities (Setyosari, 2013; Nuntasane et al., 2020). This study was validated by 12 experts, consisting of 3 material experts, three media experts, three language experts, and three learning experts.

Material expert validation aims to validate the material's content from several subcomponents of learning materials presented in problem-based electronic comics on environmental pollution material. Material expert validation was carried out by three experts consisting of 2 professors of Postgraduate Population and Environmental Education at a public university in Jakarta and one lecturer with a doctoral degree (Ph.D) from a public university in Serang in Biology Education program.

Media expert validation aims to validate the appearance of the media seen from several subcomponents of program presentation, presentation of teaching materials, and media function. Three lecturers from a public university in Jakarta and two private universities in Jakarta carried out media expert validation. The three lecturers are experts in the field of learning technology.

Language expert validation aims to validate the language of the product developed so that students easily accept it according to the predetermined objectives. The language expert validation was carried out by three experts, namely two experts who are

lecturers at a private university in Jakarta and one expert who is one of the team experts at the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

Learning expert validation aims to validate the products developed in accordance with PBL syntax and bring up learning that can achieve the specified learning objectives. Learning expert validation was carried out by three experts, including one professor in the field of environmental education at a public university in Jakarta, one biology education lecturer at the same university, and one supervisor at the West Java Region II Education Office.

Based on the validation of the twelve experts, it is described in Table 5.

Table 5. Expert Validation Result

No	Expert	Rated Aspect (%)	Qualification
1	Material	94.5	Very Good
2	Media	93	Very Good
3	Language	90.7	Very Good
4	Learning	95.3	Very Good
Total Score		**93.4**	Very Good

Based on Table 5, the highest validation percentage was given by the learning experts, while the lowest was provided by the language experts. The high validation from the learning experts was due to the integration of electronic comics with the PBL syntax in a single application. Moreover, the learning process within the application was regarded as systematic, with the PBL syntax significantly enhancing its usability. On the other hand, the lower validation from the language experts was attributed to the presence of several typos in the comics and some sentences that were considered unnecessarily lengthy in conveying information. It means problem-based electronic comics on environmental pollution material are eligible for further trials.

Even with such values and qualifications, the product still received input and suggestions for improvement. One notable suggestion from the material validator was to include a glossary, as the material contains many unfamiliar or foreign terms that students may not recognize. Adding a glossary would make it easier for students to understand the content more effectively.

In the media validator, it is suggested that there is audio/sound on the product homepage, comics are made flipbook, or there is a transition; the media is too large and better to compress, but does not reduce the quality. In the language validator, it is suggested that there are several writing errors; some information does not match the correct Indonesian spelling. Finally, the learning

validator is advised to further maximize the syntax in PBL in the main menu/stages of the product, and there is a menu for uploading assignments.

After recapitulating the validation results, several improvements were made, which can be seen in Figure 4 and Figure 5. Picture 5 is the correction of picture 4. The correction is in the writing for "CO2" (picture 4) which is supposed to be "CO_2" (picture 5).

Figure 4. Initial Comic Design

Figure 5. Design After Correcting Writing Errors in the Comic

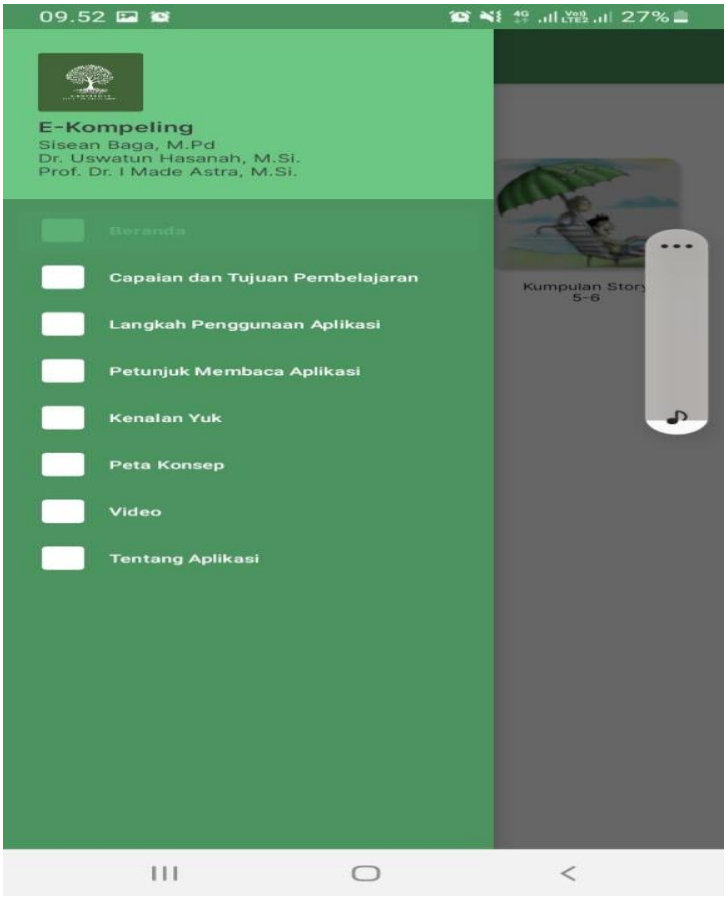

Figure 6. Initial Comic Design

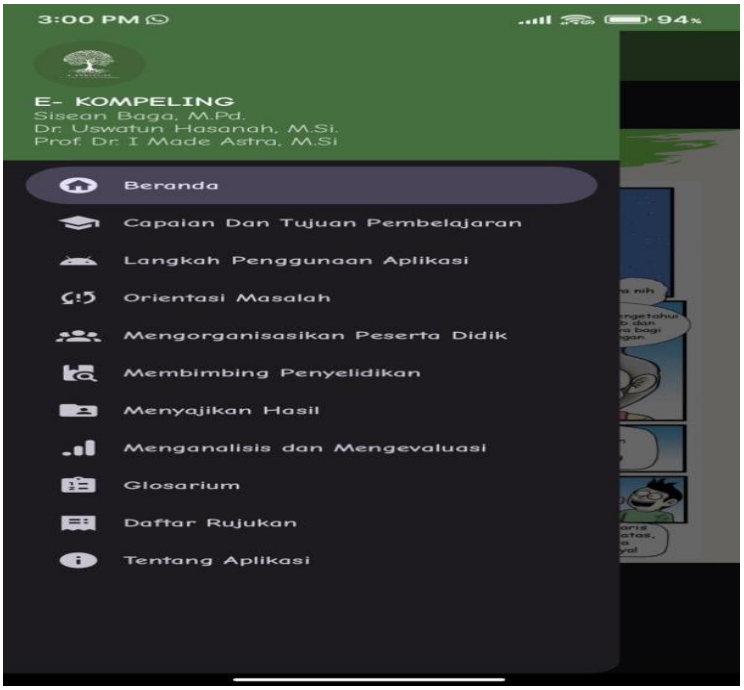

Figure 7. Design after Expert Revision

Figure 6 and 7 show the revisions after going through the expert validators. All of these changes were made based on the expert's suggestions, although quantitatively, they have passed to continue to the trial stage.

b. *Development Testing*

After going through material, media, language, and learning expert validation and revision processes, problem-based electronic comic products on environmental pollution material were tested on 12 students called small group limited trials and 34 students called large group limited trials. The aim is to determine the readability and ease of problem-based electronic comic products on environmental pollution material. The response to the product includes indicators of material eligibility assessment, language, application presentation, comic display, usefulness, and ease of use.

Data on students' responses to problem-based electronic comic products on environmental pollution material due to development are presented in Table 6.

Table 6. Response Data of Small Group Students

No	Assessment Indicators	Result
1	Material Eligibility	100%
2	Language	100%
3	Application Presentation	91,6%
4	Comic Display	91,6%
5	Usability	100%
6	Ease of Use	91,6%
	Total Score	**95,8%**

Based on the results of qualitative feedback and suggestions in the small group test, all students (12 students) responded very well to the application presented. Quantitatively, 3 (three) indicators do not get a percentage of 100% by not choosing a score of 5 (Very Good/Very Suitable). The indicators include application presentation, comic display, and ease of application use. Meanwhile, qualitatively, there is input to the appearance of the application in presenting comics, namely, the current display scrolls down; what students want is that there is a simple animation that moves to the side. After making improvements, it was continued to the large group limited trial with the results of the response data in Table 7.

Table 7. Response Data of Large Group Students

No	Assessment Indicators	Result
1	Material Eligibility	100%
2	Language	88.6
3	Application Presentation	94.1%
4	Comic Display	100%
5	Usability	100%
6	Ease of Use	97.1%
	Total Score	**96.6%**

Based on the results of qualitative feedback and suggestions in the significant group test, all students (34 students) responded very well to the application presented. Quantitatively, 3 (three) indicators do not get a percentage of 100% by not choosing a score of 5 (Very Good/Very Suitable). Such indicators are language indicators, application presentation, and ease of use.

The results of the significant group response obtained a total score of 34.55. They were categorized as very good with many positive responses, such as comics that are very interesting, funny, attractive in color, motivating, readable even without the internet, facilitate independent learning, and comprehensive.

There are suggestions related to the ease of self-learning because this product cannot be zoomed consistently. This means the comic image can be zoomed in if directed using a finger. If the finger is removed, the size returns to normal. This causes difficulty in its use because several panels are also small due to the large number of images and information bubbles. The results of the responses in small and large groups reinforce that problem-based electronic comics on environmental pollution material are suitable for dissemination or testing in the broader group and can be seen experimentally.

The results of Ural & Dadli (2020) research show that authentic PBL is an effective model in increasing students' knowledge of the environment and developing positive attitudes toward the environment. This study suggests that PBL must also be supported by media or learning applications to make the application more effective. The syntax sequence of PBL in the form of problem scenarios must be prepared by considering the attractiveness of the application and problems taken based on real life.

Based on these results, an environmental problem-based learning model with a combination of electronic media needs to be recommended to train students to think critically and be aware of environmental concerns (Sigit, et al., 2019; Astra, et.al., 2020; Erol, 2021). Asli, et al (2023) explained that the active involvement of students in studying real

environmental problems contributed significantly to increasing the acquisition of environmental knowledge related to science and their motivation to adopt environmentally friendly behavior even though the problem was only in the form of a case in a particular application. The active learning model emphasizes the active involvement of students in learning. In addition, problem-solving can provide opportunities for students to apply their knowledge in the real world (Suciati et al., 2023; Uyen, et.al., 2023).

Mobile learning-based teaching materials are highly recommended in learning today. In the post-pandemic era, mobile learning brings the benefit of teaching materials that can be accessed at anytime and anywhere and have attractive material visualization. Problem-based electronic comics on environmental pollution material attract attention because they contain contextual problems associated with environmental problems in the form of comic cases (Flores-González, et.al., 2024; Susanto et al., 2024). Comics can influence readers (students) to participate in the story and can influence students' consciousness to carry out the behavior in the comic (Nasrulloh, et.al., 2020; Rina et al., 2020; Radeswandri et al., 2021; Wajdi et al., 2022).

CONCLUSION

Based on the research results described, it is concluded that this study resulted in the validation of media, material, learning, and language experts with a total percentage of 95.7% in the Very Good category and very eligible for trials with minor revisions. The results of the small group trial, with a total percentage of 95.8%, were categorized as Very Good. The results of the large group trial, with a total percentage of 96.6%, were categorized as very good. Thus, the problem-based electronic comics developed can be used as a learning resource.

The need for technology-based learning media that can be accessed anytime and anywhere increases with the habit of students learning asynchronously and synchronously. This is supported by the many applications for making electronic comics that are increasingly developing by combining relevant learning models. The hope is that it can be used to develop problem-based electronic comics with other themes needed in the learning process.

ACKNOWLEDGEMENT

The writer expresses gratitude to the Sinar Dharma Foundation for funding this research through a doctoral research grant, which is part of the scholarship from Sinar Dharma Foundation.

REFERENCES

Abas, M, Uge, S & Alwy, AR 2023, 'The Implementation of Ecoliteracy as a Learning Resource to Improve Environmental Care Attitudes in Elementary Schools', *Mimbar Sekolah Dasar*, vol. 10, no.1, pp. 281–293. doi: 10.53400/mimbar-sd.v10i1.50333.

Ahmadi, F, Hardyanto, W, Pramono, E, Sugiarta, IM, Syahputra, H, Kristanto, A, Parinsi, MT & Sugihartono, I 2023, 'Developing Mobile Learning Application Containing Basic Pedagogy Material as the Supplement in Improving College Students' Learning Outcome in Teacher Training Institutes of Indonesia', *European Journal of Educational Research*, vol. 12, no. 1, pp. 213–227. doi: 10.12973/eu-jer.12.1.213.

Amin, S, Utaya, S, Bachri, S, Sumarmi & Susilo, S 2020, 'Effect of problem-based learning on critical thinking skills and environmental attitude', *Journal for the Education of Gifted Young Scientists*, vol. 8, no. 2, pp. 743–755. doi: 10.17478/jegys.650344.

Asli, S, Abu-Alhiga, R, Teti, T & Algma, S 2023, 'How Participation in a Teachers' Eco-Pedagogy Workshop Affects the Promotion of Teachers' Environmental Education and Organizational Concepts Sare', *European Journal of Educational Research*, vol. 13, no.1, pp. 341–352. doi:10.12973/eu.jer.13.1.341.

Astra, IM, Raihanati, R & Mujayanah, N 2020, 'Development of Electronic Module Using Creative Problem-Solving Model Equipped with HOTS Problems on The Kinetic Theory of Gases Material', *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, vol. 6, no. 2, pp. 181–194. doi: 10.21009/1.06205.

Babakr, Z.H, Mohamedamin, P & Karwan, K 2019, 'Piaget's Cognitive Developmental Theory: Critical Review', *Education Quarterly Reviews*, vol. 2, no. 3, pp. 517–524. doi: 10.31014/aior.1993.02.03.84.

Baga, S, Hendriyani, ME, Suratmi & Rosaline, MM 2021, 'Students' Interest and Cognitive Ability through the Implementation of Comic Media', *International Journal of Biology Education Towards Sustainable Development*, vol. 1, no. 1, pp. 17–26. doi: 10.53889/ijbetsd.v1i1.49.

Bancong, H & Song, J 2020, 'Exploring How Students Construct Collaborative Thought Experiments During Physics Problem-Solving Activities', *Science and Education*, vol. 29, no. 3, pp. 617–645. doi: 10.1007/s11191-020-00129-3.

Boileau, E, Dabaja, ZF & Harwood, D 2022, 'Canadian nature-based early childhood education and the UN 2030 Agenda for Sustainable Development: A Partial Alignment', *International Journal of Early Childhood Environmental Education*, vol. 9, no. 1, pp. 77–93.

BPS 2019, Indikator Perilaku Peduli Lingkungan Hidup (Hasil Survei Sosial Ekonomi Nasional 209, Modul Ketahanan Sosial) 2019, viewed 21 Maret 2024,< https://www.bps.go.id/publication/2013/12/27/26e979dbdd579d7b6db6941d/indikator-perilaku-peduli-lingkungan-hidup-2013.html>.

BPS 2020, *Statistik Lingkungan Hidup Indonesia Air dan Lingkungan*

(Environment Statistics of Indonesia: Water and Environment). Jakarta: BPS.

BPS 2022, 'Environment Indifferent Behaviour Index Report of Indonesia 2022', *BPS-Statistics Indonesia*, ISSN / ISB.

Cascolan, HMS 2024, 'Learning Loss in Chemistry : Basis for Conceptualizing a Remedial Program', *Jurnal Penelitian dan Pembelajaran IPA*, vol. 10, no. 1, pp. 25–45. Adoi: 10.30870/jppi.v10i1.24798.

Cohen, L, Manion, L, & Morrison, K 2018, *Research Methods in Education* (8 th Edition), Routledge. New York.

Dewi, NPAS, Ganing, NN & Putra, DBKNS 2022, 'E-Comic Interaktif Berbasis Problem Based Learning Materi Sistem Pencernaan pada Manusia Muatan IPA Siswa Kelas V SD', *MIMBAR PGSD Undiksha*, vol. 10, no. 1, pp. 64–72. doi: 10.23887/jjpgsd.v10i1.45204.

Angelita, D, Miarsyah, M & Komala, R 2023, 'Knowledge of ecological concepts, environmental concern, and ecological behavior: A multiple correlation analysis', *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 9, no. 3, pp. 335–345. doi: 10.22219/jpbi.v9i3.27130.

Erol, H 2021, 'Reflections on the 21st Century Skills into the Curriculum of Social Studies Course', *International Journal of Education and Literacy Studies*, vol. 9, no. 2, p. 90. doi: 10.7575/aiac.ijels.v.9n.2p.90.

Fita, MN, Jatmiko, B & Sudibyo, E 2021, 'The Effectiveness of Problem Based Learning (PBL) Based Socioscientific Issue (SSI) to Improve Critical Thinking Skills', *Studies in Learning and Teaching*, vol. 2, no. 3, pp. 1–9. doi: 10.46627/silet.v2i3.71.

Flores-González, N, Flores, VC & Hernández, MZ 2024, 'The Influence of E-Comics on English Lexical Competence in Virtual Higher Education', *IAFOR Journal of Education*, vol. 12, no. 2, pp. 149–172. doi: 10.22492/ije.12.2.07.

Gall, MD, Borg, WR & Gall, JP 2003. *Educational Research: An Introduction 7th Edition (7th ed.)*, Pearson Education. Boston.

Giordani, M, Taussi, M, Meli, MA, Roselli, C, Zambelli, G, Fagiolino, I & Mattioli, M 2024, 'High-levels of toxic elements and radioactivity in an abandoned sulphur mine: Insights on the origin and associated environmental concerns', *Science of the Total Environment*, vol. 906, no. 7, p. 167498. doi: 10.1016/j.scitotenv.2023.167498.

Gök, G & Boncukçu, G 2023, 'The Effect of Problem-Based Learning on Middle School Students ' Environmental Literacy and Problem-Solving Skills', *Journal of Science Learning*, vol. 6, no. 2, pp. 414–423. doi: 10.17509/jsl.v6i4.62781.

Goodale, TA 2021, 'Multivariate analysis of the impact of gender and college major on student levels of environmental concern and knowledge', *International Electronic Journal of Environmental Education*, vol. 11, no. 1, pp. 1–12. doi: 10.18497/iejeegreen.713165.

Gürses, D & Özdemir, AGM. 2024, 'Candidates' Use of New Media

and Social Media as Technology Tools in the TRNC 2020 Presidential Election Process', *TOJET: The Turkish Online Journal of Educational Technology*, vol. 23, no. 1, pp. 24–30.

Gutiérrez-Martín, A, Pinedo-González, R & Gil-Puente, C 2022, 'ICT and Media competencies of teachers. Convergence towards an integrated MIL-ICT model', *Comunicar*, vol. 30, no. 70, pp. 19–30. doi: 10.3916/C70-2022-02.

Hasanah, U, Sya, HMA, Sunaryo Aqil, DI, Sapsuha, S, Karnoto, BK, Astuty, ER, Hanafi, Y, Baga, S & Sukahatya, IG 2023, *Ekopedagogik Dalam Pendidikan Kependudukan Dan Lingkungan Hidup*, Karya Ilmu Media Aulia. Jakarta.

Hodijah, SRN, Rahmat, A, Priyandoko, D & Wahyudin 2023, 'Cognitive Process of Pre-service Science Teachers Using Problem-based Learning on Nervous System Concepts', *Jurnal Penelitian dan Pembelajaran IPA*, vol. 9, no. 2, p. 256. doi: 10.30870/jppi.v9i2.21274.

Hussein, H.L 2020, 'The use of comics in social studies material and its effect on achievement and retention among second-grade students', *International Journal of Innovation, Creativity and Change*, vol. 13, no. 1, pp. 341–355.

Ichsan, IZ, Sigit, DV, Miarsyah, M, Rahman, MM, El Islami, RAZ & Husamah 2020, 'Green Consumerism in Environmental Learning: 7th-grade Students Pro-Environmental Behavior in Science Subject', *Journal Of Biology Education Research (JBER)*, vol. 1, no. 1, pp. 25–32. doi: 10.55215/jber.v1i1.2633.

Ichsan, I.Z, Purwanto, A & Rahmayanti, H 2021, 'E-learning in new normal covid-19 era: Measure hots and pro-environmental behavior about environmental pollution', *International Journal of Evaluation and Research in Education*, vol. 10, no. 3, pp. 790–797. doi: 10.11591/ijere.v10i3.21382.

Indriyani, L, Ningsih, K & Yuniarti, A 2024, 'The Effectiveness of Character-Based Comic Media on Environmental Conservation Sub-Material Learning Outcomes', *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 2, pp. 506–515. doi: 10.29303/jppipa.v10i2.6148.

Irma, I, Agusta, E, Nuraini, N & Kholillah, K 2021, 'The Influence of the Scientific-Based Self-Regulated (SBSR) Bilingual Module in Improving Students' Knowledge', *Jurnal Penelitian dan Pembelajaran IPA*, vol. 7, no. 2, p. 216. doi: 10.30870/jppi.v7i2.5732.

Jang, M, Aavakare, M, Nikou, S & Kim, S 2021, 'The impact of literacy on intention to use digital technology for learning: A comparative study of Korea and Finland', *Telecommunications Policy*, vol. 45, no. 7, pp. 1–13. doi: 10.1016/j.telpol.2021.102154.

Japar, M, Hermanto, Musyaroah, S, Susila, HR, Alfani, H 2023, 'Digital Literacy-Based Multicultural Education through Civic Education in Indonesian Junior High Schools', *Journal of Social Studies Education Research*, vol. 14, no. 4, pp. 328–349.

Karimova, B, Bazylova, B, Makasheva, A, Nurlanbekova, Y, Ailauova, Z 2023, 'Students' Linguocultural Competence: Insights from Internationalization at Home', *Journal of Social Studies Education Research*, vol. 14, no. 4, pp. 379–405.

Karlimah, K, Hamdu, G, Pratiwi, V. Herdiansah, H & Kurniawan, D 2021, 'The development of motion comic storyboard based on digital literacy and elementary school mathematics ability in the new normal era during covid-19 pandemic', *Journal of Physics: Conference Series*, pp. 1-7. doi: 10.1088/1742-6596/1987/1/012026.

Ministry of Education, Culture, Research, and Technology 2023, 'Kurikulum Pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, Dan Jenjang Pendidikan Menengah', *Permendikbud Ristek Nomor 12 Tahun 2023*, pp. 1–26.

Ministry of Education, Culture, Research, and Technology 2022, 'Capaian Pembelajaran Mata Pelajaran Ilmu Pengetahuan Alam (IPA) Fase D', *Pusat Kurikulum dan Pembelajaran, Badan Standar, Kurikulum, dan Asesmen Pendidikan, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi*, 3, pp. 103–111.

Khoiri, N, Huda, C & Wiyanto, W 2020, 'Building Cognitive and Affective Learning Outcomes on the Concept of Linear Motion through Ticker Timer Experiment Using Problem Based Learning', *Jurnal Penelitian dan Pembelajaran IPA*, vol. 6, no. 2, p. 268. doi: 10.30870/jppi.v6i2.9006.

Knaus, T 2023, 'Emotions in Media Education: How media based emotions enrich classroom teaching and learning', *Social Sciences and Humanities Open*, vol. 8, no. 1, p. 100504. doi: 10.1016/j.ssaho.2023.100504.

Kudubes, AA, Ayar, D & Zengin, H 2023, 'Therapeutic communication skills level among students undertaking the pediatric nursing course and the associated influencing factors', *Journal of Pediatric Nursing*, vol 73, no. 3, pp. 34–43. doi: 10.1016/j.pedn.2023.08.015.

Marnita, Taufiq, M, Iskandar & Rahmi 2020, 'The effect of blended learning problem-based instruction model on students' critical thinking ability in thermodynamic course', *Jurnal Pendidikan IPA Indonesia*, vol. 9, no. 3, pp. 430–438. doi: 10.15294/jpii.v9i3.23144.

Miralles-Martínez, P, Gómez-Carrasco, CJ, Arias, VB & Fontal-Merillas, O 2019, 'Digital resources and didactic methodology in the initial training of history teachers', *Comunicar*, vol. 27, no. 61, pp. 41–51. doi: 10.3916/C61-2019-04.

Nasrulloh, MF, Hanik, S & Satiti, WS 2020, 'E-Comic Learning Media Based Problem Based Learning In Subject of Linear Equation System', *Hipotenusa : Journal of Mathematical Society*, vol. 2, no. 1, pp. 34–40. doi: 10.18326/hipotenusa.v2i1.34-40.

Pal, S, Cuong, TQ & Nehru, RSS 2022, *Digital Education for the 21st Century*, Apple Academic Press, Inc. Canada.

Prasetyaning, P, Vitasari, M, Wilujeng, I 2022, 'Development of Guided Inquiry-Oriented Science Interactive E-Module on Wave and Disaster Themes', *Jurnal*

Penelitian dan Pembelajaran IPA, vol. 8, no. 2, pp. 227–242. doi: 10.30870/jppi.v7i2.12058.

Pratiwi, V, Herman, T & Suryadi, D 2019, 'Algebraic thinking obstacles of elementary school students: A Hermeneutics-phenomenology study', *Journal of Physics: Conference Series*, pp. 11-21. doi: 10.1088/1742-6596/1157/3/032115.

Priyadi, A & Kuswanto, H 2023, 'the Android-Based Comic of Gajah Mungkur Dam: Improving Mathematical Representation and Critical Thinking Abilities', *Journal of Technology and Science Education*, vol. 13, no. 1, pp. 116–129. doi: 10.3926/jotse.1174

Purwanto, A, Muktiningsih, N, Suluya, R & Ichsan, IZ 2020, 'EM-SETS: An Integrated e-module of Environmental Education and Technology in Natural Science Learning', *International Journal of Advanced Science and Technology*, pp. 41-53.

Putrawan, IM 2022, *Pengujian Hipotesis dalam Penelitian-Penelitian*, Alfabeta. Bandung.

Radeswandri, R, Budiawan, A, Vebrianto, R & Thahir, M 2021, 'Developing instrument to measure the use of online comic as educational media', *Journal of Education and Learning (EduLearn)*, vol. 15, no. 1, pp. 119–126. doi: 10.11591/edulearn.v15i1.18961.

Ramdani, SD, El Islami, RAZ, Pratiwi, H, Fawaid, M, Abizar, H & Maulani, I 2021, 'Developing digital teaching material on Basic Electricity based on problem-based learning in vocational education', *Jurnal Pendidikan Vokasi*, vol. 11, no. 1, pp. 78–91. doi: 10.21831/jpv.v11i1.38894.

Rasyid, Y, Setiyowati, AJ & Flurentin, E 2019, 'Developing E-Comic to Internalize Manners for Junior High School Students', *5th International Conference on Education and Technology* (ICET), pp. 47–51. doi: 10.2991/icet-19.2019.11.

Riduwan 2013, *Pengantar statistika untuk penelitian pendidikan, sosial, ekonom, komunikasi dan bisnis*, Alfabeta. Bandung.

Ridwan, A, Rahmawati, Y, Mardiah, A & Rifai, A 2020, 'Developing 22nd century skills through the integration of STEAM into smoke absorber project', *Journal of Physics: Conference Series*, 1521(4). doi: 10.1088/1742-6596/1521/4/042077.

Rina, N, Suminar, JR, Damayani, NA, Hafiar, H 2020, 'Character education based on digital comic media', *International Journal of Interactive Mobile Technologies*, vol. 14, no. 3, pp. 107–127. doi: 10.3991/ijim.v14i03.12111.

Robbani, AS & Khoirotunnisa, U 2021, 'Online English Comics as Reading Materials for English Language Education Department Students', *European Journal of Educational Research*, vol. 10, no. 3, pp. 1359–1369.

Rusydiyah, EF, Purwati, E & Prabowo, A 2020, 'How to use digital literacy as a learning resource for teacher candidates in Indonesia', *Cakrawala Pendidikan*, vol. 39, no. 2, pp. 305–318. doi: 10.21831/cp.v39i2.30551.

Sajidan, Suranto, Atmojo, IRW, Saputri, DY & Etviana, R 2022, 'Problem-Based Learning-Collaboration (Pbl-C) Model in Elementary

School Science Learning in the Industrial Revolution Era 4.0 and Indonesia Society 5.0', *Jurnal Pendidikan IPA Indonesia*, vol. 11, no. 3, pp. 477–488. doi: 10.15294/jpii.v11i3.30631.

Santrock, JW 2008, *Educational Psychology*, McGraw-Hill Companies. Dallas.

Sezgin, ZÇ 2022, 'Systematic analysis of digital reading studies in the digital age', *Participatory Educational Research*, vol. 9, no. 1, pp. 233–250. doi: 10.17275/per.22.13.9.1.

Sigit, DV, Azrai, EP, Heryanti, E, Ichsan, IZ, Jajomi, YP & Fadrikal, R 2019, 'Development Green Consumerism E-Book for Undergraduate Students (GC-EBUS) as learning media in environmental learning', *Indian Journal of Public Health Research and Development*, vol. 10, no. 8, pp. 2026–2031. doi: 10.5958/09765506.2019.02152.1.

Suciati, S, Silvita, S, Prasetyo, O, Fauziah, MD, Santika, KD, Norawi, AM, Rahman, H. T 2023, 'Problem-Based Learning Models: Their Effectiveness in Improving Creative Thinking Skills of Students With Different Academic Skills in Science Learning', *Jurnal Pendidikan IPA Indonesia*, vol. 12, no. 4, pp. 672–683. doi: 10.15294/jpii.v12i4.44752.

Sudjana, N & Rivai, A 2020, *Media Pengajaran*, SBAlgensindo. Bandung.

Sugiyono 2017, *Metode Penelitian Kuantitatif, Kualitatif, dan R&D.* Alfabeta. Bandung.

Sumarmi, Bachri, S, Baidowi, A & Aliman, M 2020, 'Problem-based service learning's effect on environmental concern and ability to write scientific papers', *International Journal of Instruction*, vol. 13, no. 4, pp. 161–176. doi: 10.29333/iji.2020.13411a.

Suparman, AR, Rohaeti, E & Wening, S 2022, 'Development of Attitude Assessment Instruments Towards Socio- Scientific Issues in Chemistry Learning', *European Journal of Educational Research*, vol. 11, no. 4, pp. 1947–1958.

Susanto, H, Setiawan, D, Mahanal, S, Firdaus, Z, Claresia, TK 2024, 'Development and evaluation of e-comic nervous system app to enhance self-directed student learning', *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 1, pp. 143–153. doi: 10.22219/jpbi.v10i1.31451.

Thiagarajan, S, Semmel, DS & Semmel, MI 1974, *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook*, University Bloomington. Indiana. doi: 10.1016/0022-4405(76)90066-2.

Topkaya, Y, Bozkurt, A, Balci, E, Vuran, HM & Yal, F 2023, 'Educational Comics in Conveying Earthquake Topics', *Journal of Interdisciplinary Educational Research*, vol. 7, no. 15, pp. 325–335. doi: 10.57135/jier.

Tuma, F 2021, 'The use of educational technology for interactive teaching in lectures', *Annals of Medicine and Surgery*, vol. 62, no. 4, pp. 231–235. doi: 10.1016/j.amsu.2021.01.051.

Udayani, NKRTK, Wibawa, IMC & Rati, NW 2021, 'Development Of E-Comic Learning Media On The Topic Of The Human Digestive System', *Journal of Education*

Technology, vol. 5, no. 3, pp. 472–481. doi: 10.23887/jet.v5i3.34732.

Ural, E & Dadli, G 2020, 'The Effect of Problem-based Learning on 7th-grade Students' Environmental Knowledge, Attitudes, and Reflective Thinking Skills in Environmental Education', *Journal of Education in Science, Environment and Health*. doi: 10.21891/jeseh.705145.

Urbańska, M, Charzyński, P, Gadsby, H, Novák, TJ Şahin, S & Yilmaz, MD 2022, 'Environmental threats and geographical education: Students' sustainability awareness—evaluation', *Education Sciences*, vol. 12, no. 1. doi: 10.3390/educsci12010001.

Uyen, BP, Tong, DH & Tram, NTB 2023, 'Developing Mathematical Communication Skills for Students in Grade 8 in Teaching Congruent Triangle Topics', *European Journal of Educational Research*, vol. 10, no. 3, pp. 1287–1302.

Wajdi, M. *et al* 2022, 'The effectiveness of problem-based learning with environmental-based comic in enhancing students environmental literacy', *International Journal of Evaluation and Research in Education*, vol. 11, no. 3, pp. 1049–1057. doi: 10.11591/ijere.v11i3.22140.

Yani, A, Amin, M, Rohman, F, Suarsini, E, Rijal, M 2021, 'Pre-service biology teacher's perception on local environment problems as contextual learning resources', *International Journal of Evaluation and Research in Education*, vol. 10, no. 3, pp. 768–780. doi: 10.11591/ijere.v10i3.21091.

Yuntiaji, AD, Lukman, HS & Imsawatama, A 2020, 'Digital Worksheet Design Based on STEAM to Develop Students' Problem-Solving Skill', *Mathematics Education Journal*, vol. 4, no. 2. doi: 10.1128/AAC.03728-14.

Zein, M, Iskandar, E, Moenada, MS & Thahir, M 2023, 'Webtoon-based online comics in measuring the Pancasila student profile at Madrasah Tsanawiyah in Riau Province', *International Journal of Evaluation and Research in Education*, vol. 12, no. 4, pp. 2073–2084. doi: 10.11591/ijere.v12i4.25759.