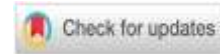




Problem-based learning quartet cards development assisted by QR code: Critical thinking on environmental change



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ABSTRACT

Conventional biology learning methods make students less active during the learning process. The lack of interactive media also causes students to have difficulty understanding the material, resulting in low critical thinking skills. This study aims to develop a Problem-Based Learning (PBL) based quartet card media assisted by QR codes on the topic of environmental change to improve students' critical thinking skills. The research method used was Research and Development with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The research subjects were 34 students of class X4. The assessment instruments included needs analysis, expert validation sheets, teacher and student response questionnaires, and pretest–posttest evaluations. The results showed that the PBL-based quartet cards assisted by QR codes obtained a validity score of 89% from media experts and 98% from material experts. The quartet cards were also categorized as very practical based on students' responses score of 90% and teachers' responses score of 93%. The N-Gain test obtained a score of 0.76, with a percentage of 76%, which falls into the high category. Therefore, the Problem-Based Learning (PBL) based quartet card media assisted by QR codes is declared valid, practical, and effective for supporting biology learning.

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INTRODUCTION

Education is a process of acquiring knowledge to enhance one's potential, including mindset, insight, character, and skills. Furthermore, education creates learning environments that support the development of students' abilities (Rahmi et al. 2021). In the 21st century, education plays a crucial role in equipping students with the ability to learn, innovate, utilize technology, and develop essential life skills (Khalifah et al., 2021). The skill that is intended to be realized in 21st-century education is critical thinking. Critical thinking is one of the essential abilities that students must



possess in this era of globalization, which is full of challenges and competition. In the context of biology learning, this ability not only supports a deep understanding of concepts but also helps students connect learning materials with the surrounding environment (Pratiwi et al., 2023)

Biology is one of the fields that is developing rapidly in this era, so teachers are required to be able to communicate and visualize learning so that easy for students to understand (Sahil et al., 2022). Biology is a branch of natural science that consists not only of a collection of knowledge or various facts to be memorized, but biology lessons require active thinking and processes to understand natural phenomena (Harita, 2024). Biology learning also involves material and how to apply it in everyday life, starting from the surrounding environment (Sari et al., 2024). Biology material that examines natural phenomena is environmental change.

Environmental change is one of the topics in biology that has the potential to accommodate learning activities in an effort to improve students' critical thinking and process skills through environmental issues in their surroundings (Wandari et al., 24). This is in line with the opinion of (Widiyastuti et al., 2024), who stated that the environment is an interesting topic for students to think critically in teaching and learning activities because of the many problems that arise due to weather and climate change. These problems are often encountered by students in their daily lives, so they are suitable for discussion with real examples of phenomena that they have experienced firsthand. According to (Putri et al., 2024), students' critical thinking skills are very important in solving problems related to the environment and nature. They also need to think about the processes behind these phenomena to find solutions. In this case, it helps students understand the problems in their surrounding environment. This is in line with the opinion of Santia & Hidayati (2024), who also stated that critical thinking skills are very important to develop in order to expand students' potential. However, in practice, students still face challenges in learning activities. Research by Pratiwi et al. (2024) found that students often experience boredom when learning about environmental change due to excessive amounts of material, a lack of images, and a lack of contextual experiences. The rigid language style also makes the material less engaging. Furthermore, Hidayati et al. (2021) emphasized that students are not yet able to think critically about environmental problems because the material is complex and abstract.

Critical thinking skills involve the ability to think logically, evaluate information objectively, and make appropriate decisions. These skills are essential in daily life, especially in education (Sugiharti & Gayatri, 2021). However, education in Indonesia has not effectively developed students' critical thinking, as shown by the 2018 PISA results: 74th in literacy, 73rd in mathematics, and 71st in science (Sofiani et al., 2024). The low critical thinking skills are mainly caused by inappropriate learning models (Dari & Ahmad, 2020) and a lack of active student participation. Students often remain silent, unfocused, and unable to analyze problems or express opinions (Lestiana & Metroyadi, 2023). One solution is to implement a learning model that encourages students' active involvement.

Based on interviews with biology teachers at MAN 2 Deli Serdang, it was found that students were still less active and less engaged during classroom learning activities. The teacher explained that this low level of participation directly affected their critical thinking skills, as students who were not actively involved were not accustomed to expressing opinions, asking questions, or responding to presented problems. As a result, their ability to analyze, evaluate, and relate concepts to environmental phenomena was underdeveloped. This situation was further exacerbated by the one-way learning process, where the teacher mostly explained the material while students merely listened without engaging in in-depth discussions or Q&A sessions. Some students also displayed a passive attitude during discussions and rarely expressed opinions or asked questions. Furthermore, the teacher stated that the teaching materials used were still limited to textbooks and lacked interactive learning media, while the questions provided did not yet cover

higher-order cognitive domains. Therefore, the teacher emphasized the need for innovation in the learning process through the implementation of more interactive and contextual models and media that can create an engaging learning atmosphere.

The model used to improve students' critical thinking skills is Problem-Based Learning (PBL), which is based on real-world problems (Nuraeni, et al., 2024). PBL is suitable for teaching and allows students to explore broader topics, be active, and responsible (Suryani et al., 2023). It helps develop logical reasoning, decision-making, and structured arguments (Ihsan et al., 2024). The use of PBL should be supported by engaging and innovative media, which influence student activeness, thinking, and conceptual understanding (Shellamita & Pramadi, 2023). Applying PBL with interactive media makes learning more engaging and easier to understand (Fauziah et al., 2024). One example is quartet cards, a game combining visual elements and text (Prameswari et al., 2022).

Quartet cards are a type of educational game consisting of several picture cards, each containing information that describes the image (Lestari et al., 2020). Quartet cards have characteristics that strongly support visualization and symbolic association, which facilitates students' understanding of complex material. By presenting information in the form of interconnected images, symbols, and text, quartet cards can simplify abstract concepts, making them easier to understand (Sulastri et al., 2020). These quartet cards can be developed as a tool to support students' critical thinking skills. They are implemented by engaging students in identifying information, analyzing relationships between concepts, and making systematic decisions.

Several researchers have used quartet cards in learning with effective results. For example, Ayatillah al. (2024) reported an increase from pre-test to post-test with an average N-Gain of 0,7 (high). Similarly, Ismail et al. (2020) developed quartet cards for reproductive system material, which were valid with a score of 3,73, practical with a score of 3.86, and effective, as 81,82% of students achieved mastery. This shows that quartet cards can enhance understanding and learning outcomes through engaging activities. In addition, Dila et al. (2024) developed problem-based learning quartet cards for social studies, with a score of 0,80 (high), very practical with a score of 92,66%, and fairly effective with an N-Gain of 0,64. Furthermore, Ningsih & Gunansyah (2023) integrated QR Codes to determine the feasibility of quartet cards.

Although research related to the development of problem-based learning-based quartet cards has been conducted, the development of quartet cards that combine problem-based learning with QR code integration and focus on environmental biology to enhance critical thinking skills is still rare. However, improving critical thinking skills is crucial for students in the 21st century, as it enables them to analyze potential environmental problems. Moreover, integrating QR codes into learning media can be highly practical for students, providing additional access to more interactive learning resources. Therefore, this research is important for developing engaging and innovative learning media that can also stimulate students' critical thinking about environmental change in a more in-depth and contextual manner.

Based on relevant previous research, this study aims to design and develop problem-based learning quartet cards assisted by QR codes as a learning medium for environmental change material, as well as to analyze their feasibility, practicality, and effectiveness in enhancing the critical thinking skills of Grade X students at MAN 2 Deli Serdang.

RESEARCH METHODS

Research Design

The methodology employed in this study follows a research and development approach, widely recognized as Research and Development (R&D). Research and Development (R&D) is a research method used to produce specific products and test their effectiveness. Research and



development (R&D) in education is a process for developing and validating products. The ADDIE development model was chosen in this study because of its systematic framework and logically structured steps, from analysis to evaluation. The development process was conducted by applying the ADDIE model (Analysis, Design, Development, Implementation, Evaluation).

Research and development (R&D) in education is a process for developing and validating educational products. Figure I shows the steps of developing the ADDIE model. The initial stage, namely analysis, is carried out by identifying a needs analysis to serve as a basic reference for media development. The design stage includes preparing the initial media design and compiling the instruments to be used. Next is the development stage, which focuses on creating or producing the product based on the initial design, followed by validation testing by experts or practitioners to obtain suggestions and improvements for the product. The developed product will be implemented to observe its practicality in the learning process. The final stage is evaluation, which assesses the effectiveness of the final product that has been revised and improved so that the media possesses the qualities to support the learning process.

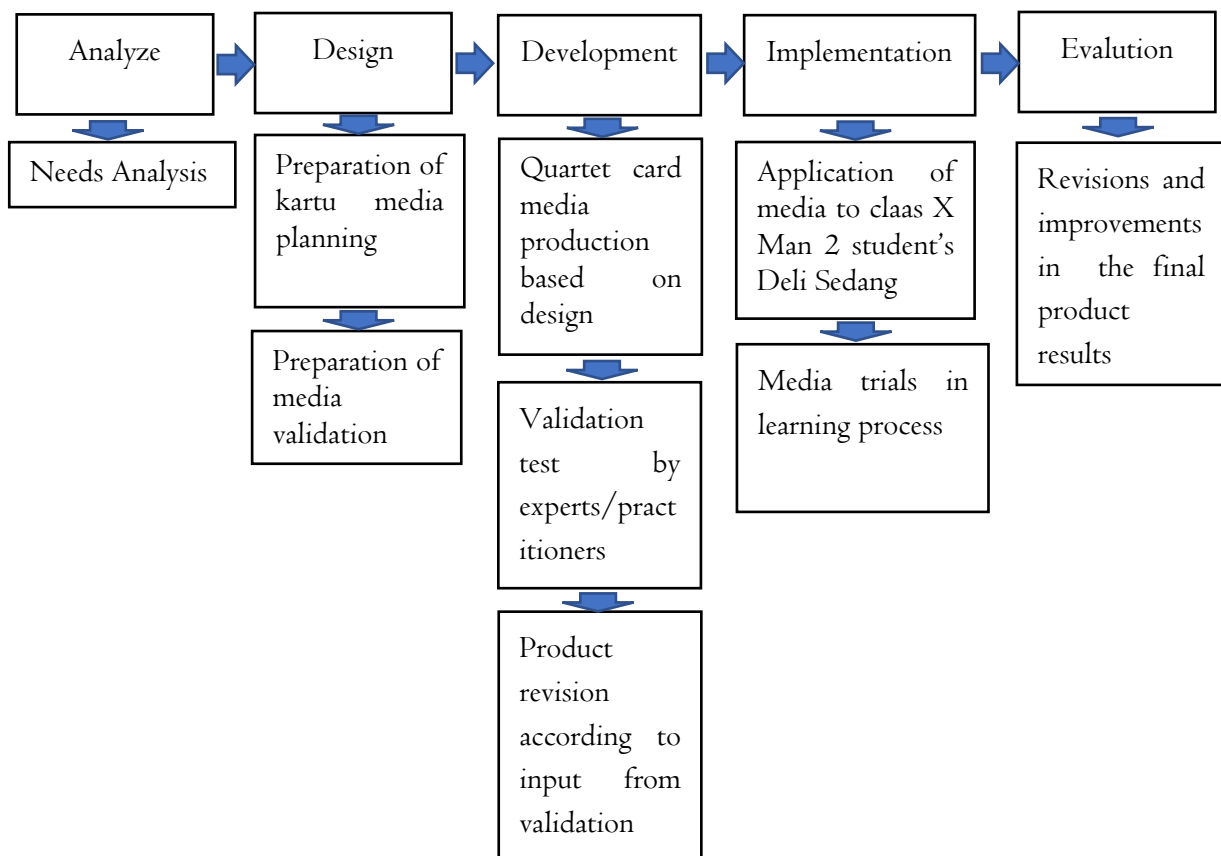


Figure I. Steps of the ADDIE Model Development

Population and Samples

The population of this study was tenth-grade students at MAN 2 Deli Serdang, totaling 12 classes, with the research sample including all students of class X4, comprising 34 students. The sampling technique used was purposive sampling, taking into account a needs analysis and classroom learning conditions. This consideration was based on the results of a needs analysis, which showed from student and teacher questionnaires that classroom learning still had limitations in the use of media, which were not yet engaging and interactive, and therefore had not guided

students to think critically in solving problems within the environment. Besides that, this study involved two validators who were experts in their fields. The validators were a media expert and a subject matter expert.

Instruments

The instruments included interview sheets, teacher and student needs analysis sheets, validity sheets, teacher and student response questionnaires, and pretests and posttests. The interview and needs analysis sheets were used to identify problems as the basis for media development. Validation was conducted by media experts, who assessed 15 statements covering aspects of appearance, design, language, and usability, and by material experts, who assessed 20 statements covering content, presentation, and contextual feasibility. The teacher response questionnaire contained 15 statements covering aspects of interest, material, and language, while the student response questionnaire contained 10 statements covering aspects of appearance, material, and language. The effectiveness of the media was tested through multiple-choice pretests and posttests to measure students' critical thinking skills. The multiple-choice questions were then evaluated for feasibility by question validator experts using a question validation questionnaire containing 15 statements assessing aspects of material, construction, language and writing, and instrument appearance.

The critical thinking instrument was developed following Ennis's (2011) opinion, which consists of five indicators: providing simple explanations (elementary clarification), building basic skills (basic support), drawing conclusions (inference), providing further explanations (advanced clarification), and organizing strategies and tactics (strategy and tactics). As one of the example questions, students are asked to analyze a case of illegal logging and choose the appropriate solution to prevent it.

Procedures

The ADDIE research model has five stages: analysis, design, development, implementation, and evaluation. The analysis stage begins with identifying learning needs through interviews and questionnaires focused on the material, classroom conditions, and media used. The design stage includes designing the quartet card concept, display, media content, and the preparation of research instruments. The development stage realizes the design into a product using Canva and Get-QR, then is validated by media experts and material experts. The implementation stage applies the revised media in class X4 MAN 2 Deli Serdang to assess its practicality through teacher and student responses. and the evaluation stage was conducted to examine the effectiveness as well as make improvements so that the product is more optimal.

Data Analysis

Data analysis techniques are methods used to process data into easily understood and useful information for identifying research solutions. This study employed both qualitative and quantitative descriptive analyses. Qualitative data consisted of interview results and input from validators, including suggestions, comments, and criticisms, which were then summarized descriptively. Quantitative data included numerical data from validation sheets, teacher and student questionnaire responses, and pre- and post-test results.

Validation Analysis

Validation data analysis involves collecting scores from competent validators on the appropriateness of the developed materials and media. Validators complete the provided validation sheets, and the scores are presented in Table I.



Table 1. Validation Criteria

Score	Criteria
5	Very good
4	Good
3	Pretty good
2	Not good
1	Very bad

Source: Sugiyono (2015)

In calculating the validation value of the quartet card, use the following formula:

$$\text{Validity Percentage} = \frac{\text{Score given by validator} \times 100\%}{\text{Maximum score}}$$

Then, to strengthen the validation results whose percentage is known, this can be done using validation criteria, as shown in Table 2.

Table 2. Product Validity Categories

Percentage	Criteria
85%-100%	Very Valid
68%-84%	Valid
52%-67%	Quite Valid
36%-51%	Less Valid
20%-35%	Totally Invalid

Source: Modified by Hikmah, (2024)

Practicality Analysis

Practicality test data analysis assesses the ease of use of the developed learning media based on user responses. The analysis involves tabulating teacher and student responses and calculating the percentage using the following formula:

$$\text{Practicality Percentage} = \frac{\text{Score per item} \times 100\%}{\text{Maximum score}}$$

Based on the percentage results obtained, the data were then categorized according to the criteria shown in Table 3.

Table 3. Product Practicality Categories

Mark	Category
81%-100%	Very practical
61%-80%	Practical
41%-60%	Quite practical
21%-40%	Less practical
0%-20%	Not practical

Source: Muliati (2023)



Effectiveness Analysis

The effectiveness of the quartet cards was assessed based on the results of the students' pre-test and post-test. If the post-test scores exceeded those of the pre-test, the quartet cards were considered effective in enhancing students' critical thinking abilities. This improvement was measured using the normalized gain formula for each individual:

$$\text{N-gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}$$

The results of the gain calculations were then interpreted based on the classification by Hake (2002), as shown in Table 4.

Table 4. N-Gain classification for effectiveness

Evaluation	Classification	Criteria
N-Gain < 0.3	Low	Ineffective
0.3 < N-Gain < 0.7	Currently	Quite effective
N-Gain > 0.7	Tall	Effective

Source: Kurniawan & Hidayah (2021)

RESULTS

The media produced in this research is a quartet card based on Problem-Based Learning (PBL) with the support of a QR Code, designed for the environmental change material in Grade X at MAN 2 Deli Serdang. The media development process was carried out using the ADDIE model, which consists of five stages, namely analysis, design, development, implementation, and evaluation. The application of the ADDIE model in this research serves as a reference to ensure that the media developed can be tested and assessed until it meets the criteria of valid, practical, and effective in supporting biology learning activities. The findings from each phase of the quartet card media development process in this research are described as follows:

Analysis Stage (Analyze)

The analysis stage (Analyze) is the first stage conducted by investigators. In this analysis stage, researchers collected information regarding problems that arise in biology learning, especially biology material, through an analysis of teacher and student needs. Based on the results of interviews with 10th-grade biology teachers, it was found that learning was still dominated by lecture methods or direct explanations. This method was considered by teachers to be ineffective because some students still tend to be passive, so critical thinking skills were still relatively low and rarely emerged. This was based on the varying levels of student understanding of environmental concepts that were not optimally understood. This was also supported by a teacher needs questionnaire that found that learning still used textbooks, and there were obstacles such as limited media that were not interesting. These findings correspond with the student needs questionnaire, which showed that 65% of critical thinking skills were still rarely trained, with 47% who considered the material on environmental change to be quite difficult. In this condition, it shows the need for learning media that can help students understand the material. In the student needs questionnaire, 38% of students thought that their understanding of biology would be more effective if assisted by educational visual media, such as Problem-Based Learning- based quartet cards combined with QR Codes that have not been used in learning environmental change material. This can be used in learning as a supporting medium in addition to printed books.

Design Stage

The second stage is design. The design stage is the initial planning stage carried out by the researcher. At this stage, the results of the analysis process will be used as a reference in designing



the quartet card. In the design stage, the researcher prepared a quartet card design based on Problem-Based Learning assisted by QR Codes for environmental change material by paying attention to the compatibility between the learning material and the intended learning outcomes and objectives. The following are several steps taken by the researcher in designing the quartet card media:

a. Quartet Card Media Design

The design of the quartet card was carried out by considering several aspects, including appearance, material scope, and instructions for use, to align with the learning objectives. The quartet card was designed with attention to various visual elements, such as background selection and color combinations to attract students' attention, image selection to support understanding, and relevant supporting text information linked to a QR code that provides access to a learning video. The video was created using the Canva application and contains explanations of supplementary material. The resulting video was then converted into a QR code using the Get QR application, allowing students to access it easily. In addition, PBL-based activities are included at the bottom of the card. The quartet card is rectangular in shape, with a standard size of 10 × 7 cm, making it easy for students to hold. The fonts used are League Spartan for the cover and Aleo for the titles and content of the card material. The design process utilized the Canva application, which is easily accessible and flexible in combining engaging visual elements. The quartet card has two sides: the front side serves as the cover and includes a QR code in the bottom right corner, while the back side contains the content, consisting of images, subtitles, material text, and questions adapted to the Problem-Based Learning (PBL) model. A divider is placed in the middle of the card to help students distinguish between the image display and explanatory text, ensuring that the information appears clear, neat, and well-structured.

b. Preparation of Instruments

The instruments designed in this study include a validity assessment instrument for the Problem-Based Learning- based quartet card, which functions to assess the validity and suitability of this quartet card through a questionnaire sheet filled out by lecturers who are experts in their fields. The teacher response questionnaire was designed to find out teachers' responses regarding the use of Problem-Based Learning- based quartet cards assisted by QR codes in learning activities, while the student response questionnaire was used to find out students' responses after learning using Problem-Based Learning-based quartet cards. Moreover, the learning outcome test instrument was employed to examine learners' critical thinking capability through preliminary and final test questions.

Development Stage

The next stage is the development stage, a process in which the design created in the design stage begins to be realized into an actual product. The product developed is a quartet card equipped with images, text, Problem-Based Learning- based activities, and supporting learning videos accessed via QR Code. Subsequently, the media is assessed by media experts and material experts with assessment aspects that can be seen in Table 5 (media validation data) and Table 6 (material validation data).

Table 5. Media Validation Data

No	Aspect	Score obtained	Maximum score	Percentage	Criteria
1	Appearance	27	30	90%	Very Valid
2.	Design	13	15	86%	Very Valid
3.	Language	12	15	80%	Valid
4.	Use	15	15	100%	Very Valid
	Total	67	75	89%	Very Valid

Based on the media validation results in Table 5, the measured aspects include appearance, design, language, and usage. The assessment results from media experts showed a score of 89%, indicating that the developed QR code-assisted problem-based learning quartet card media was categorized as highly valid.





Table 6. Material Validation Data

No	Aspect	Score obtained	Maximum score	Percentage	Criteria
1.	Content Eligibility	63	65	96%	Very Valid
2.	Presentation Eligibility	10	10	100%	Very Valid
3.	Contextual Feasibility	25	25	100%	Very Valid
	Total	98	100	98%	Very Valid

In Table 6, the material validation measures aspects of content feasibility, presentation feasibility, and contextual feasibility. Based on the results of the validation by the material expert, the assessment obtained a score of 98%, which falls into the "very valid" category.

After the validation was carried out by the media expert and the material expert, the media was declared very valid and feasible to use. This assessment was obtained after revisions and improvements were made to the media based on the suggestions from the validators. The results of the media improvements before and after the revisions can be seen in Table 7.

Table 7. Results of the Quartet Card Media Improvement

No	Validator Comments	Before Revision	After Revision
I.	Media expert		
	Addition of logo, writing based on Problem-Based Learning, and names of authors and supervisors.		

2. Subject Addition of body notes, Matter logos, and Problem-Based Expert Learning tests



The right element in the form of a coughing person is recommended to be deleted.



Additional examples of problems that occur in Indonesia

There are no images in additional examples of problems that occur in Indonesia.



Bibliography and glossary added



Implementation Stage

At the implementation stage, the media verified by experts was applied to 34 students of class X4 at MAN 2 Deli Serdang. This stage included product introduction, response questionnaires, and multiple-choice testing. The trial began with introducing the Problem Based Learning–based quartet card media, followed by its use in biology lessons. Students were divided into six groups to collect four cards on the same topic within environmental change material, including subtopics like water, air, soil, and noise pollution. During learning, students discussed in groups to answer questions based on Problem Based Learning syntax, including problem orientation, organizing learning, guiding investigations, presenting results, and evaluating problem-solving to enhance critical thinking. Students also accessed explanatory videos via QR codes on each card. After the trial, teacher and student questionnaires were given to assess practicality. Table 8 shows the responses.



Table 8. Results of Students' Practicality Responses

No	Aspect	Score obtained	Maximum score	Percentage	Criteria
1.	Appearance	755	850	88%	Very Practical
2.	Material	443	510	86%	Very Practical
3.	Language	327	340	96%	Very Practical
	Total	1,525	1,700	90%	Very Practical

Based on Table 8, the results of the student response questionnaire on the quartet cards show that the appearance aspect received 88%, the material aspect 86%, and the language aspect 96%, with an overall average score of 90%, which falls into the "very practical" category.

Table 9. Results of Teacher Practicality Responses

No	Aspect	Score obtained	Maximum score	Percentage	Criteria
1.	Interest	22	25	88%	Very practical
2.	Material	29	30	97%	Very practical
3.	Language	19	20	95%	Very practical
	Total	70	75	93%	Very practical

Based on Table 9, the results of the teacher response questionnaire show that the interest aspect is 88%, the material is 97%, and the language is 95%, with an mean score of 93% which belongs to the highly practical and is able to facilitate students in learning biology on the material of environmental changes.

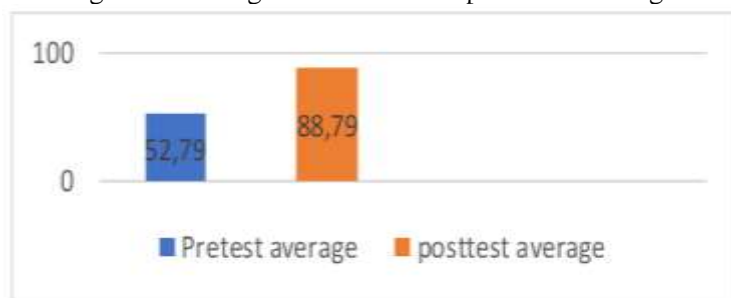
Evaluation Stage

The evaluation phase, conducted after implementation, assesses the effectiveness of quartet cards in improving critical thinking skills through students' pre-test and post-test results analyzed using the N-gain value, as shown in Table 10.

Table 10. Effectiveness Test Results Based on N-Gain

Pretest Average	Posttest Average	Pretest-Posttest	Ideal Score-Pretest	N-Gain Score	Percentage	Criteria
52.79	88.79	36.00	47.21	0.76	76.48	Effective

Based on the results in Table 10, the average pretest score of class X4 Man 2 Deli Serdang students was 52.79, while the posttest score reached 88.79. After using the Quartet Card-Based on Problem-Based Learning, the difference between the pretest and posttest scores was 36.00. The N-Gain value obtained was 0.76, which indicates a high category, and in percentage it was 76.48%. This shows that the media of the Quartet card, based on Problem-Based Learning assisted by QR code, is effective for use in biology learning on environmental change material. So the application of this media not only improves students' cognitive abilities, but also improves students' critical thinking skills through environmental problem-solving activities.

**Figure 2.** Graph of Average Pretest-Posttest Results

Based on Figure 2, which shows a graph of the average pretest and posttest scores of class X4 students, a significant increase can be observed. This increase can be seen from the average pretest score obtained by the students of 52.79, which then experienced an increase on the average posttest score of 88.79 after the implementation of the Problem-Based Learning Quartet Card. Thus, the developed media product has been proven effective in supporting learning activities.

DISCUSSION

The quartet card media developed by the researcher aims to help students easily understand biology learning materials. The urgency of developing the quartet card, which is designed with the integration of Problem-Based Learning and a QR Code feature specifically for the topic of environmental change, is based on the findings from students' needs analysis that indicate there are still problems experienced in learning biology. This shows that students need more varied and interactive learning media that facilitate concept visualization, allowing them to more easily receive and deeply understand the material.

The implementation of quartet cards in learning is systematically and structurally arranged based on the syntax of Problem-Based Learning (PBL), including student orientation to the problem, organizing learning, guiding individual or group investigations, presenting results, and evaluating problem-solving, so that students are actively involved. Using quartet cards with PBL facilitates students' understanding of complex environmental changes, as the cards are not only problem-based but also designed with a guessing-card concept that stimulates critical thinking. This aligns with Ginanjar et al. (2023), who stated that quartet cards combined with PBL build student understanding through active engagement, student interaction, and critical thinking challenges that encourage analysis, idea exploration, and argument development.

The quartet card media presents visual images with explanatory text in describing the material on the cards. This aligns with Sulastrri et al. (2020), who stated that quartet cards are media combining images and written captions explaining those images. The material presented contains sub-materials on environmental change and environmental pollution, namely water pollution, air pollution, land pollution, and noise pollution, along with real examples of events that occurred in Indonesia to provide students with concepts in a real context. Quartet cards direct students to learn biology through card games in groups by guessing and looking for cards from other groups, so they can group four cards with the same topic. After that, when the quartet cards have been collected, students are required to scan the QR code from Google to access the explanation of the material contained in the card to help their understanding in solving the problems in the quartet card. This activity resulted in class X4 MAN 2 Deli Serdang students being enthusiastic in learning, which can be seen from the emergence of active involvement in discussions, teamwork, and student understanding in analyzing each card's content, which encourages the training of critical student thinking in learning. This is in line with the opinion of Lucky & Cahya (2024), who stated that the use of quartet card media builds students understanding, encourages active student involvement, while building students critical thinking skills in quartet card game activities such as questions and answers, group work, and card grouping challenges that encourage students to think, reflect on knowledge, classify concepts, and construct arguments.

Based on the results of the research conducted, the quartet card media based on Problem-Based Learning was obtained as a valid, practical, and effective media source for use in learning activities.

a. Validity of Quartet Card Products Based on Problem-Based Learning

The Problem-Based Learning quartet card product, assisted by QR Codes for environmental change material, is declared highly valid for learning. The media was assessed by material and media



experts to ensure its feasibility and quality in terms of presentation, language, and functionality before being used by students. The media validation results showed an overall score of 89%, covering appearance, design, language, and usage. Media expert validators rated the card as highly valid for field trials with revisions. The product was also validated by subject matter experts and obtained a score of 98%, covering content, presentation, and contextual feasibility. The validation was conducted twice, with suggestions to add references, a glossary of scientific terms, and real-life examples of environmental changes in Indonesia to enrich students' understanding. According to Rizalia & Wuriani (2023), the validation aims to gather input to improve product weaknesses before implementation.

b. Practicality of Quartet Card Products Based on Problem-Based Learning

The quartet card product based on Problem-Based Learning assisted by QR Code on environmental change material was evaluated through teacher and student response questionnaires, showing that the media is highly practical for use in learning activities, with the teacher's assessment obtaining an overall score of 93% categorized as very practical, consisting of the interest aspect with a score of 88%, the material aspect with a score of 97%, and the language aspect with a score of 95%, while the student response questionnaire achieved an overall score of 90% covering the display aspect with a score of 88%, the material aspect with a score of 86%, and the language aspect with a score of 96%, where both teachers and students stated that the quartet card media is interesting, easy to understand, and helps in comprehending the learning material, in line with Sulistyono & Choirunnisa (2024), who stated that utilizing quartet card media can help students remember, understand, and analyze material information in depth.

c. Effectiveness of Quartet Card Products Based on Problem-Based Learning

The Quartet Card product, based on Problem-Based Learning assisted by QR Code on environmental change material, is considered effective in improving students' critical thinking skills observed from the pretest and posttest results based on Bloom's taxonomy C4-C6. In determining the level of students' initial knowledge before learning activities, a pretest sheet is given. While the posttest sheet is given after using the quartet card to determine students' ability to think critically, through learning outcomes. The results of the student's pre-test were obtained at 52.79 and the post-test with a score of 88.79. Based on the results of measurements using N-gain, it was found that the pretest and posttest results were 0.76, which showed high criteria with a percentage of 76% so that it can be declared effective in enhancing students' critical thinking skills, as evidenced by the posttest results having increased after using the quartet card media based on Problem-Based Learning. This is reinforced in research by Sholihah & Indana (2018) that the developed quartet card media is effective in training critical thinking skills if it obtains a value of $\geq 70\%$ with good or very good criteria.

Quartet card media is categorized as effective in improving critical thinking skills based on the N-gain calculation obtained from the learning process that has been implemented. According to Rizalia and Wuriani (2023), quartet cards can enhance critical thinking skills because this medium is presented in the form of an educational game that combines visual elements, text, and problem-based questions. It is developed not only as a medium for presenting factual information but also designed to stimulate students' critical thinking abilities. This medium can improve the critical thinking skills of class X-4 students through the application of quartet cards, where students are directed to be actively involved in learning by guessing and matching cards. Learning that encourages students to think critically occurs at the stage when they must be able to group quartet cards on the same topic, identify the problems presented on the cards, and find the correct answers through group discussions. Furthermore, students can understand the material linked to the QR code on the cards, so that they are trained to analyze, evaluate, and draw logical conclusions as a form of strengthening their critical thinking skills. This is supported by Collins et

al. (2021), who stated that QR code-assisted problem-based learning quartet cards help students analyze real-life problems and develop analytical, creative, and critical thinking. Through group interaction, students better understand and solve learning related problems.

CONCLUSION

Based on the findings and discussion, it can be inferred that quartet card media, based on Problem-Based Learning and assisted by QR codes for the environmental change material, is proven to be valid, with validation scores of 89% from media experts and 98% from material experts; practical, with responses of 93% from teachers and 90% from students; and effective, with an N-Gain of 0.76 score in enhancing students' critical thinking abilities. However, this research is limited in the scope of certain materials. Therefore, further studies are needed to broaden the generalizability of the findings. Future research can develop similar media for other materials or combine them with different learning approaches to enhance students' critical thinking skills more broadly.

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