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Development of CTL-based worksheets to facilitate students' mathematical critical thinking skills

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Abstract

This study was motivated by the low level of students' critical-thinking skills in mathematics. The purpose of this research was to produce a CTL-based student worksheet (LKPD) designed to facilitate students' mathematical critical thinking skills and meet the criteria of validity and practicality. The research used development research, employing the 4-D model, which consists of the define, design, development, and dissemination phases. The study's subjects were Phase D students at SMP Negeri 23 Pekanbaru. The instruments used to measure validity and practicality were validation sheets and practicality questionnaires. The assessment aspects on the validation sheet consisted of face validity, content validity, and construct validity. The overall average validation score was 89.98%, which was categorized as very valid, indicating that the LKPD could be tested after revisions based on the validators' suggestions. Meanwhile, the assessment aspects on the practicality sheet included ease of use, presentation, readability, and time. The practicality test conducted in the small-group trial obtained an average score of 93.11%. Thus, the valid and practical CTL-based LKPD on statistics successfully facilitates Phase D students' mathematical critical thinking skills, implying its potential as an effective instructional tool for mathematics teachers.

Keywords: mathematical critical thinking skills; student worksheet; CTL approach

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I. Introduction

Mathematics is delivered across all educational stages and contributes significantly to advancements in science and technology (Putri, Yuanita, Kartini, & Roza, 2022). Thus, mathematics is designated as a mandatory discipline that students are required to study throughout every level of formal education in Indonesia. Hendaryono (2023) states that mathematics instruction should be delivered from the elementary stage to enable students to think in logical, analytical, systematic, critical, and creative ways while also fostering collaboration skills.

Critical thinking helps learners grasp the essential aspects of a problem and make well-reasoned judgments without being easily swayed by external influences (Putri et al., 2022; Manurung, Hutapea, & Suanto, 2024). Mathematical critical thinking skills are fundamental for shaping students' character, especially in mathematics learning, whose

applications are inseparable from everyday life (Rahmaini & Chandra, 2024; Rahayu & Al Hadi, 2023). Students highly need these skills because they help them solve word problems or problems related to real-life situations (Prajono, Gunarti, & Anggo, 2022; Wulandari, Hidayanto, & Kusumasari, 2025).

Mathematical critical thinking skills in Indonesia are not yet considered good compared to those in other countries. Data from the 2022 Program for International Student Assessment (PISA) show that Indonesia ranked 69th among the 81 countries involved in the assessment (OECD, 2024). Alir & Fauziyah (2024) explain that PISA employs complex and standardized problem types designed to stimulate students' mathematical critical thinking abilities. Consequently, the PISA results indicate that Indonesian students' performance in mathematical critical thinking remains low. Several earlier studies similarly revealed that students still demonstrate weak mathematical critical thinking skills (Lestari & Roesdiana, 2021; Usman, Uno, Oroh, & Mokolinug, 2021; Yasinta, Meirista, & Taufik, 2020)

Students' mathematical critical thinking skills are categorized as very low, as indicated by several types of errors such as writing incomplete known and asked information, constructing mathematical models and assumptions inaccurately, and skipping calculation processes by directly writing answers (Fitri, Maimunah, & Suanto, 2023) These findings indicate that students are not yet accustomed to solving non-routine problems (Fitri et al., 2023; Agus & Purnama, 2022). Difficulties in understanding problems, constructing mathematical models, and errors in applying mathematical procedures also contribute to the low level of students' mathematical critical thinking skills (Purnaningsih & Zulkarnaen, 2022). In addition, this low ability is influenced by students' difficulties in interpreting problems, performing analyses and evaluations, and drawing mathematical conclusions, as stated by Putri et al. (2022).

Similar findings have also been reported in international studies. Er (2024) found a significant relationship between critical thinking skills and mathematical thinking skills among secondary school students, indicating that students with stronger critical thinking skills tend to demonstrate better mathematical thinking abilities and academic achievement. Furthermore, Alvarez-Tinajero, Basantes-Andrade, Ayala-Vásquez, Pereira-González, & Arciniegas-Romero (2026) reported that integrating mathematical competencies and critical thinking positively contributes to students' conceptual understanding, logical reasoning, creativity, self-regulation, and problem-solving skills. However, the study also highlighted several challenges, including insufficient contextualization of learning, limited teacher preparation, and a lack of validated learning materials specifically designed to facilitate mathematical critical-thinking skills. Therefore, efforts to develop instructional materials that support mathematical critical thinking remain necessary in mathematics education.

An important aspect of efforts to facilitate students' mathematical critical thinking skills in school learning is the proper selection and use of instructional materials (Irkhamni, Nugroho, & Dwijayanthi, 2025; Wiska, Musdi, Permana, & Yerizon, 2020). Suanto, Khainingsih, and Hutapea (2022) stated that developing creative and innovative learning materials can create an enjoyable learning atmosphere, while also stimulating and enhancing students' mathematical critical thinking skills. One type of learning material that can be utilized in the learning process is the Student Worksheet (Suanto et al., 2022). A worksheet is a printed instructional material containing learning content, summaries, and task guidelines designed for students to work on, referring to the basic competencies to be achieved (Prastowo in Effendi, Herpratiwi, & Sutiarso, 2021).

According to Fauziyah and Muthi (2024), the Contextual Teaching and Learning (CTL) approach is a learning model that emphasizes the

connection between the material being studied and students' real-life contexts. This approach enables learners to gain a deeper understanding of concepts through experiences that are relevant to their everyday environment. Real-world problems can develop students' mathematical critical-thinking skills (Nst, Sidabutar, & Gea, 2021). Therefore, learning using the CTL approach is considered effective in improving mathematical critical thinking skills.

Previous studies have highlighted the importance of developing students' mathematical critical thinking skills through contextual learning approaches. In Indonesia, Fatikhah, Kamid, and Syamsurizal (2021) developed contextual mathematics worksheets for vocational school students and found that the materials improved students' critical-thinking skills in mathematics. Likewise, Alvira, Ahyaningsih, and Minarni reported that CTL-based learning tools effectively enhanced junior high school students' mathematical critical thinking skills and mathematical resilience. Furthermore, Royan and Supriatna (2024) developed CTL-based worksheets on the Pythagorean theorem and demonstrated that the worksheets were feasible for supporting mathematics learning.

Evidence from international studies also supports the importance of critical thinking in mathematics education. Er (2024) found a significant relationship between critical thinking skills and mathematical thinking skills among secondary school students, indicating that stronger critical thinking skills contribute to better mathematical performance. In addition, Alvarez-Tinajero et al. (2025) reported that integrating mathematical competencies with critical thinking positively influences students' conceptual understanding, logical reasoning, creativity, self-regulation, and problem-solving abilities. However, the study also emphasized the need for learning materials specifically designed to facilitate mathematical critical thinking skills.

Despite these findings, previous studies have mainly focused on examining the effectiveness of CTL-based learning tools or investigating the relationship between critical thinking and mathematical achievement. Research specifically developing CTL-based student worksheets on Measures of Central Tendency that explicitly integrate CTL components with mathematical critical thinking indicators remains limited. Moreover, few studies have focused on Phase D students within the context of the Merdeka Curriculum.

Therefore, this study seeks to address the identified gap by developing a CTL-based student worksheet on Measures of Central Tendency that explicitly integrates CTL components with indicators of mathematical critical thinking skills. The novelty of this study lies in integrating contextual learning activities with indicators of interpretation, analysis, evaluation, and inference into a worksheet designed for Phase D students. This study is significant because it provides a valid and practical learning resource to support mathematics teachers in facilitating students' mathematical critical thinking through meaningful, contextual learning experiences. In the application of CTL, seven essential elements are involved, namely constructivism, questioning, inquiry, learning community, modelling, reflection, and authentic assessment (Royan & Supriatna, 2024).

The development of mathematical critical thinking skills has become increasingly important in contemporary mathematics education, particularly within the implementation of the Merdeka Curriculum, which emphasizes higher-order thinking skills and meaningful learning experiences. Although several previous studies have developed CTL-based learning materials and demonstrated their effectiveness in improving students' critical thinking skills, most have focused on different mathematical topics and have not explicitly integrated mathematical critical thinking indicators into worksheet activities. Therefore, developing a CTL-based student worksheet on Measures of Central Tendency that systematically incorporates the indicators of interpretation, analysis, evaluation, and inference

is considered necessary and relevant to current educational needs.

Based on the identified problem, the existing research gap, and the potential of CTL to facilitate mathematical critical thinking skills, this study aims to develop a CTL-based Student Worksheet on Measures of Central Tendency and evaluate its validity and practicality.

II. Research Method

This study employs a Research and Development (R&D) design, often referred to as development research. The objective is to produce a CTL-based student worksheet (LKPD) for Phase D on the topic of measures of central tendency and range, in alignment with the Merdeka Curriculum, that fulfils the criteria of validity and practicality. The development process adopts the 4-D model formulated by S. Thiagarajan, Dorothy S. Semmel, and Melvyn L. Semmel. Introduced in 1974, this model comprises four sequential stages: define, design, develop, and disseminate.

Figure 1. Flowchart model 4-D

The research procedure followed the four stages of the 4-D development model, with specific activities detailed as follows:

a. Define Stage: This stage involves front-end analysis, learner analysis, concept analysis, and task analysis. These analyses were conducted to identify the core problems in understanding statistics, specifically focusing on the measures of central tendency and range for eighth-grade students.
b. Design Stage: The activities included designing criterion-referenced tests aligned with learning indicators, selecting appropriate instructional media, determining the worksheet format, and constructing the initial draft of the student worksheet (LKPD) integrated with the Contextual Teaching and Learning (CTL) approach.
c. Development Stage: This stage focuses on evaluation and refinement. It involved expert review by validators to assess the content and construct validity, followed by developmental testing consisting of one-to-one evaluations and small-group trials to ensure the worksheet's practicality and readability.
d. Dissemination Stage: The finalized product was packaged into a print-ready book format. The dissemination was conducted on a limited basis by distributing the final LKPD to mathematics teachers at SMP/MTs in Pekanbaru to promote its usage in the classroom.

To evaluate the product, this study utilized both qualitative and quantitative data. The participants for the developmental testing phase were eighth-grade students at SMP Negeri 23 Pekanbaru. These participants were purposively selected because they were the intended users of the developed CTL-based student worksheet and had studied Measures of Central Tendency as part of the Phase D mathematics curriculum. Furthermore, preliminary observations and interviews with mathematics teachers indicated that students experienced difficulties in interpreting problems, analyzing information, evaluating solutions, and drawing mathematical conclusions. Therefore, this group was considered appropriate for evaluating the practicality of the developed worksheet and its potential to facilitate students' critical thinking in mathematics. Data were gathered through multiple methods, including interviews, classroom observations, validation forms, and practicality questionnaires.

The primary data collection instruments consisted of expert validation questionnaires to evaluate the validity of the developed CTL-based LKPD and student response questionnaires to assess its practicality. Both instruments utilized a 5-point Likert scale to measure respondents' attitudes, opinions, and perceptions. The response options were categorized as 5 (Strongly Agree), 4 (Agree), 3 (Neutral), 2 (Disagree), and 1 (Strongly Disagree) (Sugiyono, 2022). The collected data were subsequently analyzed using validity and practicality analysis techniques.

The validity analysis technique for the student worksheet (LKPD) used a formula adapted from Novita, Lufri, Ardi, & Selaras (2023), as follows:

$$V_a = \frac{T_{se}}{T_{sh}} \times 100\%$$

Description:

V_a is the percentage of validity.

T_{se} is the total score obtained from the validators.

T_{sh} is the maximum expected score.

The practicality analysis technique of the student worksheet (LKPD) also uses a formula adopted from Ariani (2022), as follows:

$$V_p = \frac{T_{se}}{T_{sh}} \times 100\%$$

Description:

V_p is the percentage of practicality

T_{se} is the empirical score obtained from the observers

T_{sh} is the maximum expected score

The resulting values were then analyzed using the validity and practicality categories presented in Table 1 to determine the extent to which the developed student worksheets meet these criteria.

Table 1. Validity and practicality categories

Interval	Validity Category	Practicality Category
$V < 21\%$	Not Valid	Not Practical
$21\% \leq V < 40\%$	Less Valid	Less Practical
$40\% \leq V < 60\%$	Fairly Valid	Fairly Practical
$60\% \leq V < 80\%$	Valid	Practical
$80\% \leq V \leq 100\%$	Highly Valid	Highly Practical

(Source: Adapted from Riduwan, 2015)

Based on Table 1, CTL-based student worksheets are considered valid and practical if they obtain validity and practicality scores of ≥ 60%, and are considered invalid and impractical if the validity and practicality scores are < 60%.

III. Results and Discussion

Sugiyono (2022) explains that research and development (R&D) is a research approach aimed at producing a specific product. In this study, the development process aims to create CTL-based student worksheets for statistics content that support students' mathematical critical thinking skills and satisfy the criteria of validity and practicality. The research adopted the 4-D (Four-D) development model proposed by Thiagarajan (1974), which comprises four stages: define, design, develop, and disseminate.

Within the define stage, five main activities were undertaken, which included conducting a preliminary–final analysis, examining student characteristics, analyzing tasks, reviewing the relevant concepts, and formulating the learning objectives. The purpose of the preliminary final analysis was to identify the study's main problems. The results of the analysis showed that no existing student worksheets were specifically designed to support students' mathematical critical thinking skills in statistics, and that, overall, students' levels of mathematical critical thinking remained relatively low. The low level of students' mathematical critical thinking skills was caused by their inability to interpret problems, conduct analysis and evaluation, and draw conclusions about mathematical issues. This aligns with the findings of Purnaningsih and Zulkarnaen (2022), who highlight that students' challenges in comprehending problems, formulating mathematical models, and correctly implementing mathematical procedures contribute to their low levels of mathematical critical thinking. In addition, learning remains teacher-centered, and students are not fully allowed to explore knowledge independently. Thus, this analysis revealed the need for a learning approach that provides students with full opportunities to solve problems independently to enhance their mathematical critical thinking skills, such as the CTL approach This result is consistent with the study conducted by Alvira et al. (2022), which demonstrates that learning tools developed using the CTL approach are effective in enhancing students' mathematical critical thinking skills.

The student analysis was conducted to identify the characteristics of Phase D students who participate in the mathematics learning process. The results of this analysis served as the basis for designing the student worksheets to be developed. Phase D students are generally 12–14 years old, which is categorized as early adolescence. According to Piaget's theory of cognitive development, students in this age range have entered the formal operational stage, allowing them to reason and think logically. Furthermore, observations at SMP Negeri 23 Pekanbaru revealed that students tend to be more enthusiastic when learning through peer discussions and when they are directly involved in solving problems. Students also demonstrated greater interest in visually appealing learning media, such as the use of colors and images. Based on these findings, the development of the student worksheets will be adapted to the characteristics of the learners by designing visually engaging layouts and contextual learning activities. This is intended to encourage active participation and optimally enhance students' mathematical critical thinking skills.

The task analysis was conducted to examine the Learning Outcomes (*Capaian Pembelajaran*/CP) stated in *Kemendikdasmen* Number 046/H/KR/2025 to produce the Learning Objective Flow (*Alur Tujuan Pembelajaran*/ATP). The resulting ATP is presented in the following table.

Table 2. Result of learning objective flow (ATP)

Learning Outcomes (CP) Phase D	Students can determine and interpret the mean, median, mode, and range of a given data set to solve problems (including comparing data sets using tables and bar charts, grouping data, and making decisions).	
Learning Objectives Flow (ATP)	Unit 1	Students are able to determine the mean.
	Unit 2	Students are able to determine the median.
	Unit 3	Students are able to determine the mode.
	Unit 4	Students are able to determine the range.
Elements	Data Analysis and Probability	
Content	Measures of Central Tendency and Range	
Total Learning Hours (JP)	8	
Pancasila Student Profile	Independent, cooperative, critical, and creative	

The concept analysis activity was carried out to identify the main concepts to be taught and to examine in detail the concepts that must be delivered. From this activity, a concept map for the topic of trigonometric comparison was developed and is presented in the following figure.

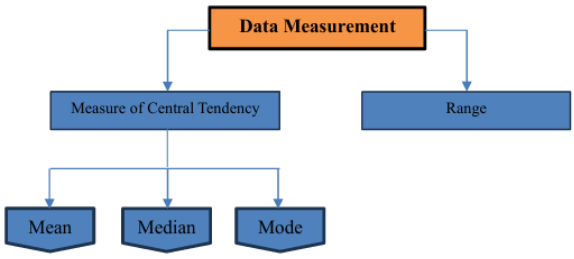

Figure 2. Concept map

The specification of learning objectives was conducted to determine the competencies that students are expected to achieve. The results of the learning objective analysis for the material on measures of central tendency and range are summarized in Table 3.

Table 3. Result of learning objective specifications

Meeting	Learning Objectives	JP
1	Students are able to determine the mean and solve related problems	2
2	Students are able to determine the median and solve related problems	2
3	Students are able to determine the mode and solve related problems	2
4	Students are able to determine the range and solve related problems	2

During the design stage, activities included developing student worksheets and validation and practicality instruments to assess the validity and practicality of the resulting worksheets. The worksheets were developed with their essential components in mind. The worksheets contained student identity, the title of the learning material, learning objectives, and general instructions for use.

In the learning activities, particularly in the core activities, the components of the CTL approach were integrated. The components of the CTL approach can facilitate students' critical thinking in mathematics. In the constructivism component, students were presented with contextual problems to observe and understand, enabling them to build new knowledge. They wrote down the known information and what was being asked based on the interpretation indicators. Next, in the modelling component, students were guided to discover concepts, discuss with peers, and ask the teacher questions, in accordance with the learning community and questioning components, which were integrated with the analysis indicators. Subsequently, students engaged in inquiry, learning community, and questioning activities to solve the problems on the worksheets, drawing on their conceptual understanding, while simultaneously practicing the evaluation indicators for mathematical critical thinking. Finally, in the reflection component, students wrote conclusions that supported the development of inference indicators. The components of the CTL approach were found to support the development of students' critical-thinking skills in mathematics. This is consistent with the findings of Fatikhah et al. (2021), who reported that the CTL approach effectively enhances students' mathematical critical thinking abilities. The worksheets produced during this stage were designated as prototype 1. After designing the validity instrument, the practicality instrument, and the worksheets, the process continued to the development stage of the worksheets.

During the development stage, the worksheets from the design phase were validated by three validators to assess their feasibility across the face, content, and construct dimensions. The validity results of the worksheets are presented in Table 4.

Table 4. Results of LKPD validation analysis

Aspect Assessed	**Worksheets Student No**				**V_a**	**Category**
	1	**2**	**3**	**4**		
Face	90,63	91,15	95,83	93,75	92,84	Highly Valid
Content	92,42	92,42	93,18	93,94	93,99	Highly Valid
Construct	81,14	82,89	84,40	85,96	84,09	Highly Valid
V_a = Overall Percentage					**89,98%**	**Highly Valid**

Based on Table 4, the validity scores of Worksheets Student 1–4 reached 89.98%, categorized as "Highly Valid", and deemed suitable for implementation with revisions according to the validators' suggestions, in line with Akbar (2017). Alongside the validation process, the researcher also conducted a one-to-one trial with three students. This trial aimed to assess readability and identify weaknesses found in the worksheets as a basis for refinement.

The validation results indicate that the developed CTL-based student worksheets achieved an overall validity score of 89.98%, placing them in the highly valid category. This finding suggests that the worksheets are theoretically appropriate and consistent with the intended learning objectives, content requirements, and students' characteristics. The high validity score may be attributed to the integration of CTL components, namely constructivism, questioning, inquiry, learning community, modelling, reflection, and authentic assessment, with indicators of mathematical critical thinking skills. Through this integration, the learning activities are systematically designed to encourage students to interpret problems, analyze information, evaluate solutions, and draw mathematical conclusions.

In addition, the validation results indicate that the developed worksheets possess strong content and construct validity. The contextual problems presented in the worksheets are closely related to students' daily experiences, allowing them to connect mathematical concepts with real-life situations. This finding is in line with Fauziyah and Muthi (2024), who stated that contextual learning helps students achieve a

deeper understanding of concepts through meaningful learning experiences. Furthermore, the findings support the study of Royan and Supriatna (2024), which reported that learning materials developed using the CTL approach can facilitate students' active engagement and improve the quality of mathematics learning.

The subsequent product testing was conducted as a small-group trial involving six eighth-grade students from SMP N 23 Pekanbaru. After working on the worksheets, students were given a response questionnaire to evaluate the practicality of the developed worksheets. The results of the student response questionnaire from the small-group trial are presented in Table 5.

Table 5. Summary of student response questionnaire results from the small-group trial

Aspect	Average (%)
Ease of Use Aspect	92,53%
Presentation Aspect	93,54%
Readability Aspect	92,08%
Time Aspect	94,27%
Average Practicality Score of LKPD Items 1–4	**93,11%**
Category	**Highly Practical**

Based on Table 5, it is known that the average practicality score of LKPD 1–4 is 94.27%, which falls into the "highly practical" category. According to Ariani (2022), this score indicates that the developed LKPD is considered practical because its practicality value exceeds 60%.

The practicality test yielded an average score of 93.11%, indicating that the developed worksheets are highly practical for classroom use. This result demonstrates that students were able to use the worksheets easily, understand the instructions provided, and complete the learning activities within the allocated time. The practicality of the worksheets may be influenced by the systematic organization of learning activities and the use of contextual problems that are familiar to students. Such characteristics enable students to participate actively in learning and reduce difficulties in understanding mathematical concepts.

The findings also suggest that the developed worksheets are capable of creating a more student-centered learning environment. Through inquiry activities, group discussions, and reflection tasks, students are encouraged to construct their own understanding and engage in meaningful learning experiences. This result is consistent with the findings of Fatikhah et al. (2021), who reported that contextual learning materials can effectively support students' mathematical critical thinking skills. Similarly, Alvira et al. (2022) found that learning tools developed using the CTL approach positively contribute to improving students' mathematical critical thinking abilities.

Therefore, the high practicality score indicates that the developed CTL-based worksheets are not only feasible to implement but also have the potential to support the development of students' mathematical critical-thinking skills through contextual, meaningful learning activities.

Based on the validity and practicality analyses conducted, the CTL-based student worksheet designed to enhance students' mathematical critical thinking skills met the criteria for both validity and practicality, indicating that it is suitable for advancement to the final development stage.

The final stage is dissemination, which involves packaging the LKPD for printing and distributing it to the schools that contributed. The following is the cover design for the packaging of the CTL-based LKPD intended to facilitate students' mathematical critical thinking skills.

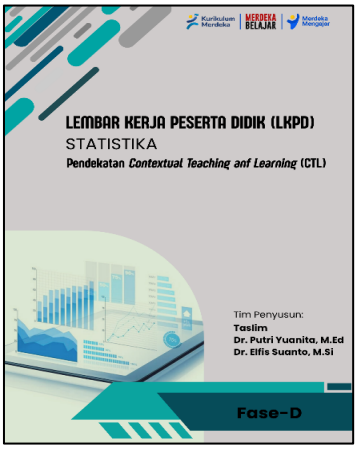

Figure 3. Design of the LKPD packaging cover

IV. Conclusion

This research resulted in a CTL-based student worksheet intended to support the development of students' mathematical critical thinking skills, and the product fulfilled the criteria for validity and practicality. The development process employed the 4-D model, encompassing the define, design, develop, and disseminate stages. Based on the outcomes of the validity and practicality evaluations, it can be concluded that the LKPD developed in this study meets the required standards and is feasible for use in the learning process. Consequently, this study implies that the developed CTL-based LKPD can serve as a valuable instructional resource for mathematics teachers to design a more contextual learning environment, thereby providing a potential learning resource to facilitate middle school students' mathematical critical thinking skills.

This study was conducted only up to the validity and practicality testing stages; therefore, it is recommended that future researchers continue the development to the effectiveness testing stage. In addition, it is suggested that CTL-based LKPD be developed for different content areas and educational levels.

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