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Improving Critical Thinking Skills through Mathematics Textbooks Integrated with a Challenge-Based Learning Model in a STEM Context Assisted by Quizizz Application

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Abstract. *The limitations of textbooks that focus on developing critical thinking skills are the urgency of this research. Developing a mathematics textbook integretaed with the challenge-based learning model in STEM Context, assisted by the Quizizz application, is an option to answer this challenge. Development research using the 4D model has been conducted with a focus on creating a product that is feasible, easy to understand, effective in enhancing critical thinking skills, and receives a positive response from students. Data were collected using interview techniques, questionnaires, and tests, which were then analyzed both descriptively and quantitatively, as well as through several parametric statistical tests. The results show that the mathematics textbooks are feasible as seen from the average score of 92.66%, easy to understand as seen from the average score of 98%, effective in improving critical thinking skills as seen from the achievement of the research hypothesis and has a good response from students as seen from the average score of 94.6%. Further implementation, as a form of dissemination and adoption, needs to be carried out by teachers in the classroom so that the challenge of developing critical thinking skills can be appropriately addressed.*

Keywords*: challenge-based learning, critical thinking skill, quizizz application, STEM context, textbooks*

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Introduction

Critical thinking skills are among the essential skills that students must master in the 21st century. Current education is highly dependent on the development of science and technology, which requires students to think critically and creatively. Critical thinking skills are essential for life, as they are included in one of the objectives of mathematics lessons: to develop logical, analytical, systematic, critical, and creative thinking skills in students (Depdiknas, 2006). Critical thinking skills refer to cognitive abilities that involve interpreting, analyzing, evaluating, inferring, explaining, and self-managing, which are then used as indicators to measure critical thinking skills in this study (Facione, 2011; Facione & Facione, 2007). Thus, the development of critical thinking skills becomes urgent in this research.

PISA, an international survey of students' mathematics performance, categorizes levels of mathematics ability into 1c, 1b, 1a, 2, 3, 4, 5, and 6 (OECD, 2023). The results of PISA

2022 show that no students from Indonesia achieved levels 5 and 6. In the document, level 5 is a level where students can develop and work with models for complex situations that require systematic and planned problem-solving strategies. Level 6, on the other hand, expects students to be able to solve abstract problems, demonstrate creativity in developing solutions, and think critically. Levels 5 and 6 in PISA are related to the Higher Order Thinking level, which requires critical thinking skills. Thus, the critical thinking skills of students in Indonesia are still relatively low.

Facts in schools also show the same results. A preliminary study, conducted through teacher interviews and the measurement of critical thinking skills, was undertaken at a school in Indonesia. The results of interviews with one of the mathematics teachers indicated that students still struggle with critical thinking questions. This is supported by the results of measuring critical thinking skills, which were conducted by administering two critical thinking skill test items on algebraic material to 8th-grade students. The results indicate that the critical thinking skills of 8th-grade students are relatively low, with an average score of 28.69 out of a maximum of 100. Based on these results, the critical thinking skills of 8th-grade students are still low.

Efforts to improve students' critical thinking skills include the development of innovative learning resources. Learning resources have a significant influence on the sustainability of the learning process because they are one of the components of the facilities and infrastructure in learning (Azani et al., 2024). The learning resources included books, printed materials, such as magazines and bulletins, as well as learning media that present messages or information that can be seen, including radio, television, and hardware (Suhirman, 2018). Learning resources serve as references for various teaching materials that help students understand concepts or ideas during the learning process. Learning resources commonly used in mathematics include teaching materials. Teaching materials are something used by teachers or students to facilitate the learning process (Kosasih, 2020).

Mathematics learning must be able to keep pace with developments in the era of globalization, aligning with existing trends such as STEM-based learning. STEM is an approach that combines several disciplines, namely Science, Technology, Engineering, and Mathematics (Acar et al., 2018; Hasanah et al., 2020). STEM can form human resources who can think critically, logically, and systematically, enabling them to face global challenges. STEM-based learning, which integrates its four components, can produce student thinking activities that are useful for helping to develop students' critical thinking skills, characterized by the ability to solve problems, make decisions, analyze assumptions, evaluate, and conduct investigations (Khoiriyah et al., 2018). One implementation of STEM in mathematics learning

is the provision of problem contexts in real-world problems, known as STEM Contexts (Ardiansyah & Asikin, 2023). The development of mathematics teaching materials with a STEM Context is essential to improve students' critical thinking skills.

In preparing teaching materials, an appropriate learning model is needed. The Challenge-Based Learning model is an option that can be integrated into teaching materials alongside STEM to enhance critical thinking skills. This model is a new teaching model that combines important aspects such as problem-based learning, project-based learning, and contextual learning, which focuses on fundamental problems in everyday life (Nawawi, 2016). As a learning framework that provides collaborative opportunities for students to find the solution to the challenge given, students will be faced with problems or projects that focus on learning by doing activities (Baloian et al., 2004; Johnson et al., 2009; Nichols et al., 2016). By considering this, the Challenge-based Learning model can be implemented to optimize critical thinking skills, which are still not optimal in Indonesia.

The development of teaching materials to optimize critical thinking skills can be maximized by applying Information and Communication Technology (ICT). One of the ICTs that can be used to help learning is the Quizizz application. Quizizz is a web tool in the form of an interactive quiz game that can be used in classroom learning to make it more fun (Mulyati & Evendi, 2020). The use of Quizizz media or educational game websites in learning can help students develop critical thinking, and help them capture students' memories (Arif et al., 2022).

Considering the importance of students' critical thinking skills, efforts are needed to develop these skills. The innovations explained can be combined into a single effort to develop students' critical thinking skills. The combination of CBL, STEM Context, and Quizizz in textbooks will help students develop their critical thinking skills. Based on this background, this article aims to develop mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by Quizizz, to improve students' critical thinking skills. The focus of this study is to develop a product that is feasible, easy to understand, effective in improving critical thinking skills, and has a positive response. In developing this teaching material, the system of linear equations in two variables used is suitable for 8th-grade students.

Several previous researchers have conducted related studies. Nawawi (2016) has studied the implementation of the Challenge-Based Learning model in empowering critical thinking skills. Ritonga and Zulkarnaini (2021) have studied the application of STEM in improving critical thinking skill. Arif et al., (2022) have studied the use of Quizizz in

developing critical thinking skills. The literature reveals the implementation of each topic on critical thinking skills. However, the combination will be discussed in this research.

Method

Development research using a 4D model, consisting of the define stage, design stage, develop stage, and disseminate stage, has been conducted to develop mathematics textbooks (Thiagarajan et al., 1974). At the define stage, several things related to the reasons for developing the product, materials, and defining the learning objectives to be achieved will be described. At the design stage, the textbook is designed to obtain a product prototype. At the develop stage, a feasibility assessment, readability assessment, small-scale implementation to test effectiveness, and student response assessment will be carried out. The dissemination stage will be carried out by distributing the product. These activities are comprehensively integrated as presented in the product development flow in Figure 1.

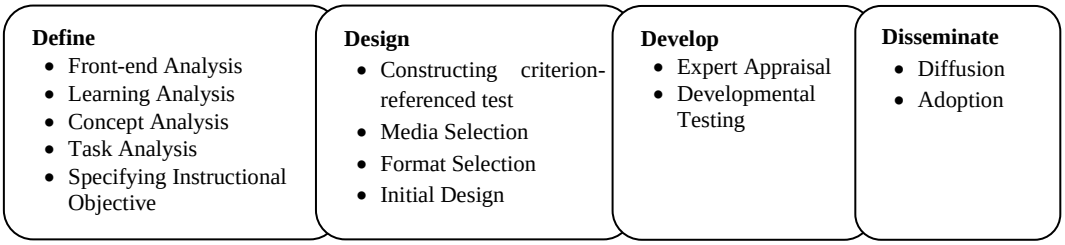

Figure 1. Flow of textbooks development (Thiagarajan et al., 1974)

In developmental testing, experimental research with the Pretest-Posttest Control Group Design is presented in Table 1. This activity was conducted to ensure that the implementation of statistically tested textbooks was effective in enhancing students' critical thinking skills. The effectiveness criteria in this study include (1) achievement of average completeness, (2) achievement of proportion completeness, (3) average difference for experiment and control, (4) difference in proportion for experiment and control, (5) achievement of increased critical thinking skills, and (6) difference in increase for experiment and control (Ardiansyah et al., 2024).

Table 1. Design of textbooks implementation

Sample	Pretest	Treatment	Posttest
R	O_1	X	O_2
R	O_3	Y	O_4

(Sugiyono, 2017)

Note: R = Random sampling; X = Treatment for the group that uses textbooks; Y = Treatment for the group that does not use textbooks; O_1= Pretest for a class that uses textbooks; O_2= Posttest for the group that uses textbooks; O_3= Pretest for classes that do not use textbooks; O_4= Posttest for the group that does not use textbooks.

The study was conducted over a period of three months at SMP Negeri 1 Boja, Kendal Regency, Jawa Tengah. The population in this study consisted of all 8th-grade students at SMP Negeri 1 Boja, which comprised eight classes. The sample in this study was selected by random sampling for two classes. Class 8G was selected as the experimental group, and Class 8H was selected as the control group, each consisting of 30 students.

In this study, the data that needs to be collected is interview data, which is qualitative data, data on the feasibility of teaching materials, data on the readability of teaching materials, data on critical thinking ability tests, and data on the results of student responses to teaching materials, which is quantitative data. Interview data were collected through interviews with teachers and students to gather information about the problems faced by the school. Data on the feasibility of teaching materials, their readability, and student responses to these materials were collected using a questionnaire based on several related studies. The assessment of feasibility refers to the questionnaire developed by Ardiansyah et al. (2021). The assessment of readability refers to the questionnaire developed by Ardiansyah et al., (2021). The assessment of student responses to teaching materials refers to the questionnaire developed by Ardiansyah et al., (2024). The data sources included experts, practitioners, and students who had acquired knowledge of the two-variable linear equation system. Notes from the assessor were qualitative data for product improvement. Tests consisting of pretests and posttests were used to collect quantitative data on critical thinking skills. The data sources were students in the experimental and control groups.

The validity of the instrument in this study was assessed through expert and practitioner evaluations of the interview guidelines, questionnaires on eligibility, readability, and student responses to textbooks, as well as critical thinking ability tests. The validating experts were lecturers, and the validating practitioners were teachers. The validation results indicate that the instrument is valid, allowing for its use in data collection.

Table 2. Effective criteria and types of statistics

No	Criteria of Effectiveness	Types of Statistics
1	Achievement of average completeness	One sample t test
2	Achievement of proportion completeness	One sample proportion test
3	Difference in average for experiment and control	Two-sample t-test
4	Difference in proportion for experiment and control	Two-sample proportion test
5	Achievement of increased critical thinking skills	Paired sample t test
6	Difference in increase for experiment and control	Two-sample t-test

Quantitative descriptive analysis was conducted to draw conclusions related to feasibility, readability, and student responses. In this case, the product is considered feasible if the average feasibility score is at least 85%. The product is also considered easy to understand if the average readability score is at least 85%. The product is said to have a positive response if the average

student response is at least 85%. Simple statistical tests were also used to ensure that product implementation was effective in improving critical thinking skills. The description of the types of statistical tests and effectiveness criteria is presented in Table 2.

Results and Discussion

The Define Stage

Front-end Analysis is the initial activity for the Define stage. This activity aims to analyze problems that occur during the learning process. Interviews have been conducted with mathematics teachers and several students at partner schools. The results of this activity are (1) the learning resources available are only textbookss from the government and several video presentations from the internet, (2) the use of ICT has been implemented several times, (3) the availability of supporting facilities and infrastructure such as LCDs so that they can support the use of ICT in class, (4) the implementation of Challenge based Learning and STEM has never been done, (5) the curriculum applied is the 2013 Curriculum, and (6) the provision of HOTS questions has been carried out even though it has not led to critical thinking skills. From these results, it was determined that the development of mathematics textbooks as a supplement to learning resources for students' needs needs to be developed. The implementation of the Challenge, based on the STEM Context Learning model, can also be used to develop critical thinking skills. Thus, students' critical thinking skills can develop.

Learning Analysis is the next activity conducted to identify the form of learning outcomes, specifically the critical thinking skills of students. A preliminary study has been conducted in two classes at partner schools. Students were given two questions that measure critical thinking skills. The results showed that the average score obtained was 28.69 out of a maximum score of 100. This finding is supported by the interview results, which indicated that participants were less interested in learning mathematics in class. To address this problem, the Challenge, based on the STEM Context Learning model, can be implemented. The use of ICT, such as Quizizz, will also provide students with an interest in learning. If students are interested in learning, then their abilities will develop. Thus, students' critical thinking skills can develop.

Concept Analysis and Task Analysis are two key activities in the development of this textbook. Concept analysis activities focus on literature studies on the minimum achievements that students must master through Learning Outcomes. The learning outcomes to be achieved are in accordance with the Kurikulum Merdeka document in Phase D, where students can solve a system of two-variable linear equations through several ways to solve problems. Furthermore, task analysis activities are conducted by focusing on the skills that students will acquire. In this study, students are expected to develop their critical thinking skills in accordance with the

indicators outlined by Facione and Facione (2007). The focus on achieving concepts and tasks is the basis for subsequent activities related to developing learning objectives. After describing the learning outcomes and indicators of critical thinking skills that students will achieve, the Specifying Instructional Objective activity is carried out. The result of this activity is the formulation of learning objectives as presented in Table 3.

Table 3. Formulation of learning objectives

Learning Outcome	Learning Objectives
Students can solve systems of linear equations in two variables using several methods to solve problems.	Through the implementation of mathematics textbooks that integrated Challenge based on STEM Context Learning Model assisted by Quizizz Application, students can 1. analyze the concept of two-variable linear equations correctly, 2. create mathematical models of contextual problems related to two-variable linear equation systems correctly, and 3. think critically in solving contextual problems related to two-variable linear equation systems with various correct methods

The Design Stage

Table 4. Test instruments

Learning Objectives	Test Instrument
create mathematical models of contextual problems related to two-variable linear equation systems correctly	Cotton is a type of fabric that comes from cotton fibers. The cotton in question is not typically used for beauty products. Cotton fibers for cotton fabric are derived from cellulose, a natural fiber extracted from plants. Cotton fabric is one of the materials used for making pants, shirts, and other garments. Mrs. Tuti bought two cotton pants and three cotton shirts for a total price of $Rp690{,}000.00$. The next day, at the same shop, Mrs. Rani purchased a cotton pants and a cotton shirt in the same model, as well as one cotton pants and two cotton shirts, for a total price of Rp 420,000.00. Is it true that the system of linear equations of two variables from the problem becomes $\begin{cases} 2x + 3y = 420000 \\ x + 2y = 690000 \end{cases}$
think critically in solving contextual problems related to two-variable linear equation systems with various correct methods	Food can be stored in the refrigerator to prolong its shelf life, but some fruits are not suitable for refrigeration. This is because cold air can reduce the nutritional content of the fruit, including oranges and mangoes. Mr. Nugroho will hold a social gathering at his house, as he wants to serve his guests fruit without needing to refrigerate it. He has finally bought oranges and mangoes. Before buying fruit, Mr. Nugroho first asked his two neighbors, Mrs. Yuli and Mrs. Yanti, who had bought fruit at the same shop. Mrs. Yuli once bought 2 kg of oranges and 4 kg of mangoes for 80,000 IDR. Meanwhile, Mrs. Yanti once bought 3 kg of oranges and 2 kg of mangoes for 60,000 IDR. Mr. Nugroho only has 120,000 IDR. Is that enough money to buy 5 kg of oranges and 3 kg of mangoes at the same shop as Mrs. Yuli and Mrs. Yanti? If it is enough, does Mr. Nugroho still have any remaining money or change? If not enough, how much money should be added?

Constructing criterion-referenced tests is the initial activity of the Define stage. The results of formulating learning objectives, as presented in Table 3, are then developed into an appropriate test instrument. STEM Context is integrated into test development, and it is expected to provide direct learning experiences for students to become part of the problem-solving process being carried out (Ardiansyah & Asikin, 2023). Table 4 presents test

instruments that align with the learning objectives and STEM Context. Students are asked to think critically about solving the problems presented to them. For case 1, they are asked to ensure that the mathematical model presented is consistent with the given problem. For case 2, they are asked to ensure that the funds owned by the buyer are sufficient to purchase the known goods. In developing the test instrument, the critical thinking ability indicators used are based on the work of Facione (2011). In this case, students indirectly become problem solvers, making the learning process more meaningful. Through these activities, students' critical thinking skills can be developed and enhanced.

Media Selection and Format Selection are the main activities in this stage. Clearly, the media to be developed is a textbook assisted by the Quizizz application. The textbooks are developed with attention to the standard textbook format, including an introduction, content, and conclusion. Supporting information, including the CBL framework, STEM Context framework, Critical Thinking Skills Indicators, Learning Outcomes, and Learning Objectives, is presented in the introduction. The content of the material and learning activities, as outlined in the steps of the CBL model, is presented in the content section. Other supporting elements, such as a bibliography, glossary, and author profiles, are included in the conclusion section.

The Develop Stage

After obtaining a prototype in the **Initial Design** activity, the **Expert Appraisal** activity is carried out to ensure that the product being developed is feasible. The feasibility assessment is based on the BSNP assessment (2006) which was then adjusted according to Ardiansyah et al. (2021). The aspects assessed include the feasibility of content, presentation, language, and learning innovation. The results of the feasibility test are presented in Table 5 and Table 6.

Table 5. The results of feasibility test from the expert (%)

Assessment Aspects	A1	A2	A3	A4	A5	Mean
Content Feasibility	92.85	94.05	92.54	82.14	76.76	87.67
Presentation Feasibility	91.67	91.67	95	90	83.33	90.33
Language	96.42	91.07	91.1	89.29	80.36	89.65
Learning Innovation	85.71	92.86	96.43	89.29	78.56	88.57
Mean	92.54	92.54	94.3	86.24	80.7	89.26

As shown in Table 5, all five expert assessors assigned a feasible category, except for the chemical expert assessor (A5), who provided an assessment of 80.7%. These results indicate that the product developed has reached the feasible category. The final average result from the expert was 89.26%, which falls within a feasible category.

Table 6. The results of feasibility test from the practitioner (%)

Assessment Aspects	A1	A2	A3	A4	A5	Mean
Content Feasibility	100	100	88.1	100	94.05	96.43
Presentation Feasibility	95	100	93.3	100	93.33	96.33
Language	100	96.43	92.86	96.43	91.07	95.36
Learning Innovation	96.43	100	100	100	82.14	95.71
Mean	98.24	99.12	92.11	99.12	91.67	96.05

The same thing is also shown by practitioners through the results of Table 6. Based on those results, all practitioners gave an assessment with a feasible category with a final average of 96.05%. The overall average score from both experts and practitioners was 92.66%. This score qualifies as adequate. Therefore, the developed book is feasible and ready for implementation.

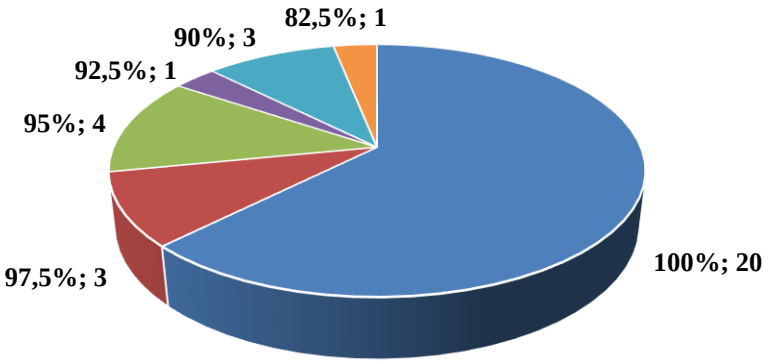

Figure 2. Readability test results of textbooks

In this activity, a readability assessment was also conducted by students who had studied the material on the system of linear equations of two variables—grade 9 students from SMP Negeri 1 Boja, who evaluated the textbook product. The assessment results are presented in Figure 2. The assessment results showed that 97% of students found the assessment easy to understand. The final score of this assessment was 98% with an easy-to-understand category. Thus, the textbooks are easy to understand for students.

After obtaining both the feasibility assessment and the readability assessment, improvements were made based on the input from the assessors. Some of the main improvements made were to enrich the material and contextual questions related to STEM Context and critical thinking skills. The concept of a linear equation system was also criticized by the assessors, who provided additional non-zero requirements for the material concept. Other notes, such as neatness in writing and consistency, were also conveyed by the assessors. This improvement is a follow-up to the Develop Stage, aiming to produce a product ready for implementation in class.

The next activity is Developmental Testing, where the product is implemented in class. The product implementation is carried out over three meetings to achieve the learning objectives that have been set. Before and after implementation, students are asked to work on pretest and posttest questions to measure their critical thinking skills. The test results will be analyzed statistically to determine the effectiveness of the product.

Table 7. The results of normality and homogeneity tests

Data	Sig. of KS Test	Data	Sig. of Levene Test
Posttest-Experiment	0.986	Posttest	0.169
Posttest-Control	0.619	Experiment-Control	
Pretest-Experiment	0.936	Pretest-Posttest Experiment	0.212
Gain-Experiment	0.986	Gain	0.368
Gain-Control	0.643	Experiment-Control	

Parametric statistics are used in this study to test the established hypothesis. Therefore, normality and homogeneity requirements are needed in this study. Table 7 6 presents the results of the normality and homogeneity of the related data. The results reveal that the research data is usually distributed and homogeneous. Thus, parametric statistical tests can be used to test the established hypothesis.

Table 8. Calculation results of the first hypothesis test

μ_0	$\bar{x}$	n	s	p_{value}
75	83.6	30	8.15	0.000

The first hypothesis test conducted was to determine whether the critical thinking skills of students who used mathematics textbooks that integrated the Challenge-based STEM Context Learning Model, assisted by the Quizizz Application, were able to achieve an average level of completeness. The average completeness referred to in this study is the average critical thinking skill, which reaches a minimum score of 75. The average achievement of at least 75 refers to the effectiveness criteria carried out by Ardiansyah et al., (2024). A one-sample t-test was conducted to answer the hypothesis. The average obtained is 83.6; mathematically, the score is more than 75. However, further statistical testing is needed. The results of the statistical test show that $p_{value} = 0.000 < 0.05$. Based on these results, it can be concluded that the average obtained is more than 75. Thus, the critical thinking skills of students who use mathematics textbooks integrated with the Challenge-based STEM Context Learning Model, assisted by the Quizizz Application, achieved a significant average completion rate.

Table 9. Calculation results of the second hypothesis test

π_0	x	n	p_{value}
0.7	27	30	0.001

The second hypothesis test was conducted to determine whether the proportion of students who used mathematics textbooks that integrated the Challenge-based STEM Context

Learning Model, assisted by the Quizizz Application, was able to achieve completion. The proportion of completion referred to in this study is the percentage of students who achieved a minimum score of 75% or higher. The achievement of the 70% proportion refers to the effectiveness criteria carried by Ardiansyah et al., (2024). A one-sample proportion test was conducted to answer the hypothesis. The proportion obtained is 0.9; mathematically, the score is more than 70%. However, further statistical testing is needed. The results of the statistical test show that $p_{value} = 0.001 < 0.05$. Based on these results, it can be concluded that the proportion obtained is more than 70%. Thus, the proportion of students who use the integrated mathematics textbooks, Challenge, based on the STEM Context Learning Model, assisted by the Quizizz Application, achieves significant completion.

Table 10. Calculation results of the third hypothesis test

	$\bar{x}$	n	s	p_{value}
Experiment	83.6	30	11.076	0.000
Control	77.83	30		

The third hypothesis test was conducted to determine whether the critical thinking skills of students who used mathematics textbooks that integrated Challenge-based STEM Context Learning Model, assisted by Quizizz Application, were greater than those of students who did not use the textbooks. This achievement indicator refers to the effectiveness criteria that have been carried out by Ardiansyah et al., (2024). A two-sample t-test was conducted to answer the hypothesis. The average critical thinking skill of students who used mathematics textbooks integrated with a challenge-based learning model in a STEM context assisted by the Quizizz Application, was 81.08, while the critical thinking skill of students who did not use the textbooks was 72.50. Mathematically, it has been proven; however, further statistical testing is needed. The results of the statistical test show that $p_{value} = 0.000 < 0.05$. Thus, the critical thinking skills of students who used mathematics textbooks that integrated Challenge-based STEM Context Learning Model, assisted by the Quizizz Application, were significantly greater than those of students who did not use the textbooks.

Table 11. Results of calculation of the fourth hypothesis test

	x	n	p	p_{value}
Experiment	27	30	0.9	0.000
Control	21	30	0.7	

The fourth hypothesis test was conducted to determine whether the proportion of students' completion using mathematics textbooks that integrated challenge-based learning model in STEM context, assisted by Quizizz Application, was greater than the proportion of students' completion who did not use the textbooks. This achievement indicator refers to the effectiveness criteria outlined by Ardiansyah et al., (2024). A two-sample proportion test was conducted to

test the hypothesis. The proportion of students completing the mathematics textbooks that integrated Challenge-based learning on a STEM Context Model, assisted by the Quizizz Application, was 90%. In comparison, the proportion of students who completed the course without using the textbooks was 70%. Mathematically, it has been proven; however, further statistical testing is needed. The results of the statistical test show that the p-value is < 0.05. Thus, the proportion of students' completion using the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by Quizizz Application, is significantly greater than the proportion of students' completion who did not use the textbooks.

Table 12. Calculation results of the fifth hypothesis test

	$\bar{x}$	n	s	p_{value}
Pretest	34.46	30	10.042	17.706
Posttest	83.6	30		

The fifth hypothesis test aimed to determine if using the Challenge-based STEM Context Learning Model with Quizizz improved students' critical thinking skills. Specifically, it compared the average posttest scores to pretest scores for students using the textbooks. The effectiveness criterion was based on this comparison by Ardiansyah et al., (2024). A paired-sample t-test was conducted to test this hypothesis. The calculation results are presented in Table 12. The average posttest score for their critical thinking skills was 83.6, while the average pretest score was 34.46. Mathematically, this has been proven; however, further statistical testing is still needed. The results of the statistical test show that $p_{value} = 0.000 < 0.05$. This means that the average posttest critical thinking skills of students who used mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by Quizizz Application, were higher than their average pretest critical thinking skills. Thus, there is a significant increase in critical thinking skills among students who use mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by Quizizz Application.

Further testing was carried out to determine the increase in critical thinking skills among students who used mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application. N-Gain was conducted to assess the extent of the increase in critical thinking skills. The results showed a 74% gain. Thus, the increase in critical thinking skills for students who used mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application, was categorized as high.

Table 13. Calculation results of the sixth hypothesis test

	$\bar{x}$	n	s	p_{value}
Experiment	0.74	30	0.15	0.000
Control	0.67	30		

The sixth hypothesis test assessed whether the increase in critical thinking skills was greater for students using the textbooks with the integrated with a challenge-based learning model in STEM context, assisted by quizizz application and Quizizz than for those who did not. A two-sample t-test was used to compare the average gains between the two groups, yielding results that indicated a significant difference by Ardiansyah et al., (2024). A two-sample t-test was conducted to answer the hypothesis. The calculation results are presented in Table 13. The average increase in critical thinking skills for students who used the mathematics integrated with a challenge-based learning model in STEM context, assisted by quizizz application, was 0.74, while the increase in critical thinking skills for students who did not use the product was 0.67. Mathematically, this has been proven; however, further statistical testing is still needed. The results of the statistical test show that $p_{value} = 0.000 < 0.05$The sixth hypothesis test showed that the increase in critical thinking skills was significantly higher for students using the Challenge-based STEM Context Learning Model with Quizizz compared to those who did not. The data confirms the intervention's effectiveness in enhancing critical thinking skills.

Based on the results of statistical calculations for each hypothesis, information was obtained that (1) the average completeness was achieved, (2) the proportion completeness was achieved, (3) the average critical thinking skill of students who used the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application was more than the average critical thinking skill of students who did not use the product, (4) the proportion of completeness for students who used the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application was more than the proportion of completeness for students who did not use the product, (5) there was an increase in the critical thinking skill of students who used the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application by 74% which is categorized as high, and (6) the increase in the critical thinking skill of students who used the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application was more than the increase in the critical thinking skill of students who did not use the product. Based on the results, the implementation of mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by the Quizizz Application, is efficacious in improving critical thinking skills.

After implementing mathematics textbooks that integrated the Challenge-based STEM Context Learning Model, assisted by the Quizizz Application, students were asked to assess how they responded to the product. Students in the experimental group completed the questionnaire, and the results of the assessment are presented in Figure 3. Seventy percent of the

respondents provided a very good response, with a minimum score of 86%. The remaining respondents gave a good assessment, with a minimum score of 80%. Upon further review, the final average of the student response assessment was 94.6%, indicating a very good category. Thus, students agreed to provide a very good response to the implementation of mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application.

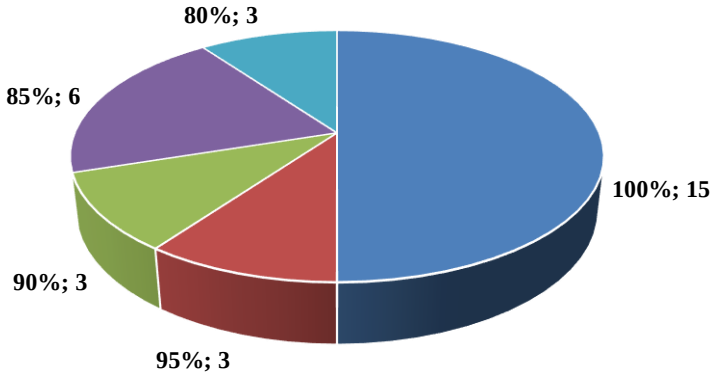

Figure 3. Student response test results of textbooks

The Disseminate Stage

Diffusion and Adoption activities are the last activities implemented in this study. At the Disseminate stage, the products that have been implemented and obtained notes on implementation in class and student response assessments are subject to final improvements. Furthermore, the final draft of this product is then disseminated to several schools in Kendal Regency. Adoption activities are also carried out in partner schools for other classes. Furthermore, the developed products are submitted as Copyrights. Several presentations of the textbooks are presented in Figure 4.

A comprehensive study of mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application, has been carried out from the Define, Design, Develop to Disseminate stage. The result of this study is a mathematics textbook integrated with a challenge-based learning model in STEM context, assisted by quizizz application and the Quizizz application. This approach is feasible, easy to understand, and effective in improving critical thinking skills, with a positive response from students. This finding cannot be separated from the study of related literature that supports this research activity.

Figure 4. Textbooks presentation

In-depth analysis starting from describing the problems experienced by partner schools, analyzing student needs, and reviewing the applicable curriculum to ensure that what will be targeted in this study has similarities with the expected completeness standards. The result of the Define stage is the formulation of learning objectives that serve as the benchmark for success, both for this research and for the students' learning process. The alignment of these objectives provides certainty of the research's success and ensures that students obtain their rights, enabling them to achieve their learning outcomes properly. In developing a product, it must be based on clear problems, clear and measurable goals, and goals that are in line with the learning process (Penuel et al., 2011).

After obtaining clear objectives, the Design stage is carried out. Formulating the instrument is the first step taken. STEM Context plays an important role in formulating the instrument. The STEM Context concept will provide students with meaningful learning opportunities because they will construct new knowledge through experiences gained in their daily lives (Ardiansyah & Asikin, 2023). Again, students are directly involved in the problem-solving process through tests integrated with STEM Context. The integration of critical thinking skill indicators also plays a role in ensuring that their abilities will be appropriately measured. Furthermore, the product is designed to yield the expected textbook prototype.

The finished prototype is then assessed; it was checked for feasibility. The developed product will be implemented in the classroom, so the certainty of feasibility must be met. The feasibility analysis is based on the learning resource criteria put forward by BSNP (2006) and adjusted to the feasibility questionnaire used by Ardiansyah et al. (2021). Several experts in their fields and practitioners from several teachers were selected to assess the prototype that had been developed. Satisfactory results were obtained in this activity. Nine out of ten assessors agreed to give a final assessment with a feasible category (with a score interval of 86% to 100%). The final average score obtained was also categorized as feasible at 92.66%. These results indicate that the developed textbooks have certain feasibility, both in terms of content feasibility, presentation feasibility, language, and innovation in mathematics learning. The developed textbooks have been well-adjusted to achieve learning outcomes and learning objectives, as well as to ensure the accuracy of the definitions, principles, facts, and problems presented. The presentation of the textbooks is also considered interesting and comprehensive, from the introduction to the conclusion. The language used in the textbooks has also been adjusted to match the level of student knowledge, and the language used does not convey a duality of different meanings. Related to the development of innovation, the integration of challenge-based learning within STEM Contexts and indicators of critical thinking skills is also considered to have been met well. Given the fulfillment of all these aspects, the certainty of the success of research and learning can occur well, including the achievement of feasibility, practicality, effectiveness, and increasing critical thinking skills (Ardiansyah, et al., 2024; Ardiansyah, et al., 2024; Roswahyuliani et al., 2024)

Product implementation is the next stage in this research. During the three meetings, students used mathematics textbooks that integrated Challenge-based learning in a STEM context, assisted by the Quizizz Application, to achieve the learning objectives as presented in Table 3. In the first three-hour meeting, students were introduced to the concept of linear equations in two variables and asked to create a mathematical model of a system of linear equations in two variables for the given contextual problem. In the second meeting, which lasted two hours, students were asked to apply their critical thinking skills to solve contextual problems, with a focus on using graphical methods to determine solutions to systems of linear equations in two variables. In the last meeting, which had three lesson hours, students were asked to use their critical thinking skills to solve contextual problems, focusing on the use of substitution, elimination, and mixed methods to determine solutions to systems of linear equations in two variables. In the learning process, students are the ones who are actively engaged. Student activities in the Guiding Activities, Guiding Questions, and Solution Discovery steps align with Piaget's learning concept, where students are encouraged to be active participants in class interactions. So, what is the role of the teacher? The teacher is only a facilitator. This aligns with the scaffolding concept, where the teacher provides learning assistance to students

throughout the learning process. Students will receive this assistance if they find solutions to the challenges given. This is also reinforced by several literature reviews, which state that critical thinking skills can be developed through the implementation of the CBL model with a STEM context, assisted by ICT (Ayu et al., 2023; Lestari & Ardiansyah, 2023).

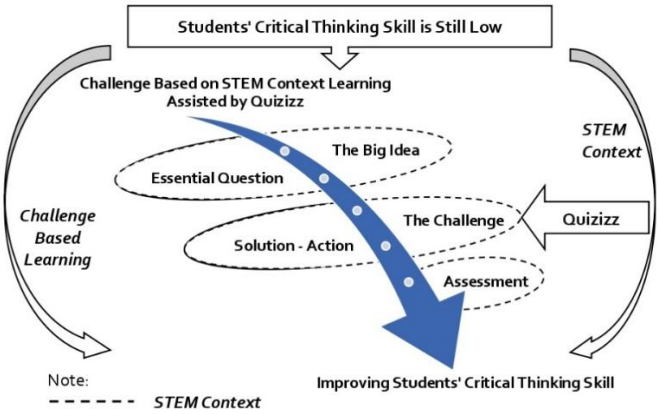

Figure 5. Framework of challenge based on STEM context learning model assisted by quizizz application

The innovation of Challenge-based STEM Context Learning, assisted by ICT, is key to achieving success in enhancing critical thinking skills. This model framework provides collaborative learning opportunities for students to find solutions to the challenges given. The challenges are integrated with the STEM Context, so that students indirectly play a role as problem solvers. The assistance of the Quizizz application is a response to technological developments and the fulfillment of students' learning needs. In simple terms, learning activities begin with the presentation of a Big Idea integrated with the STEM Context. Then, students are asked to create Essential Questions related to the Big Idea. Students are faced with Challenges, but to deal with these, they are given guidance consisting of Guiding Resources, Activities, and Questions. Furthermore, students in groups find Solutions to the Challenges given. The results of these activities are then published to the public. The goal of this learning activity is for students to engage in self-reflection and complete several assessments that have been provided. Figure 5 presents a summary of the implementation of the textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application.

The results of the statistical test demonstrate the achievement of all hypotheses, indicating that the implementation of mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application, is effective in improving critical thinking skills. Student responses also show good results. Thus, the implementation of the product demonstrates effectiveness in enhancing critical thinking skills and eliciting positive responses from students.

The Challenge-based Learning model plays a role in developing critical thinking skills (Ardiansyah et al., 2022). Students can develop their analysis skills through Essential Question activities, where they are asked to formulate questions based on the given Big Idea. In finding a Solution, students develop their interpretation, evaluation, and inference indicators because the Solution to the Challenge given must be answered well. Several relevant previous studies certainly support this success. CBL implementation research with the results that critical thinking skills can be empowered well (Nawawi, 2016). Teaching materials with the CBL model have proven effective in improving critical thinking skills (Azis et al., 2016).

T The STEM Context concept acts as a wrapper for the problem context developed in this study. The context provides direct learning experiences for students to become problem solvers (Ardiansyah & Asikin, 2023). The context challenges students' potential to develop their critical thinking skills through a meaningful learning process by connecting their experiences in everyday life (Bahrum et al., 2017). Through these activities, students' explanations and self-regulation indicators develop well. STEM Context provides students with the opportunity to provide rational reasons based on their findings, allowing their cognitive activities to develop effectively. The application of STEM provides opportunities to improve students' critical thinking skills (Ritonga & Zulkarnaini, 2021). The development of STEM-integrated e-modules is also effective in improving students' critical thinking skills (Fathiya & Asrizal, 2022).

Innovation in technological developments through the application of the Quizizz application was carried out in this study. In addition to following up on technological developments, the Quizizz application is expected to provide another engaging learning experience for students, ensuring they stay motivated and avoid boredom. Mathematical abstraction becomes more interesting with the application of fun technology like Quizizz. Another note states that the use of Quizizz as a learning medium also has a positive impact on improving critical thinking skills (Angraini & Nurmaliza, 2022; Arif et al., 2022).

Conclusion

Developing critical thinking skills is a challenge for educators. This complex skill can be developed well through appropriate learning innovations. The mathematics textbooks Integrated with a Challenge-Based Learning Model in a STEM context assisted by the Quizizz application, provide a solution to this problem, so they need to be developed appropriately. The results show that the mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by the Quizizz Application, are feasible, easy to understand, and effective in improving critical thinking skills, with a good response from students. This finding is supported by the average feasibility test score of 92.66%, which is categorized as feasible; the average

readability test score of 98%, which is categorized as easy to understand; and the average student response assessment score of 94.6%, which is categorized as very good. To achieve effectiveness, it can be seen how the implementation of the product can (1) achieve average completeness, (2) achieve proportion completeness, (3) achieve success where the average critical thinking skill of students who use the product is greater than that of students who do not use the product, (4) achieve success where the proportion of completeness of students who use the product is greater than that of students who do not use the product, (5) there is an increase in the critical thinking skill of students who use the product, (6) achieve success where the increase in the critical thinking skill of students who use the product is greater than that of students who do not use the product.

Undeniably, the implementation of mathematics textbooks integrated with a challenge-based learning model in STEM context, assisted by the Quizizz application, should be done by teachers to improve students' critical thinking skills in their classes. Large-scale dissemination and adoption are necessary. Recommendations are submitted to the education office or mathematics teacher groups for implementation of the product. Further development of the textbooks integrated with a challenge-based learning model in STEM context, assisted by quizizz application can be undertaken to enhance other abilities and utilize additional ICT to attract more students' attention.

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