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Design of Critical Thinking Ability Questions with Colorful Ribbon Context for Hearing Impaired Students

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Abstract. *This study aimed to develop a mathematics test instrument that assesses the critical thinking skills of hard-impaired students using a Realistic Mathematics Education (RME) approach in a colored ribbon context. The research employed a design research method with a development type, consisting of the preliminary and prototyping stages, including self-evaluation, expert review, and one-to-one. The instrument was developed based on Ennis's (1985) critical thinking indicators, comprising five items adapted to the visual characteristics of Grade XI deaf students at SMALB. Content and language validation by experts confirmed the qualitative validity of the items. A limited trial (one-to-one) involving three hearing-impaired students revealed that the items were understandable and suitable, particularly due to the use of simple language, visual aids, and concrete objects. In conclusion, the critical thinking questions based on the RME approach and visual context are effective for hearing-impaired students and offer an alternative assessment tool that accommodates their sensory limitations.*

Keywords: *critical thinking; hearing-impaired students; realistic mathematics education.*

INTRODUCTION

The intelligence of deaf students is challenging to develop due to hearing impairments (Nurhabibah et al., 2023). However, no significant differences in outcomes have been observed between deaf students and their hearing peers. Deaf and hearing students have similar cognitive potential (Martin et al., 2001). Nevertheless, deaf students' sensory (hearing) limitations make it difficult for them to understand abstract concepts, including mathematical ones (Nur Azmi & Andriyani, 2022). Deaf students also perform lower on abstract calculation tasks and symbolic addition and subtraction problems (L. Marcelino, C. Sousa, 2019). Despite having similar cognitive potential, sensory limitations create unique learning challenges that require specialized instructional approaches.

Deaf students face significant challenges in critical thinking. This is because they often focus on obtaining the correct answer rather than understanding the process. As a result, their critical thinking skills have not yet reached the expected indicators (Nur Azmi & Andriyani, 2022). However, higher-order questions

stimulate students to engage substantively with the information and to produce creative responses. Improving the ability to ask and answer higher-order questions will enhance overall critical thinking (Easterbrooks & Scheetz, 2004). Given these challenges, there is an urgent need to develop assessment tools specifically designed to measure and support the development of critical thinking in deaf students.

Critical thinking is essential for logical reasoning, problem-solving, and decision-making, which are necessary for success in the 21st century (Putri & Darussyamsu, 2022; Rusmin et al., 2024). According to Febrianti et al. (2021), students' low critical thinking skills stem from their unfamiliarity with critical thinking questions. Therefore, it is necessary to present critical thinking questions in an engaging visual-based format, as deaf students have strong visual skills (Esam et al., 2017). When teaching deaf students, visualizing learning materials is one of the key methods to meet their special educational needs (Krasavina et al., 2019). Therefore, integrating visual-based materials with pedagogically sound approaches becomes essential for effective mathematics learning.

Realistic Mathematics Education (RME) is an approach that emphasizes the use of relevant and meaningful real-world contexts to help students understand mathematical concepts through direct connections to everyday life situations and interactions with their environment (Adriwati et al., 2023; Amaliawan, N. et al., 2024; Webb et al., 2011). The RME approach can be applied not only to regular students but has also been widely tested on deaf students. The computational ability of deaf children in fraction operations improved when taught using the PMR approach (Kushartina, 2019). Specifically, using pipettes as a contextual tool was effective in improving deaf students' mathematical understanding and learning outcomes when learning fractions (Jannah, A. F., & Prahmana, 2019). Building on these findings, the present study extends the application of RME beyond learning media development to the creation of specialized assessment instruments.

Therefore, RME significantly enhances the meaningfulness of mathematics learning by linking mathematical concepts with real-world contexts. This method fosters analytical reasoning, improves problem-solving skills, and encourages

active student engagement, making mathematics more relevant and applicable to everyday experiences (Amalia Soleha et al., 2024; Koerunnisa et al., 2024; Sutrisna, 2023). However, existing studies are still limited to the development of learning models and media, rather than to the development of test instruments that specifically measure critical thinking indicators.

Colored ribbons were selected as the contextual tool in this study for several reasons. First, ribbons are tangible, colorful objects that align with deaf students' visual learning strengths. Second, ribbons naturally involve measurement concepts (length, comparison) that are fundamental in mathematics learning. Third, the variety of colors provides visual differentiation, supporting comprehension without relying on auditory input. This context is practical in similar studies with deaf learners using concrete objects (Jannah, A. F., & Prahmana, 2019), making it an appropriate medium for embedding critical thinking questions.

For example, research by Nur Azmi & Andriyani (2022) showed that students' critical thinking skills remain unclear and lack clarity. However, this study was purely analytical and did not develop critical-thinking question instruments to train and directly measure these indicators. Research by W. K. Sari et al. (2023) proved that contextual learning methods can train the ability to answer "why" questions, construct arguments, and find alternative solutions. However, this study did not explicitly develop critical-thinking evaluation questions that matched the visual communication characteristics of deaf students.

Based on previous research, the authors identified a gap in developing critical-thinking questions, tailored to the visual characteristics of deaf students, using Ennis's (1985) indicators. This study aims to fill this gap by developing critical thinking questions grounded in colored ribbons as a visual tool suited to the needs of deaf students.

METHOD

This study employed a design research method with a development type. It consisted of two stages, namely the *preliminary* stage and the *prototyping* stage (*formative evaluation*), as outlined by Tessemeer and Zulkardi (2013), which

included self-evaluation, expert reviews, one-to-one, small-group, and field testing (Tessemeer, 1993). This study was conducted only up to the one-to-one stage due to the limited number of research subjects. This development research aimed to create valid critical thinking questions for deaf students and to examine critical thinking-oriented questions with a colored ribbon context for deaf students.

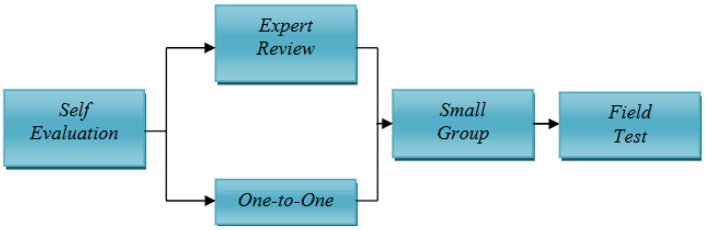

Figure 1. Formative Evaluation Design Process (adapted from Tessmer (1993) and Zulkardi & Kohar (2018))

Preliminary Stage

The researcher selected and analyzed the research location and subjects. In addition, the researcher reviewed literature related to previous development studies and relevant to the planned research. Next, the researcher created a test blueprint aligned with the *Kurikulum Merdeka* and linked it to the syntax of critical thinking skills. The researcher developed test instruments consisting of a blueprint and a scoring rubric. The researcher also determined the test validators and research subjects and prepared the research implementation procedures. The result of this preliminary stage was the initial prototype.

Self-Evaluation Stage

This stage consisted of evaluation and design. The researcher evaluated and reviewed the initial prototype, namely the test blueprint and scoring rubric. Furthermore, the researcher also evaluated and reviewed other instruments supporting this study. Then, the design of mathematics problems embedded with critical thinking skills using the context of colored ribbons for deaf students was carried out with the aid of Wordwall. The design process applied two characteristics: content (subject matter and construct) and language. These two characteristics were validated by the researcher, a teacher of a deaf class, and an

expert instrument validator. The results of this process were analyzed to produce the prototype.

The prototype, developed based on self-evaluation, was given to three students and an expert reviewer. The expert review stage involved testing each item's validity. Each question was examined and evaluated based on content (subject matter and construct) and language. Content evaluation considered alignment with the curriculum used and the material taught to grade XI deaf students. The material was assessed for its suitability with the characteristics of critical thinking skills using the colored ribbon context. Language validation referred to compliance with standard Indonesian (EBI) rules. The expert review process for prototype 1 was conducted face-to-face. Suggestions and comments from the validators were used as input for revising prototype 1.

After validation by the experts, the process continued to the one-to-one stage. This stage involved three deaf students with varying abilities (low, medium, and high). The students were asked to read and review the questions, then provide feedback on readability and clarity of meaning. The trial subjects were Grade XI deaf students in phase F according to the *Kurikulum Merdeka*. The research took place at SLB Negeri 1 Kota Jambi. The total number of Grade XI students was three, representing high, medium, and low ability levels for the one-to-one stage.

RESULT AND DISCUSSION

In the preliminary stage, the researcher prepared by reviewing and analyzing the students, the curriculum, the materials, the critical thinking questions, and the question design. The student analysis aimed to determine the students' mathematical abilities. The research subjects consisted of three individuals with heterogeneous abilities and total hearing impairments. Next, the curriculum analysis was conducted by identifying learning materials related to the colored ribbon context based on the Kurikulum Merdeka, formulated for Grade XI students in phase F.

In the design stage, the researcher developed critical thinking questions aligned with the indicators of critical thinking skills: elementary clarification

(providing simple explanations), basic support (building basic skills), inference (concluding), advanced clarification (providing further explanations), and strategy and tactics. The result of the preliminary stage was the initial prototype. The initial prototype consisted of five questions, all related to the colored ribbon context for deaf students. The following is the initial prototype of the questions developed by the researcher.

Table 1. Development of Critical Thinking Questions

Reference Questions	Question Description
Critical Thinking Ability Questions by Nur Azmi & Andriyani (2022)	1. Ibu memiliki sebuah kue seperti pada gambar ini.  $\frac{1}{2}$ bagian dari kue Ibu diberikan kepada Ani, kemudian $\frac{1}{3}$ bagian dari sisa kue Ibu diberikan Ana. Tiba-tiba Paman mengabari kemungkinan ketiga keponakan Ibu yang akan datang berkunjung ke rumah. Jika Ibu ingin memberikan kue sebanyak yang diterima oleh Ana untuk keponakan-keponakannya tersebut, maka coba buat berbagai kemungkinan sisa kue Ibu berdasarkan jumlah keponakan Ibu yang mungkin datang! Translation of the question above: Mom has a box of cakes, as shown in the picture. ¼ portion of the box Ibu gave to Ana. Then, Mom gave ⅓ of the remaining box to Ana. Suddenly, Uncle announces that the gift box Mom was going to bring will be delivered to the house. If Mom wants to give the box as much as Ana received for the guests, try to share the possibility of the remaining portion of the box based on the total number of boxes Mom might bring!

Developed questions	 **Nia punya uang Rp 30.000. Dari uang yang ia punya, 1/3 digunakan untuk membeli pita. Dalam kotak terdapat pita merah, kuning, dan orange. Panjang bahan yang digunakan untuk membuat pita merah adalah 420 cm. Panjang bahan yang digunakan untuk membuat pita kuning 10 cm lebih panjang dari pita merah. Panjang bahan yang digunakan untuk membuat pita orange 45 cm lebih pendek dari pita kuning. Panjang pita yang diperlukan untuk membuat pita merah, kuning, dan orange adalah 5cm.** Nia has Rp. 30,000. From that total, one-third is used to purchase ribbon materials. There are three colors of ribbon in the box: red, yellow, and orange. Regarding the material details, the red ribbon requires 420 cm of material. The yellow ribbon requires 10 cm more than the red one, while the orange ribbon requires 45 cm less than the yellow one. Meanwhile, each ribbon (red, yellow, or orange) requires a finished length of 5 cm.

In this problem, the researcher presents several pieces of information: the amount of money Nia has, the portion to be spent on buying ribbons, the ribbon materials (red, yellow, and orange), and the ribbon lengths. From this problem, the researcher derived five items, each representing a critical thinking skill indicator, described as follows:

a. The first question asks what information can be identified.
b. The second question asks for the length of material used to make the red, yellow, and orange ribbons.
c. The third question asks for the number of red, yellow, and orange ribbons that can be made.
d. The fourth question asks for the remaining money Nia has, and
e. The fifth question asks to arrange the ribbons from the smallest quantity to the largest.

The following are indicators of critical thinking questions, presented in the context of colored ribbons.

Table 2. Critical Thinking Skills Indicators

Critical Thinking Skills Indicators	Competency Achievement Indicators	Question Indicator	Question Number
Elementary clarification	Providing a simple explanation of the information obtained.	A story about numbers in the context of ribbons is presented. Students can explain the information they obtain.	1a
Basic support	Calculate the length of the yellow and orange ribbons.	A story related to numbers is presented. Students can calculate the length of the yellow and orange ribbons.	1b
Inference	Conclude the total number of ribbons.	A word problem related to numbers is presented. Students can conclude the total number of ribbons.	1c
Advanced clarification	Provide the correct reasoning regarding Nia's remaining money after buying the red ribbon.	A word problem related to numbers is presented. Students can give a further explanation regarding Nia's remaining money.	1d
Strategy and tactics	Determine the correct mathematical concept or problem-solving procedure and identify whether there is an alternative strategy.	An illustration related to numbers is presented. Students can provide an alternative strategy for the given problem.	1e

A draft of the mathematics questions incorporating critical thinking skills, with the context of colored ribbons for deaf students, was designed. Prior to that, it was evaluated and self-reviewed by the researcher in accordance with the critical thinking skill indicators, focusing on language and content (content and construct). From the content perspective, the researcher evaluated whether the designed questions already included critical thinking skill indicators, assessed the context, and predicted the question levels.

In addition, the researcher analyzed the developed questions in relation to the Learning Outcomes (*Capaian Pembelajaran* / CP) and the Learning Objectives

Flow (*Alur Tujuan Pembelajaran* / ATP) outlined in the *Kurikulum Merdeka*. From a construct perspective, the researcher evaluated whether the designed questions could develop critical thinking skills and whether the images were presented clearly, legibly, and functionally. From a language perspective, the researcher evaluated whether the language complied with the Indonesian Spelling System (Ejaan Bahasa Indonesia / EBI), ensured that the questions did not invite multiple interpretations or were convoluted, and that the question boundaries and expected answers were clear. The results obtained at this stage were referred to as Prototype 1.

The questions were validated for content and language, consulted, and examined by a Mathematics Education lecturer at Universitas Jambi, Dr. Dra. Nizlel Huda, M.Kes, and a teacher of the deaf class, Suratmie Rachmat, M.Pd. The suggestions and comments from the experts are as follows:

Table 3. Comments/Suggestions from the validator and revision decisions

Validator Name	Comment and Suggestions
Dr. Dra. Nizlel Huda, M. Kes	1. One question is sufficient, but it should cover all critical thinking indicators. 2. Replace several sentences that contain ambiguous interpretations. 3. The question can already assess deaf students' critical thinking skills, as it involves multiple arithmetic operations.
Suratmie Rachmat, M.Pd.	1. Use effective sentences. 2. The question should only contain one unit of measurement. 3. Use concrete objects (ribbons and money) when students work on the question.
Conclusion	1. Replace sentences with ambiguous interpretations with more effective sentences. 2. Create one unit of questions with five items corresponding to the critical thinking skill indicators. 3. Use concrete objects.

In the one-to-one stage, three students with different ability levels were given questions containing critical thinking skills in the context of colored ribbons. The three students were asked to work on a set of five questions. After completing them, they were asked to provide comments, opinions, and suggestions about the

questions. This aimed to allow the researcher to observe how the students responded to the questions and to focus on their readability and clarity.

This also aimed to enable the researcher to observe students' responses and challenges as they worked on the questions, with a focus on readability and clarity. During the students' work on the questions and during the interviews, the researcher was assisted by the teacher of the deaf class, who served as an interpreter to translate sign language. The revised questions are shown in the following table.

Table 4. Question Revisions in the One-to-One Stage

No.	Question Before Revision	Comments or Suggestions	Question After Revision
1.	Nia receives Rp 30.000 in pocket money from her mother. $\frac{1}{3}$ Some of the money she has is used to buy ribbon. In the jar, there are ribbons of different colors: red, yellow, and orange.	The sentence used was not effective.	Nia has Rp 30.000. Of the money she has, $\frac{1}{3}$ It is used to buy ribbons. In the box, there are red, yellow, and orange ribbons.
2.	The length of material used to make the red ribbon is 4.2 meters.	The unit of length used was changed to centimeters (cm).	The length of material used to make the red ribbon is 420 cm.
3.	When working on the problem, the researcher did not bring concrete objects, namely, colored ribbons and money.	Bring the concrete objects mentioned in the problem	Use the concrete objects, namely the money and colored ribbons stated in the problem, when students work on the task.

The researcher's critical thinking questions have been adjusted to the characteristics of deaf students. Deaf students face considerable challenges in acquiring age-appropriate vocabulary due to their limited access to spoken language (Hermans, D. et al., 2015). Therefore, effective vocabulary interventions are needed to support their development (Saldaña, D., & Rodríguez-Ortiz, 2023). The questions also use images and contextual instructions, which have been proven effective in enhancing vocabulary learning among deaf students (Tshering, 2023).

The findings of this study indicate that critical thinking questions designed with a Realistic Mathematics Education (RME) approach and a colored ribbon context are valid and suitable for deaf students, both in terms of content and

language. This aligns with research on critical thinking assessment for students with special needs (Easterbrooks & Scheetz, 2004; N. M. Sari et al., 2023), which emphasizes that practical assessment must include elementary clarification, basic support, inference, advanced clarification, and strategy formulation—components originally outlined by Ennis (1985) and now adapted for diverse learners.

The integration of visual contexts and concrete objects, such as ribbons and money, was found to enhance the readability and comprehension of the question. This result supports prior research (Esam et al., 2017), which emphasized that deaf students have strong visual abilities, making visually based materials more effective for learning. Furthermore, the use of concrete objects during the *one-to-one* stage is consistent with Krasavina et al. (2019), who found that tangible materials help bridge abstract mathematical concepts for hearing-impaired learners.

The RME approach proved to be effective in linking mathematical concepts to real-world situations, enabling students to engage in higher-order thinking. This finding is in line with previous studies (Jannah, A. F., & Prahmana, 2019; Kushartina, 2019), which demonstrated that RME significantly improved computation and conceptual understanding among deaf students, particularly when using contextual tools. Similarly, (Amaliawan, N. et al., 2024) and (Sutrisna, 2023) highlight that contextualized mathematics instruction fosters problem-solving and reasoning skills, which are essential components of critical thinking.

Compared to prior research that mainly focused on teaching models or media (Nur Azmi & Andriyani, 2022; W. K. Sari et al., 2023), this study offers a novel approach by developing an assessment instrument specifically adapted to the visual communication needs of deaf students. The validation process, involving both content and language experts and student feedback, ensured that the instrument met pedagogical, linguistic, and accessibility standards. In addition, this study reinforces Febrianti et al.'s (2021) assertion that exposure to well-designed critical thinking questions can improve students' ability to analyze, reason, and make decisions. It also addresses the vocabulary acquisition challenges highlighted by (Hermans, D. et al., 2015) and (Saldaña, D., & Rodríguez-Ortiz, 2023) by

embedding contextual language and images, which have been shown to improve comprehension (Tshering, 2023).

Overall, the results confirm that the developed instrument not only aligns with the curriculum objectives but also addresses the specific sensory and cognitive needs of deaf learners. Future studies could extend this work by conducting small-group and field tests to examine the instrument's reliability further and by exploring its effectiveness in diverse inclusive classroom settings.

CONCLUSION

The number problems, which combine mixed operations and critical thinking skills, were given to deaf students in the context of colored ribbons and consisted of five questions. All of the questions were related to critical thinking skill indicators, such as basic explanation, providing basic skills, drawing conclusions, giving further explanation, and strategy and tactics. The assessment results from validators during the expert review stage and from the teacher of the deaf class indicated that the prototype questions were qualitatively valid. Recommendations and comments regarding language and content (content and construct) were provided to the researcher. Student feedback on the readability of the questions during the one-to-one stage was also taken into account. To evaluate deaf students' critical thinking abilities, assessments can be conducted in the field and in small groups, as well as through a field test.

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