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Development of STEM-Nuanced Mathematics Teaching Materials to Enhance Critical Thinking in the Challenge Based Learning Model

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Abstract

This research aims to develop STEM-based mathematics teaching materials in the Challenge-Based Learning model to enhance students' critical thinking. This research used the Research and Development method with the 4D model, but up to the development stage. The research was conducted at SMP Negeri 3 Karanganyar. The data collection techniques used were interviews, tests, and questionnaires. The purpose of this research is to produce a product that meets the feasibility, readability, effectiveness, and positive student response. The results showed that the average percentage of feasibility of the mathematics teaching materials developed was 91.34% which is very feasible. The results of the readability test, obtained Q = 6.0967, show teaching materials that are easy for students to understand. The mathematics teaching materials developed are effective in improving students' critical thinking skills because they meet the five research hypotheses. The average score of students' responses to the developed teaching materials is a very good criterion. Based on the results of the research, STEM-nuanced mathematics teaching material products were obtained to improve critical thinking in 94% the Challenge-Based Learning model, which is feasible, easy to understand, effective in improving students' critical thinking skills, and received a very good response. Similar research can be done by applying learning styles in depth and maximizing the use of Padlet media to be active in discussions to hone analysis and inference skills.

1. Introduction

Advances in science and technology require students to master skills relevant to the 21st century. Critical thinking skills are one of the skills that students must master in the 21st century. Students are required to master soft skills, which are referred to as the 4Cs (communication, collaboration, critical thinking and problem solving, dan creativity and innovation) (Makhrus et al., 2018), where critical thinking plays an important role in life as stated in the mathematics curriculum standards, namely that students should be equipped with logical, analytical, systematic, critical, and creative thinking skills as well as cooperation skills (Depdiknas, 2006). In addition, the importance of critical thinking skills in students is necessary in the process of analyzing and comparing information to build an argument and is a learning requirement to face challenges and problems in learning, which emphasizes the development of a broader learning experience. Critical thinking is closely related to the learning process to prepare students to solve problems. With the critical thinking skills they possess, students are able to solve the problems they face, thereby minimizing errors when solving problems and achieving solutions with accurate conclusions (Juhji & Suardi, 2018).

Critical thinking skills are essential for students to understand the concepts of learning materials that will become their future knowledge. According to Agnafia (2019), critical thinking skills in facing challenges are one of the things that need to be prepared in an effort to develop quality human resources.

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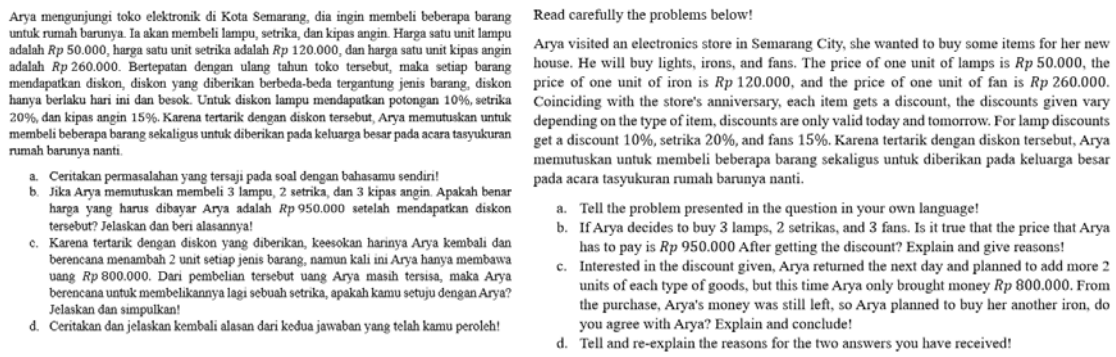
Therefore, critical thinking must be developed because the level of critical thinking skills affects the quality of competitive graduates. The critical thinking skills of Indonesian students are relatively low. This can be proven by the 2022 PISA results. PISA is a survey conducted every three years on 15-year-old students worldwide to assess how much knowledge and skills students have acquired. The 2018 PISA results for Indonesia, initiated by the Organisation for Economic Co-operation and Development (OECD), ranked 73rd out of 79 countries with an average score of 386, compared to the OECD average of 489 (Hewi & Saleh, 2020). Meanwhile, Indonesia's 2022 PISA results, according to the OECD, ranked 69th out of 80 countries. However, despite the increase in ranking, Indonesia's average score actually decreased to 366. According to the OECD's analysis of the 2022 PISA survey results, there are eight levels reflecting students' mathematical abilities: levels 1c, 1b, 1a, 2, 3, 4, 5, and 6 (OECD, 2022:24). At levels 4 and 6, which focus on critical thinking skills, 0.5% of Indonesian students are at Level 4 and 0.0% are at Level 6 (OECD, 2022:92). This is in line with the results of a preliminary study conducted by researchers at SMP Negeri 3 Karanganyar, which involved giving students one critical thinking question that covered the skills of interpretation, analysis, evaluation, conclusion, and explanation. The preliminary study showed that most students were unable to solve problems using the above skills. Based on the results of the preliminary study, the average score was 42.34 It appears that students' critical thinking skills are still low. The following are preliminary study questions presented in Figure 1.



Baca dengan teliti permasalahan di bawah ini!

Arya mengunjungi toko elektronik di Kota Semarang, dia ingin membeli beberapa barang untuk rumah barunya. Ia akan membeli lampu, setrika, dan kipas angin. Harga satu unit lampu adalah *Rp* 50.000, harga satu unit setrika adalah *Rp* 120.000, dan harga satu unit kipas angin adalah *Rp* 260.000. Bertepatan dengan ulang tahun toko tersebut, maka setiap barang mendapatkan diskon, diskon yang diberikan berbeda-beda tergantung jenis barang, diskon hanya berlaku hari ini dan besok. Untuk diskon lampu mendapatkan potongan 10%, setrika 20%, dan kipas angin 15%. Karena tertarik dengan diskon tersebut, Arya memutuskan untuk membeli beberapa barang sekaligus untuk diberikan pada keluarga besar pada acara tasyukuran rumah barunya nanti.

a. Ceritakan permasalahan yang tersaji pada soal dengan bahasamu sendiri!
b. Jika Arya memutuskan membeli 3 lampu, 2 setrika, dan 3 kipas angin. Apakah benar harga yang harus dibayar Arya adalah *Rp* 950.000 setelah mendapatkan diskon tersebut? Jelaskan dan beri alasannya!
c. Karena tertarik dengan diskon yang diberikan, keesokan harinya Arya kembali dan berencana menambah 2 unit setiap jenis barang, namun kali ini Arya hanya membawa uang *Rp* 800.000. Dari pembelian tersebut uang Arya masih tersisa, maka Arya berencana untuk membelikannya lagi sebuah setrika, apakah kamu setuju dengan Arya? Jelaskan dan simpulkan!
d. Ceritakan dan jelaskan kembali alasan dari kedua jawaban yang telah kamu peroleh!

Read carefully the problems below!

Arya visited an electronics store in Semarang City, she wanted to buy some items for her new house. He will buy lights, irons, and fans. The price of one unit of lamps is *Rp* 50.000, the price of one unit of iron is *Rp* 120.000, and the price of one unit of fan is *Rp* 260.000. Coinciding with the store's anniversary, each item gets a discount, the discounts given vary depending on the type of item, discounts are only valid today and tomorrow. For lamp discounts get a discount 10%, setrika 20%, and fans 15%. Karena tertarik dengan diskon tersebut, Arya memutuskan untuk membeli beberapa barang sekaligus untuk diberikan pada keluarga besar pada acara tasyukuran rumah barunya nanti.

a. Tell the problem presented in the question in your own language!
b. If Arya decides to buy 3 lamps, 2 setrikas, and 3 fans. Is it true that the price that Arya has to pay is *Rp* 950.000 After getting the discount? Explain and give reasons!
c. Interested in the discount given, Arya returned the next day and planned to add more 2 units of each type of goods, but this time Arya only brought money *Rp* 800.000. From the purchase, Arya's money was still left, so Arya planned to buy her another iron, do you agree with Arya? Explain and conclude!
d. Tell and re-explain the reasons for the two answers you have received!

Figure 1. Critical Thinking Questions Preliminary Study

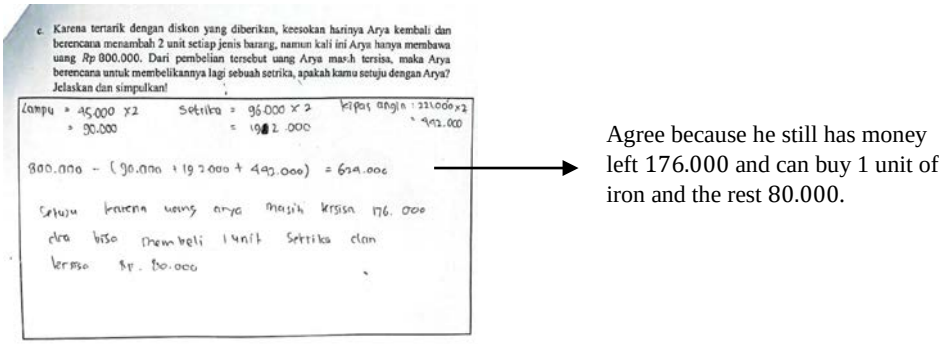


Figure 2. Answers to Critical Thinking Questions Preliminary Study

Based on the questions, there were students who answered the evaluation incorrectly. In Figure 2, students answered using the correct strategy by multiplying the discounted price of each unit by two, but they made a mistake in their calculations. This resulted in the students' opinions and reasons being inaccurate. The students answered that Arya could buy an iron, but the remaining money should not be enough to buy an iron. This indicates that the students' critical thinking skills still need to be developed

Based on interviews conducted on November 12, 2024 with teachers and stated that the learning resources used have not focused on critical thinking, learning using teaching materials from publishers has not met the needs of students, this has caused low critical thinking. In addition, this was supported by the low average percentage of preliminary studies, which showed that these learning resources were not being used optimally in mathematics learning. Teachers often face difficulties in selecting and determining the teaching materials used in learning. One of the challenges in the Indonesian education system relates to the availability of reading materials and students' reading interests. Teaching materials that do not meet the criteria will result in various problems in learning. Learning resources are used by students as a guide and reference for learning. According to Nurhikmayati & Gilar Jatisunda (2019) Critical thinking can be

developed by providing students with thinking exercises, where critical thinking exercises can be obtained by students through teaching materials that facilitate the development of critical thinking skills. Teaching materials become a supporting tool for the learning process that can have an impact on the development of critical thinking in students (Syehab *et al* ., 2023).

Based on interviews with teachers and students, learning has not yet integrated aspects of science, technology, engineering, and mathematics. Learning occasionally integrates aspects of science, with problems that are easily found in the surrounding environment. The lack of STEM integration in mathematics learning is one of the factors contributing to low critical thinking skills among students. With science, technology, engineering, and mathematics education, student engagement in building arguments is an aspect that needs to be explored. The problems provided aim to encourage students to think deeply about solving current issues. Based on this, the development of integrated STEM teaching materials has an impact on critical thinking skills (Hidayati & Priyanto, 2023), it is hoped that this will help integrate the aspects of science, technology, engineering, and mathematics.

The model used in schools is PBL, but the application of PBL syntaxes has not been maximized. Students express boredom with monotonous learning, lack of group discussions, and insufficient challenges. Therefore, the researcher employs the Challenge-Based Learning (CBL) model, a new learning model that combines problem-based learning, project-based learning, and contextual learning, focusing on solving or addressing issues that arise in daily life. CBL is capable of enhancing students' critical thinking skills, encouraging active participation in learning activities, and solving problems through higher-order thinking processes, also known as critical thinking. It is hoped that this approach will help integrate aspects of science, technology, engineering, and mathematics (Nawawi, 2016), challenge-based learning that encourages students to develop critical thinking skills in problem solving, beginning with issues and problems that arise in everyday life, as well as projects that must be completed and discussed together, will encourage students to reason and think critically in solving problems and draw conclusions (Johnson *et al.*, 2009).

Mathematics learning has not yet implemented Information and Communication Technology (ICT), and students say they are more interested in learning with learning media. The application of ICT is one of the innovations in mathematics learning media that can help students and keep up with technological developments in the world of education. The application of ICT in the development of mathematics teaching materials is the Padlet application, which is a web-based media application that contains multimedia panels that provide services with many ideas such as images, music, recordings, or connections (Aneros & Herniwati, 2020). Padlet is a learning tool that serves to share information and ideas among students in various formats, including text, images, videos, recordings, and links, displayed on a virtual wall or board that can be used interactively during synchronous or asynchronous learning. Padlet facilitates collaboration among students in the classroom, offering features for group discussions, information sharing, and presenting perspectives on an issue to the forum.

Research related and similar to this study is research that examines the potential of the Challenge Based Learning model in empowering critical thinking skills (Nawawi, 2016). Next research Ash-Showy *et al* (2022) examining the development of integrated comparative teaching materials for Challenge Based Learning using a STEM approach to critical thinking skills. Related research on the application of the STEM approach to improve students' critical thinking skills. Further research (Ritonga & Zulkarnaini, 2021). Based on this research, what distinguishes it from this study is the integration of Challenge Based Learning and the use of Padlet media in teaching materials to improve students' critical thinking skills. Furthermore, research related to the development of statistics teaching materials containing STEM-oriented numeracy literacy questions to improve students' critical thinking skills in PBL (Musyafak & Agoestanto, 2022). A literature study examines the effect of multimedia-assisted problem-based learning (PBL) using Padlet on students' critical thinking skills (Rahmawati & Rahmawati, 2024).

Based on the description above, this study carry out the development of mathematics teaching materials with Science, Technology, Engineering, and Mathematics (STEM) nuances to improve critical thinking in the Challenge Based Learning model for students on the material of linear equations of one variable in class VII. ICT innovation in the research to be carried out is the use of Padlet learning applications in teaching materials and the combination of CBL, STEM learning models into a developed teaching material. The purpose of this research is to produce a product that meets the feasibility, readability, effectiveness test, and positive student response. The development of mathematics teaching materials with STEM nuances is expected to be able to improve students' critical thinking skills by presenting meaningful, challenging, and contextualized learning through active involvement in real problem solving. This is supported by Nichols et al (2016) which states that the Challenge Based Learning model is effective in developing higher order thinking skills because it places learners as problem solvers in real-world challenges.

2. Methods

This research was an R&D (Research and Development) model focused on product creation and testing product effectiveness. The development model used in this research was the 4D model developed by Thiagarajan et al in 1946 (Thiagarajan *et al.*, 1946). This study will only be conducted up to the development stage. The R&D research designed in this study consists of three stages, namely the definition stage, the design stage, and the development stage. The desiminate stage was not carried out due to limited research time. The research design used in this study was a pretest-posttest control group design, which refers to Sugiyono's design (2017).

The data collection techniques used in this development study included interviews, questionnaires, and tests. Interviews were conducted to obtain data on the problems and analysis of the mathematics learning system at SMP Negeri 3 Karanganyar through two mathematics teachers and several students as informants. The questionnaires used in the study were a feasibility test questionnaire (to obtain suitable teaching materials), a readability test questionnaire (to obtain teaching materials that are easy to understand), and a student response questionnaire (to obtain teaching materials with positive responses). The tests administered were pre-tests and post-tests to measure students' critical thinking skills. The research questions are as follows: (1) What is the level of suitability of STEM-based mathematics teaching materials for improving critical thinking in the Challenge Based Learning model for students? (2) What is the level of readability of STEM-based mathematics teaching materials for improving critical thinking in the Challenge Based Learning model for students? (3) How effective are STEM-based mathematics teaching materials in enhancing critical thinking in the Challenge-Based Learning model for students? and (4) What is the students' response to STEM-based mathematics teaching materials in enhancing critical thinking in the Challenge-Based Learning model for students?

The data analysis techniques used in this study were descriptive qualitative and quantitative techniques. Qualitative data analysis was derived from interviews with teachers and students, which were used as a reference in the process of developing teaching materials tailored to students' needs. Quantitative data analysis was used to analyze data from the assessment of teaching material suitability and student response evaluation. Scores were based on a Likert scale with assessment criteria of 1 (Unsuitable), 2 (Sufficiently Suitable), 3 (Suitable), and 4 (Very Suitable) (Sugiyono, 2022). The scoring calculation guidelines used the formula according to Asrul *et al* (2014).

The analysis of teaching materials refers to the achievement of content feasibility, presentation feasibility, linguistic aspects, and product innovation as mentioned by BNSP (2006). The assessment of teaching materials and other instruments such as modules, ATP, and critical thinking tests was conducted by two mathematics education lecturers from UNNES as experts and two mathematics teachers from SMP Negeri 3 Karanganyar as practitioners. The results of the assessment were represented based on the categories mentioned by Ardiansyah & Pratama (2021) as presented in Table 2.1. Based on these categories, the developed product is considered feasible if it obtains a minimum percentage of 85%. If it does not reach this percentage, improvements and reassessment by experts and practitioners are required.

Table 1. Criteria for the Suitability of Mathematics Teaching Materials

Score Percentage	Eligibility Criteria
$1\% \leq P \leq 50\%$	Unsuitable
$50\% \leq P \leq 70\%$	Quite Adequate
$70\% \leq P \leq 85\%$	Suitable
$85\% \leq P \leq 100\%$	Very Worthwhile

Readability questionnaire for teaching materials, from all aspects assessed in the readability questionnaire for teaching materials, a score of very good is sought Q to determine whether there are differences in opinion among students and supported by the average of each question item, which is then used to calculate the final average readability of teaching materials using the Cochran Test analysis formula, which refers to research conducted on teaching material readability questionnaires. From all aspects assessed in the teaching material readability questionnaire, a very appropriate score is sought Dewi *et al* (2020). The test criteria are if $Q_{count} \geq$ critical Chi-Square value for a given significance level and $db = k - 1$ then H_0 rejected and H_1 accepted. Mathematics teaching materials are considered readable if the score is Q lsmaller than the score χ^2tabel. This is supported by the readability test percentage.

Based on the results of the feasibility and readability assessment as a product ready for implementation, the next step was to conduct an effectiveness test with feasibility and readability assessment results that took into account student achievement, as well as a test of the improvement in the posttest results of students in the experimental class and the control class. The hypotheses in this study are presented in Table 2.

Table 2. Research Hypotheses and Statistical Tests

Research Hypothesis	Statistical Test
Average Completion of Critical Thinking Skills (Min 75)	One Sample t-Test
Proportion Complection of Critical Thinking Skills (Min 75%)	One Sample z-Test
Improvement Difference of Critical Thinking Skills	Independent Sample t-Tes

In addition to testing effectiveness, after the product was implemented, an assessment of student response to the use of teaching materials was conducted. To test student response, the researcher calculated the overall percentage score of each student's questionnaire, then converted it into a pie chart using the formula used by Arifin (2013).

From these calculations, the percentages are categorized based on Table 3. Based on the table, a product is said to have a positive response if it meets at least the “very good” criterion or at least the “good” criterion. In addition to the effectiveness test, after the product is implemented, an assessment of students' responses to the use of instructional materials is conducted. To test students' responses, the researcher calculates the overall percentage score of each student's questionnaire, then converts it into a pie chart using the formula employed by 85%. If it does not meet the requirements, improvements must be made and then reassessed.

Table 3. Student Response Level Criteria

Score Percentage	Eligibility Criteria
$1\% \leq P \leq 50\%$	Unsuitable
$50\% \leq P \leq 70\%$	Quite Adequate
$70\% \leq P \leq 85\%$	Suitable
$85\% \leq P \leq 100\%$	Very Worthwhile

3. Results & Discussions

The research was conducted by developing STEM-based mathematics teaching materials to improve critical thinking in the CBL model for seventh-grade junior high school/MTs students. The teaching materials discuss single-variable linear equations and include critical thinking skill indicators so that students can be trained to solve problems. The research results include the outcomes of the instructional material development process, the results of the instructional material feasibility test, the results of the instructional material readability test, the results of the instructional material effectiveness test, and the results of student responses to the instructional material. The instructional material was developed using the Research and Development (R&D) method with the 4D model developed by Thiagarajan. This model consists of four development stages: definition, design, development, and disseminate. However, in this study, the process was carried out only up to the development stage. The results obtained at each stage are described as follows.

The define stage is the first stage to be carried out. This stage aims to identify and describe the needs that need to be developed in the learning process and to gather information related to the instructional materials that will be developed. The results of the define stage form the basis for the development of instructional materials. This stage includes initial analysis, learner analysis, concept analysis, task analysis, and the formulation of learning objectives. The following is a description of the stages involved.

The initial-final analysis aims to analyze the problems that occur during the learning process in the classroom, which underlies the need for the development of teaching materials at SMP Negeri 3 Karanganyar. Based on an interview on November 12, 2024, with one of the mathematics teachers at SMP Negeri 3 Karanganyar, it was stated that the response of students in class VII C in receiving learning was still less than optimal. Therefore, the researcher obtained information on the needs that need to be developed in teaching materials. Based on the existing problems, there is a need to develop STEM-based mathematics

teaching materials to enhance critical thinking in the Challenge-Based Learning model with the assistance of Padlet.

Next, student analysis, task analysis, concept analysis, and formulation of learning objectives were carried out at the definition stage. The above analysis included a discussion of the material to be covered, namely Single Variable Linear Equations for seventh grade students. Based on the independent curriculum, this material is in line with learning outcomes at stage D for junior high school students. This analysis is based on alignment with critical thinking skill indicators as activities for task analysis. Following this, learning objectives were formulated based on the previous analyses. The description of learning outcomes in the learning objectives implemented in the teaching materials, taking into account the material on critical thinking skill indicators, can be seen in the table below.

Table 4. Learning Objectives

Learning Objectives
After participating in learning activities with the Challenge Based Learning learning model with the help of ICT to foster an independent attitude, working together, and reasoning critically, it is expected: 1. Students can understand concepts and design models of one-variable linear equations precisely and according to mathematical rules. 2. Students can solve contextual problems related to one-variable linear equations with the correct solution steps. 3. Students can design mathematical models of one-variable linear inequality precisely and logically. 4. Students can solve contextual problems related to one-variable linear inequality with the correct solution steps.

The teaching materials prepared consist of four learning objectives. This considers the functions of learning objectives in learning, including: 1) determining the direction of learning 2) the basis of selection and methods and media 3) evaluation guidelines and 4) increasing the effectiveness of learning (Albina & Pratama, 2025). In addition to considering the function of the learning objectives, the preparation of learning objectives is designed so that learning is formulated based on the basic competency standards that have been set (Amanda & Albina, 2024).

The planning stage is carried out to prepare teaching materials to be developed. At this stage, the researcher designs the design of teaching materials to be consulted with the supervisor before validation. This stage includes the preparation of criterion-test construction, media selection, format selection, and initial design. In this study, the test was used to measure students' critical thinking skills. The preparation of tests in this study was carried out with a trial to measure the validity, reliability, differentiating power of the questions, and the level of difficulty of the questions. The test trial was carried out to the trial class. Class VIII I SMP Negeri 3 Karanganyar was chosen as a trial class. Then the researcher conducted a question item analysis on the results of the critical thinking test of grade VII students.

Based on the results of the validity, reliability, difficulty level, and discriminating power tests conducted, it was found that there were four questions that would be used in the research class. However, based on the advice of experts and practitioners, only three questions were used, taking into account the time required to complete the test. This was in line with the constraints encountered by the researcher during the trial, where students did not finish the questions due to lack of time. Therefore, based on this, the researcher only used three questions by removing question number 4. The removal of question number 4 was considered because the high difficulty level of the question could cause students to be reluctant to answer it (Magdalena *et al.*, 2021). And considering the clarity and construction of questions that confuse students, if the questions confuse students, they choose not to answer (Putro *et al.*, 2021). In addition, based on the researcher's suggestions and observations, number 4 was removed due to time constraints. Time constraints were one of the factors that affected the implementation of the instrument trial, which meant that students were unable to complete all the questions given, even though the questions were declared valid and reliable (Jaya *et al.*, 2020).

Furthermore, teaching materials are developed by paying attention to the preparation of books based on BNSP (2006). The final result of this product is a draft of 1 teaching material with STEM nuances to improve critical thinking in the Padlet-assisted Challenge Based Learning model. Some of the teaching materials that will be tested to experts and practitioners can be seen in the following figure 3.

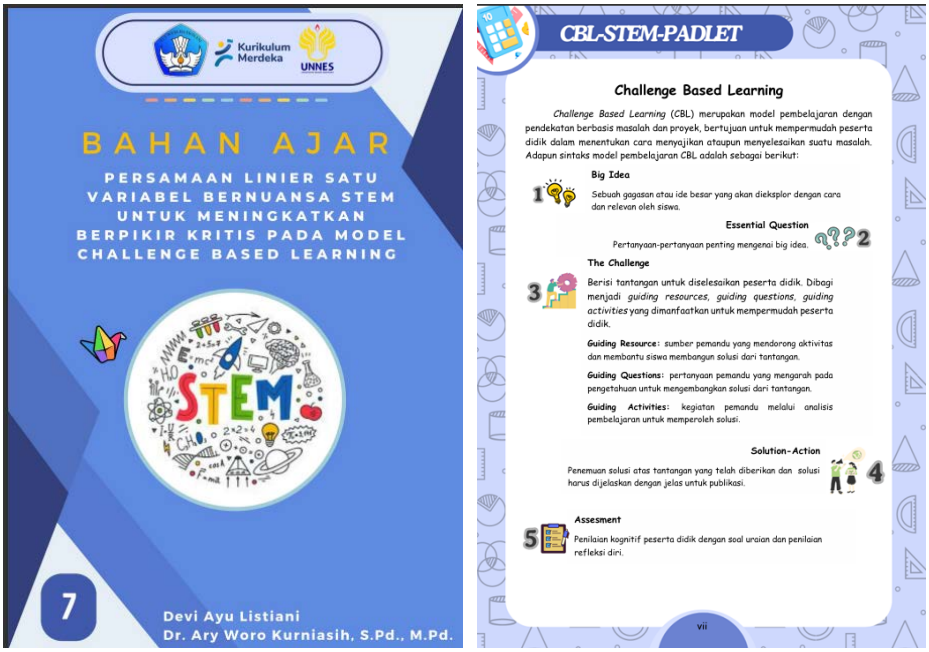


Figure 3. Preliminary Draft of Teaching Materials

The next stage is the development stage where the draft that is prepared is tested for feasibility, readability, effectiveness and student response. A feasibility assessment is carried out by two experts and two practitioners to ensure that the developed product is feasible to be implemented in the research to be carried out. The readability assessment was carried out by grade VIII students of SMP Negeri 3 Karanganyar who had received material to ensure that the product received a positive response and was easy to understand for implementation. Effectiveness testing was carried out after the implementation of teaching materials with data from the pretest and posttest scores of the experimental class and the control class. This test is carried out to ensure that the developed product meets the achievement of the effectiveness indicators that have been set previously. Next is the test of students' response to the teaching materials, the assessment is carried out to find out the response and perspective of the students after using the developed teaching materials.

The assessment of the feasibility was carried out by two mathematics education lecturers (A) and two mathematics teachers (P). The results obtained are used as a recapitulation of the results of the feasibility test of teaching materials in table 5 with an average percentage of feasibility of 91.34% with very feasible criteria, meaning that teaching materials with STEM nuances to enhance critical thinking on the Padlet-assisted Challenge Based Learning model can be implemented in learning. The following is a recapitulation table of the results of the feasibility test.

Table 5. Recapitulation of Expert and Practitioner Feasibility Test Results

Assessment	Feasibility (%)				
	Contents	Presentation	Language	Learning innovations	Final Results
A1	85.7	81.67	91.07	89.28	86.4
A2	88.09	85.24	87.50	85.71	87.28
P1	92.86	98.34	94.64	96.43	95.18
P2	97.62	95	96.43	96.43	96.49
Average	91.07	90.06	92.41	91.96	91.34

Based on the results of the overall feasibility test, the final score was obtained 91.34% with a very decent category. It can be seen that the teaching materials developed have an average overall feasibility test score 91.34% which is a very feasible criterion. The details of the acquisition of the four aspects are as follows: based on the feasibility aspect, it can be seen that the feasibility aspect of the content has a final score percentage 91.07% which includes the criteria of very feasible, the feasibility aspect of the presentation has a final score percentage 90.06% which includes the criteria of very feasible, linguistic

feasibility has a percentage of final score 92.41% which includes very feasible criteria, and the feasibility aspect of learning innovations has a percentage of final score 91.96% yang included in the criteria is very feasible. The results of this study are in accordance with previous research. So it can be concluded that in this study, STEM-nuanced teaching materials in the Challenge Based Learning model are suitable for use in learning.

After the feasibility test is carried out, a readability test of the teaching material is carried out which aims to find out whether the teaching material can be understood by students or not. The readability test of this teaching material was distributed to thirty students of VIII I SMP Negeri 3 Karanganyar in the form of a readability test questionnaire. Preparation of a readability test questionnaire based on the readability test instrument in the research Dewi *et al* (2020) which consists of four criteria, namely readability, ease, attractiveness, and comprehension with ten statements. The analysis of the data from the readability test was carried out using the Cochran Test.

The readability test of this study was analyzed using the Cochran Test. The hypothesis used in this readability test is as follows.

H_0 : There is no difference of opinion among students regarding their understanding of STEM-nuanced mathematics teaching materials in the Challenge Based Learning model on one-variable linear equation material.

H_1 : There are differences of opinion among students regarding their understanding of STEM-nuanced mathematics teaching materials in the Challenge Based Learning model on one-variable linear equation material.

The level of significance used is $\alpha = 0{,}05$ and the test criteria for this readability test are if $Q_{count} \geq$ critical price Chi-Squares for a certain level of significance and $db = k - 1$ so H_0 rejected and H_1 Accepted. Based on the results of the Cochran test, a score of $Q_{count} = 6.0967 < \mathcal{X}^2_{(0,05;29)} = 16.919$. Thus, the criteria obtained are H_0 Accepted. This shows that there is no difference of opinion among students regarding their understanding of STEM-nuanced mathematics teaching materials in the Challenge Based Learning model on one-variable linear equation material.

Based the average understanding of students of mathematics teaching materials reaches 95.5% of the ten items, the average percentage gain is only used as support for the calculation results Q_{count}. Descriptively, the readability test of teaching materials obtained an average percentage of 95.5%. These results prove that the teaching materials are easy for students to understand well.

After obtaining a valid and usable learning tool, a trial was carried out to determine the effectiveness of teaching materials in improving students' critical thinking skills. The test was carried out with one-variable linear equation material. In this trial, there were 6 meetings in the experimental group. The first meeting was held as a pretest, the second meeting on the implementation of teaching materials in activity 1 related to the concept of Linear Equation of One Variable, the second meeting on the implementation of teaching materials in activity 2 related to the completion of Linear Equation of One Variable, the fourth meeting on the implementation of teaching materials in activity 3 related to the concept of Linear Inequality of One Variable, the fifth meeting on the implementation of teaching materials in activity 4 related to the completion of Linear Inequality of One Variable, and the sixth meeting was held posttest. After conducting the trial, pretest and posttest data from the control group and experiments were obtained which were then analyzed to ensure that the product implementation was effective. The effectiveness indicators in this study consisted of (1) the average achievement of completeness, (2) the proportion of achievement of completeness, and (3) the difference in the improvement of critical thinking skills.

Table 6. Results of the Statistical Test of Average Completeness Achievement

Account	Result
$\bar{x}$	82.07
μ_0	75
s	8.329
n	29
t_{count}	4.57

Based on the results of the calculation obtained $t_{count} = 4.57$ while $t_{table} = 1.701$. It can be seen that $t_{count} > t_{table}$ so H_0 rejected. H_0 rejected, meaning that the average posttest results of the critical thinking ability of students in the experimental group have reached the Minimum Completion Criteria (MCC). 75. However, it can be concluded that the implementation of the product has achieved significant completeness on average.

Table 7. Results of the Statistical Test on the Proportion of Completeness Achievement

Account	Result
x	26
π_0	0.75
n	29
z_{count}	1.823

Based on the results of the calculation obtained $z_{count} = 1.823$ while $z_{table} = 1.64$. It can be seen that $z_{count} > z_{table}$ so H_0 rejected. H_0 rejected, meaning that the percentage of students in the experimental group who have completed critical thinking skills has reached 75%. Thus, it can be concluded that the implementation of the product has reached a significant proportion of completenes.

Table 8. Statistical Test Results of Difference in Improvement

N-Gain	n	$\bar{x}$	s^2	t_{table}	t_{count}
Experimental Group	29	0.757	0.1186	1.672	7.0845
Control Group	29	0.54			

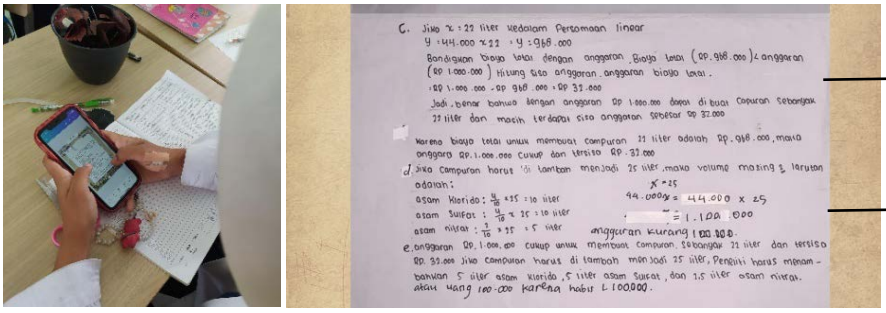
Based on the results of the calculation obtained $t_{count} = 7.0845$ and $t_{table} = 1.672$. It can be seen that $t_{count} > t_{table}$ so H_0 rejected means that the average increase in the critical thinking ability of students in the experimental group is more than the average increase in the critical thinking ability of students in the control group. Thus, it can be concluded that the improvement in critical thinking skills of the experimental group was significantly greater than the improvement of critical thinking skills of the control group.

Student learning activities use teaching materials that have been carefully developed. Students read the teaching materials following the syntax of the Challenge Based Learning model, then scan the barcode to complete the challenge. Each group receives a different challenge related to STEM.

Figure 4. Use of Teaching Materials during Learning

There are several syntaxes that must be carried out by students. Where the syntax is interconnected. Learners complete the challenge with a project to make a poster or video explanation. After learners complete a series of syntax in CBL, learners upload projects from the challenge to the Padlet media that has been provided.

The next activity is students completing the project by utilizing the editing application. Here students are making posters with the Canva application, students divide the tasks in their group members. Students are active and creative in making posters and completing this challenge.

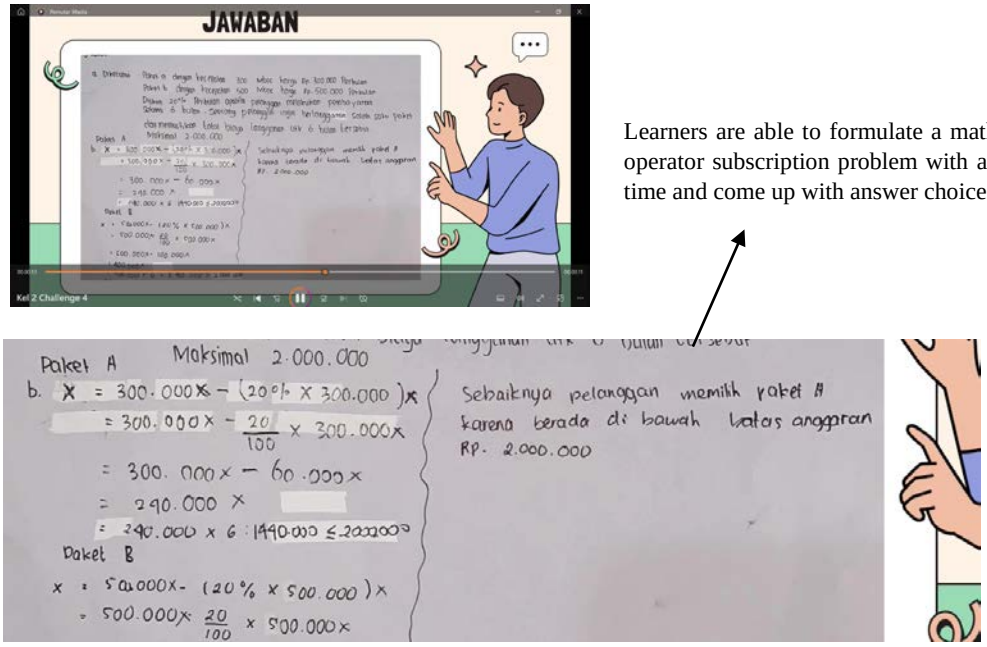


Completion challenge is able to apply linear equation of one variable.

Poster making from students' challenge completion

Figure 5. Poster Making Learning Activities

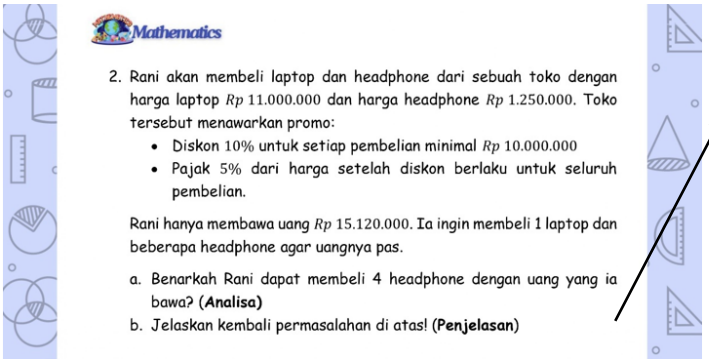
Here is one of the learner animation videos that has been uploaded on the media padlet. The poster is a combination of challenge and project where challenge questions related to STEM and critical thinking are given that students must solve. Then learners make an animated video of the answers that have been solved earlier. The following display of student results is presented in Figure 6.



Learners are able to formulate a mathematical model of the operator subscription problem with a specified discount and time and come up with answer choices.

Figure 6. Some of the Posters and Videos of the Students' Challenge Results

Presented one of the STEM questions from the teaching materials developed in this study. The following presented STEM critical thinking questions compiled in teaching materials can be seen in Figure 7. Next, the syntax included in this teaching material, with the challenge-based learning model includes several syntaxes including Big Idea, Essential Question, Challenge, Guiding Resource, Guiding Question, Guiding Activity, Solution Action, and Assessment. Due to page limitations, the following will be presented and explained one of the syntaxes of CBL, namely Challenge. In Figure 8, the Challenge syntax is presented in the developed teaching materials. Next, the syntax included in this teaching material, with the challenge-based learning model includes several syntaxes including Big Idea, Essential Question, Challenge, Guiding Resource, Guiding Question, Guiding Activity, Solution Action, and Assessment. Due to page limitations, the following will be presented and explained one of the syntaxes of CBL, namely Challenge. In Figure 8, the Challenge syntax is presented in the developed teaching materials.



Learners are asked to determine the truth. With the discount and tax available can Rani buy 4 headphones with the money she brought?

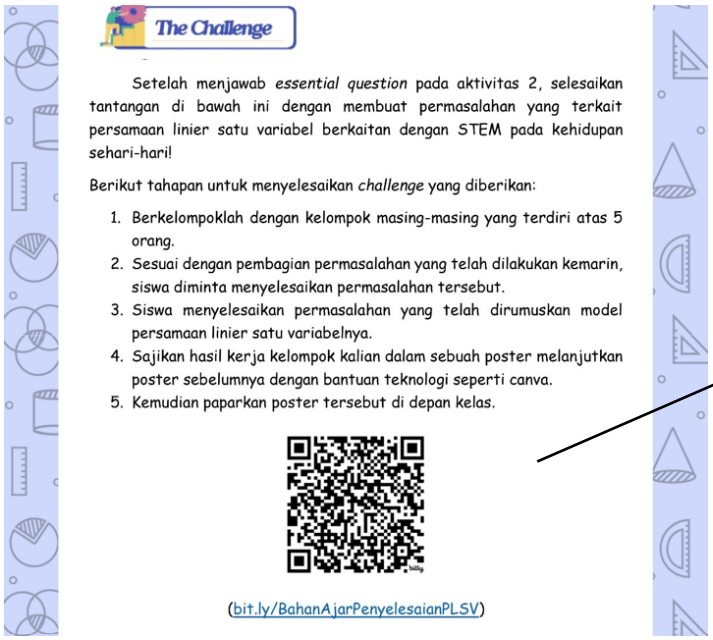
Rani will buy a laptop and headphones from a store at the price of a laptop Rp 11.000.000 and headphone prices Rp 1.250.000. The store offers promos:

- Discount 10% for every minimum purchase Rp 10.000.000
- Tax 5% from the price after the discount applies to the entire purchase.

Rani only brought money Rp 15.120.000. He wants to buy 1 laptop and some headphones so that the money is right.

a. Is it true that Rani can buy 4 headphones with the money she brings? (**Analysis)**
b. Explain the above problem again! (**Penjelasan**)

Figure 7. STEM critical thinking questions in teaching materials



Learners complete the challenge by opening the available Padlet web, then working on the challenge questions according to their respective divisions. the completion of the challenge is presented in the form of a poster that is edited with the application according to the creativity of the learners. Furthermore, it is uploaded on the Padlet web provided.

After answering the *essential question* in activity 2, solve the challenge below by creating a problem related to the linear equation of one variable related to STEM in everyday life!

Here are the steps to complete *the challenge* given:

1. Group with a group of 5 people each.
2. In accordance with the division of problems that had been carried out yesterday, students were asked to solve the problems.
3. Students solve problems that have been formulated with a one-variable linear equation model.
4. Present the results of your group's work in a poster continuing the previous poster with the help of technology like Canva.
5. Then display the poster in front of the class.

Figure 8. Syntax of Challenge Based Learning included in Teaching Materials

The learning process of the Challenge Based learning model combines aspects of problem-based learning, project and contextual learning (Nawawi, 2016). The syntax above is a challenge syntax where the challenge given is a project that is done in groups. Learners seem interested in project activities and solving problems in everyday life. They feel challenged by the problem then done in the form of a project that increases cooperation between friends to make it lighter. Before working on the challenge, learners are given a Guiding Resource which contains guiding material to determine the solution to the challenge given. As a support material, learners are given a Guiding Question which contains guiding questions to sharpen and develop the thinking of learners so that it makes it easier to answer challenges. In Guiding Resource, students pay close attention to the researcher's explanation, several times the researcher threw questions to students, some students were not able to answer correctly. After re-explaining, learners are able to understand and answer questions correctly. The project results of the challenges produced by learners are less varied, this is because the groups work together to complete the project quickly due to time constraints. The results of their posters are uploaded on the padlet provided by the teacher. The challenges provided are able to hone students' critical thinking skills in all the skills used. Challenges 1 and 3 focus on interpretation and analysis skills while challenges 2 and 4 focus on evaluation, inference, and explanation skills. The challenge syntax provides learners with real challenges and forces them to think analytically and reflectively in solving them. In line with the research data Maylani et al (2017) which proves that the application of challenge syntax is effective in improving the quality of critical thinking of students.

The other syntaxes in the CBL model can help students develop critical thinking skills. The following is an explanation of the activities of each syntax of Challenge Based Learning combined with STEM. Learners are given a Big Idea that contains an overview of the material to be learned with STEM nuances. Essential Question, in this syntax learners will be invited to change the question on essential into a challenge. Learners are able to formulate equations from the Big Idea given, in activities 1 and 2 learners still have to be explained slowly if given questions that are more difficult than the Big Idea. However, in activities 3 and 4 learners are able to answer several examples of problem development from the Big Idea problem.

Guiding Question 1 and 3 are done together during learning, but in Guiding Question 2 and 4 the researcher appoints several students to work forward, students have difficulty in evaluating. Learners have not been able to capture the information provided clearly, this is due to changes in question information from questions on analysis and evaluation questions, students are still focused on analysis questions. Furthermore, students are given Guiding Activity to actively search for problems and solutions from various sources (internet, books, etc.) in accordance with the learning objectives. All of the above activities can be accessed and uploaded through the padlet developed by the researcher. Learners can also conduct discussions and respond to each other on the padlet media provided if they experience difficulties during learning outside of class hours. Some groups still write the same learning resources and lack of communication between groups due to time constraints.

After completing the above activities, learners discuss the challenge with their respective groups to determine the solution and complete the project. Learners solve the problem carefully, there are learners who have difficulty working on the challenge and ask to be helped to be directed, this happens because there are differences in learners' perspectives on the problem. After working on the problem, learners make posters. Learners use canva media to complete the challenge of making posters, but the results of the posters are almost the same from various groups because learners imitate the methods of other groups, so that the posters produced are less varied.

Once the challenge is complete, learners implement the solution by presenting it in front of the class. When the presentation group of other groups pay close attention, learners ask necessary questions such as “why is the formula obtained like that?” or “what if this one is operated first, will the result be the same?”. The presentation group answered with a fairly clear and precise explanation. However, there are some groups that are still less active in the presentation. After that, students are given a reflection that contains problems in everyday life that are given STEM nuances to do independently as an exercise. From the series of activities above, students are required to be active in class and can develop their critical thinking skills supported by the results of the students' work displayed. A series of CBL syntaxes proved relevant to the research Nawawi (2016) which states that CBL syntax such as Challenge, Guiding Question, Guiding Activities, Guiding Resources, and Solution as a form of contextual learning directly contributes to the development of students' critical thinking skills.

The results of product implementation show that students are able to achieve achievements such as (1) achievement of average completeness, (2) achievement of proportional completeness, and (3) improvement of different critical thinking skills. Thus, the implementation of STEM nuanced teaching materials in the

Challenge Based Learning model is effective in improving students' critical thinking. Similar research can be conducted by applying learning styles in depth and maximizing. The use of Padlet media can be actively used in discussions to hone analysis and inference skills. Padlet is not just uploading the results of students' work, but must be used as a medium for discussion and communication between students and students, students and teachers to argue so that inference and evaluation skills are increasingly developed.

After the effectiveness test, the researchers then conducted a student response test to 32 students from the experimental group, namely class VII C SMP Negeri 3 Karanganyar. This was done to find out the response of students to the teaching materials developed by researchers. The following diagram of the results of the students' questionnaire is shown in Figure 9.

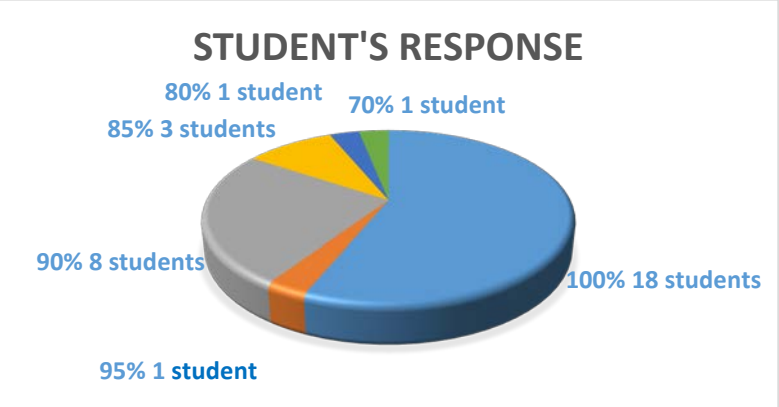


Figure 9. Student Response Results

The results of the students' responses were carried out to 32 students in class VII C SMP Negeri 3 Karanganyar. The class is an experimental class in the research conducted. Class VII C received treatment by being given learning using Linear Equation of One Variable teaching materials with STEM nuances on the CBL model with the help of a padlet application. The results of the student response test to the developed teaching materials stated that the score percentage with the criteria was very good. It can be concluded that Linear Equation of One Variable teaching materials with STEM nuances in the 94% Challenge Based Learning model with the help of the padlet application received a very good response from students in grade VII C SMP Negeri 3 Karanganyar. The results of student responses carried out are relevant to previous research. Research Ash-Showy *et al* (2022) related to the development of integrated comparative teaching materials, challenge based learning with a STEM approach to students' critical thinking skills, showing the results of student responses to teaching materials of 89%.

4. Conclusion

Based on the results of the research and discussion that has been described above, the conclusion of the teaching materials of the One Variable Linear Equation with STEM nuances to improve critical thinking on the Challenge Based Learning model has been produced (1) the teaching materials produced meet the feasibility level with the very feasible category based on the results of the feasibility test reviewed from the feasibility aspects of content, presentation, language, and graphics with a percentage of $\mathbf{91.34}$; (2) Teaching Materials Get Calculations $\boldsymbol{Q_{count} = 6.0967 < \chi^2_{(0,05;29)} = 16.919}$ categorized as easy to understand by students; (3) Linear Equation of One Variable mathematics teaching materials with STEM nuances with a Challenge Based Learning model are effective in increasing critical thinking seen from the five hypotheses; and (4) teaching materials get a positive response from students with a percentage of $\mathbf{94}$% show that the teaching materials developed are categorized as suitable for use in mathematics learning. Similar research can be done by applying learning styles in depth and maximizing. The use of Padlet media can be actively used in discussions to hone analysis and inference skills so that students' skills develop.

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