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Development Worksheets with an Intuition-Based Concrete-Representational-Abstract Approach to Facilitate Students' Mathematical Reasoning

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ABSTRAK

Penelitian ini bertujuan untuk mengetahui kelayakan lembar kerja yang disusun dengan pendekatan concrete-representational-abstract (CRA) berbasis intuisi untuk memfasilitasi kemampuan penalaran matematis siswa pada materi bangun ruang sisi datar SMP kelas VIII dan respon siswa ketika menggunakannya. Penelitian yang digunakan adalah penelitian pengembangan model ADDIE dengan instrumen berupa angket penilaian validator dan angket respon siswa. Hasil penelitian ini menunjukkan bahwa lembar kerja siswa dengan pendekatan CRA berbasis intuisi untuk memfasilitasi kemampuan penalaran matematis siswa dinyatakan layak dan memenuhi standar penggunaan media dengan rata-rata persentase ahli media dan ahli matematika sebesar 91,37%. Sementara itu, rata-rata presentase respon siswa pada uji coba terbatas dan uji lapangan sebesar 82% dengan kriteria sangat menarik.

Kata Kunci: Lembar kerja berbasis intuisi; Lembar kerja siswa; Penalaran matematis; Pendekatan concrete representational abstract.

ABSTRACT

This study aims to determine the feasibility of worksheets using the intuition-based Concrete-Representational-Abstract (CRA) approach to facilitate students' mathematical reasoning abilities on the topic of polyhedral shapes for eighth-grade students and to assess students' responses when using these worksheets. The research employed the ADDIE development model with instruments including a validation questionnaire and a student response questionnaire. The results indicated that the student worksheets using the intuition-based CRA approach were highly feasible and met the media usage standards with an average percentage of 91.37% from media and mathematics experts. Meanwhile, the average student response percentage in limited and field tests was 82%, categorized as highly engaging.

Keywords: Concrete representational abstract approach; Mathematical reasoning; Students' mathematics worksheet; Worksheet intuition-based.

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1. INTRODUCTION

Mathematical reasoning ability is a habitual brain activity that must be consistently developed to enhance its efficacy, especially in solving non-routine mathematical problems (Hudiria, Haji, & Zamzaili, 2022; Minggi, Arwadi, & Bakri, 2022). According to Oktaviyanthi & Agus (2020), reasoning is a process of thinking to draw conclusions or make new statements based on previous ones whose validity has been proven. Mathematical reasoning abilities into four levels: (a) Level 1: Not understanding a reasoning process; (b) Level 2: Possessing knowledge of models, facts, properties, and their relationships but unable to make arguments; (c) Level 3: Able to reason and make arguments, although the arguments are still weak; (d) Level 4: Able to make strong arguments to support the results of their reasoning (Jawad, Majeed, & ALRikabi, 2021; Ardiansyah & Wahyuningrum, 2022). According to Çoban and Tezci (2022), a student is said to have mathematical reasoning ability if they can apply reasoning to patterns and properties, manipulate mathematics to draw general conclusions, construct proofs, or explain mathematical ideas and statements. The indicators of mathematical reasoning ability according to Khotimah, Supriani and Oktaviyanthi (2022) include: 1) presenting mathematical statements through writing, drawings, sketches, or diagrams; 2) proposing conjectures; 3) providing reasons for several solutions; 4) examining the validity of an argument; 5) making generalizations. It is hoped that through this pattern, students will find the correct answers. However, Aminah (2020) found that students' mathematical reasoning ability is very low, at 73.66%. One factor contributing to the low mathematical reasoning ability is that many students are not interested in the material presented by teachers, possibly due to the lack of supportive learning media.

Besides mathematical reasoning ability, intuitive thinking ability (intuition) is also essential in mathematics learning (Arnandi dkk., 2023). Although the use of intuition in mathematics can lead to errors in decision-making, numerous studies support the importance of intuition in mathematics learning (Husniah & Azka, 2022; Yunisca & Nasution, 2023). Intuition can enhance problem-solving and is beneficial in determining the first steps to finding a solution (Yohanes, 2021; Putra, Juandi, & Jufri, 2023). Therefore, mathematical reasoning and intuition abilities complement each other in solving mathematical problems (Cahyani & Sritresna, 2023). However, in reality, students are not accustomed to using their intuition to solve mathematical problems. This is consistent with R (2017), who found that students' mathematical intuitive thinking ability is still moderate, at 69.88%. To address this, an approach that encourages students to use their intuition while enhancing their mathematical reasoning is needed. One such approach is the intuition-based Concrete-Representational-Abstract (CRA) approach.

Witzel (Reyes, 2021) describes the CRA method or approach as a learning process that involves students solving mathematical problems by physically manipulating objects, then representing these manipulations through drawings, and finally solving the mathematical problems using abstract notation (Rahmawati & Astuti, 2022; Rahayu, Liddini, & Maarif, 2022). The intuition-based CRA approach involves guiding students through the CRA stages-concrete, representational, and abstract-while incorporating an initial intuitive stage at the beginning of each learning session. Additionally, to facilitate students in thelearning process, an instructional medium (worksheets) is required.

Using worksheets can help students learn the material independently, allowing them not only to focus on what the teacher provides but also to develop what they have received (Iswanto & Faradillah, 2023). However, the worksheets currently in use are less focused on the intuitive aspect, hindering students' reasoning. Therefore, the intuition-based CRA approach is necessary as a guideline in designing activities within the worksheets to facilitate students' mathematical reasoning abilities. These worksheets contain materials, activities, and contextually relevant practice problems, differentiated into two activities aligned with the intuition-based CRA approach, dividing between the intuitive stage and the CRA stage. Through these worksheets, students are expected to systematically train their thinking patterns, indirectly enhancing their mathematical reasoning as they construct their understanding through concrete objects.

2. METHOD

The research method in this study is development research or Research and Development (R&D). The ADDIE model is used in designing the worksheet product. The ADDIE instructional model consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The analysis phase consists of two processes: needs analysis to determine the instructional materials to be developed and curriculum analysis to examine the basic competencies to formulate learning achievement indicators in the topic of flat-sided space. The design phase involves planning and designing the instructional media development. This phase results in the instructional material to be used in learning along with the competency achievement indicators, serving as a guide in creating the worksheet intuition-based CRA approach. Moreover, product design and the development of test and non-test instruments are also conducted in this phase. After the design phase, the development phase involves developing the previously designed product into a complete worksheet. Following product design, validation is conducted by media and mathematics experts. The product is then revised based on feedback and suggestions from the experts to address any deficiencies. The implementation phase involves testing the revised product with students, both in limited and field tests. The final phase, evaluation, reviews the entire process to produce a high-quality worksheet after improvements based on expert feedback and field test results. The following diagram illustrates the development process of the worksheet intuition-based CRA approach to facilitate students' mathematical reasoning abilities (see Figure 1):

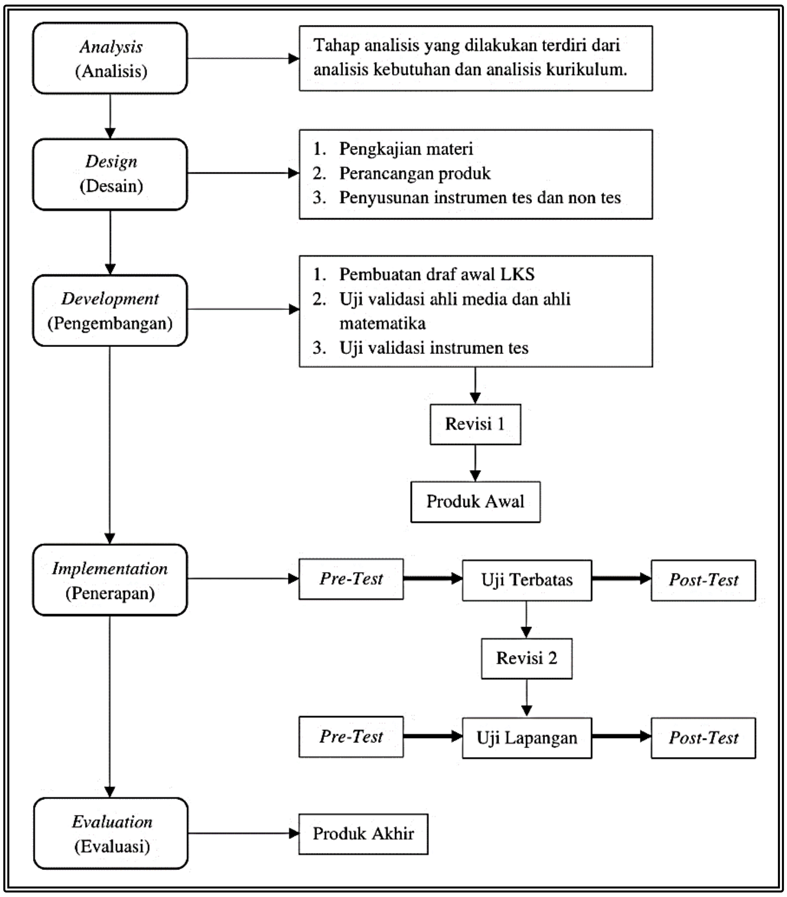


Figure 1. Research Process

The data collection techniques used in this study include expert validation questionnaires referring to the validation questionnaires developed by Oktaviyanthi&Sholahudin (2023) and student response questionnaires referring to the response questionnaires developed by Azrillia et al. (2024). Data on the feasibility assessment of the student worksheets, filled out by validators, and the assessment of the student worksheets' usage, filled out by students, were measured using an interval scale, namely the Likert scale with intervals of 1-4 or a modified Likert scale (see Table 1) (Sugiarnii, 2021).

Table 1. Likert Scale for Expert Evaluation

Category	Score
Very Good (VB)	4
Good (G)	3
Fair (F)	2
Poor (P)	1

To determine the feasibility of the worksheet from the experts' assessments, a rating scale was also used. The rating scale was calculated using the following formula (see Figure 2):

$$P = \frac{Data\ Collection\ Score}{Maxium\ Score} \times 100\%$$

Figure 2. Calculated Formula Rating Score Scale

The next step is to conclude the results by observing the range and product quality criteria as follows (see Table 2) (Wahyuni, 2017).

Table 2. Percentage Range and Product Quality Criteria

Percentage	Criteria
81,25% - 100%	Highly Feasible/ Highly Engaging
62,5% - 81,24%	Feasible/ Engaging
43,75% - 62,49%	Less Feasible/ Less Engaging
≤ 43,74%	Not Feasible/ Not Engaging

3. RESULT AND DISCUSSION

a. Result

1) Analysis Phase Results

a) Needs Analysis

Observations during Classroom Action Research showed that mathematics instruction often used conventional methods, and the use of worksheet in eighth grade only included standard formulas and exercises without activities or questions aimed at developing students' abilities and aiding their understanding of the material. This contributed to students' low mathematical reasoning abilities. Based on these results, this study aimed to develop the worksheet intuition-based CRA approach to facilitate students' mathematical reasoning abilities.

b) Curriculum Analysis

In this phase, the curriculum was analyzed to select the material, focusing on the eighth-grade second semester topic of polyhedral shapes, based on the 2013 Curriculum. This material was chosen due to the learning difficulties students' face, such as calculating the surface area of cubes, cuboids, prisms, and pyramids accurately. Weak mathematical reasoning abilities also hinder understanding, necessitating instructional media to assist students in learning and comprehending polyhedral shapes.

2) Design Phase Results

a) Material Review

This phase involved identifying the core competencies and basic competencies required for developing intuition-based CRA worksheets on polyhedral shapes, aligned with the 2013 Curriculum. The competencies and indicators are outlined in the Table 3.

Table 3. Basic Competencies and Competency

Core Competency (CC)	Competency Achievement Indicator (CAI)
3.9 Distinguish and determine the surface area and volume of polyhedral shapes (cubes, cuboids, prisms, and pyramids)	3.9.1 Draw nets of polyhedral shapes 3.9.2 Calculate the surface area of polyhedral shapes based on the nets of cubes

Core Competency (CC)	Competency Achievement Indicator (CAI)
	3.9.3 Determine the formula for the surface area of polyhedral shapes
1.9 Solve problems related to the surface area and volume of polyhedral shapes (cubes, cuboids, prisms, and pyramids) and their combinations	4.9.1 Solve real-world problems related to the surface area of polyhedral shapes

(As’ ari et al., 2017)

b) Product Design

A storyboard was created as a guide for designing the instructional media. The following is the storyboard for the intuition-based CRA worksheets (see Figure 3).

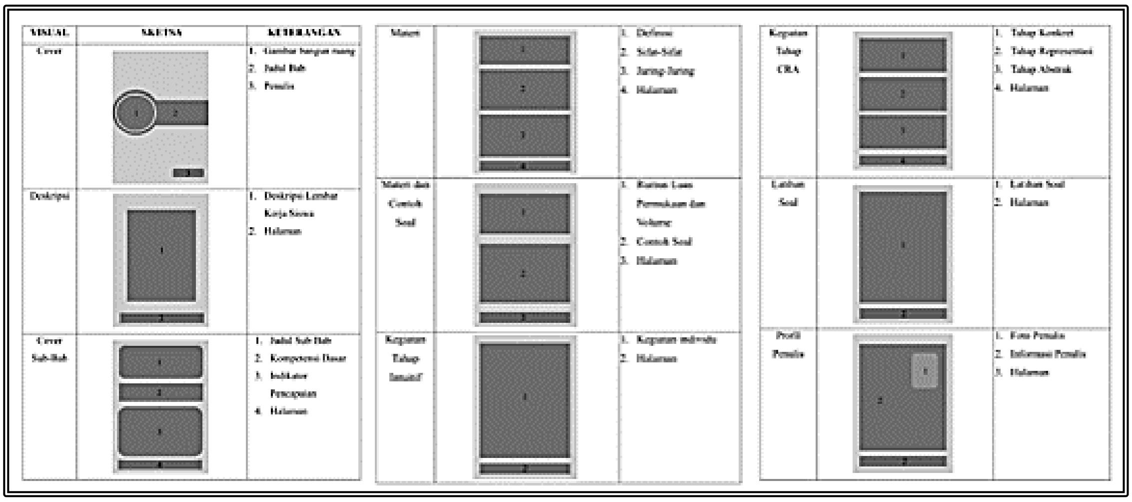


Figure 3. Storyboard

3) Development Phase Results

After designing the product, the next phase involves development. This phase includes creating the instructional media based on the storyboard with the help of the Canva application. The development steps taken by the researcher are as follows:

a) Initial Worksheet Design

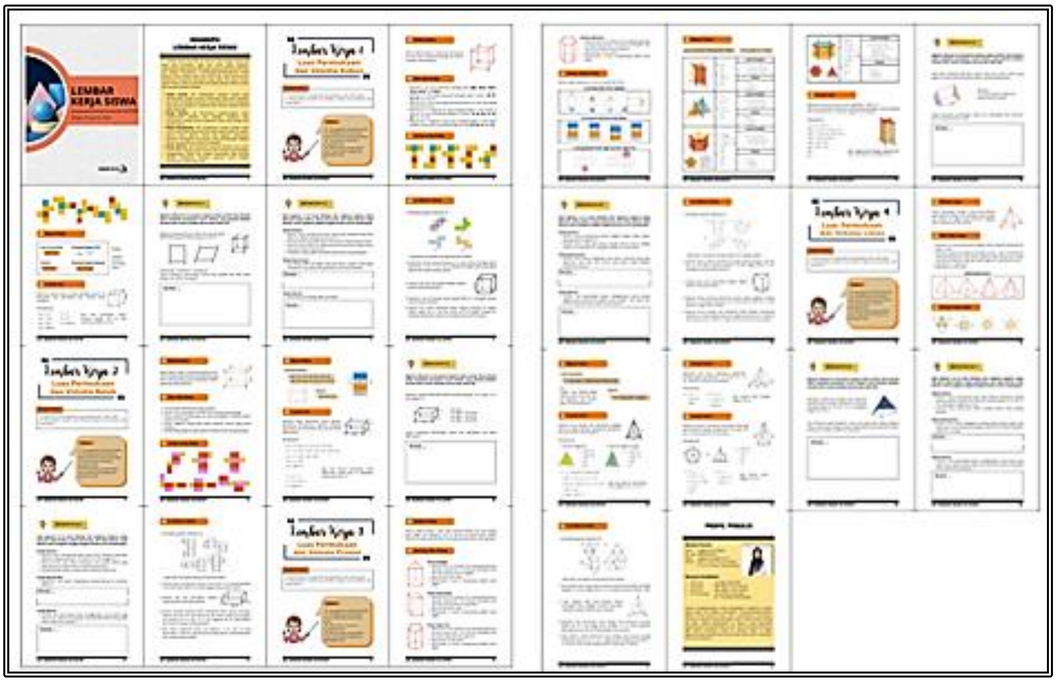


Figure 4. Initial Design of Student's Worksheet

The design of the student worksheets (LKS) was created to be as engaging as possible, with the material presented not only in text but also accompanied by supporting images to aid students in understanding the conveyed content (see Figure 4). The student activities section consists of two stages: the intuitive stage and the CRA stage, each containing problems that students need to solve.

b) Expert Validation

The developed worksheets were validated by media and mathematics experts. The results of the validation are as follows:

Table 4. Media Expert Validation Results

Aspect	Data Score	Max Score	Percentage
Student's Worksheet Cover Design	51	56	91,07%
Student's Worksheet Content	94	104	90,38%
Total	**145**	**160**	**181,46%**
Average	**90,73%**		
Criteria	**Highly Feasible**		

From Table 4, the average percentage rating from both validators is 90.37%, categorized as highly feasible indicating that the intuition-based CRA approach worksheets developed can be used as a mathematics instructional medium. However, some feedback and suggestions were provided by the validators for improving the worksheets, including: 1) Aligning the competencies with the curriculum, 2) Including information about the colors used in the net diagrams, 3) Ensuring that student activities align with the competency achievement indicators.

Table 5. Mathematics Expert Validation Results

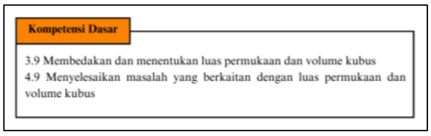
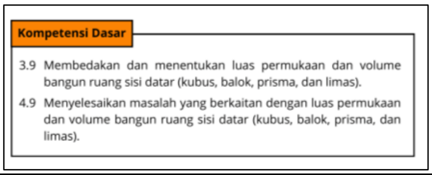
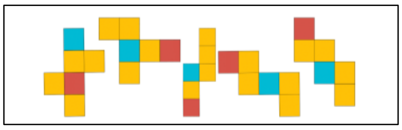
Aspect	Data Score	Max Score	Percentage
Content appropriateness	75	80	94%
Language effectiveness	16	16	100%%
Presentation layout and method	40	48	83%
Total	**131**	**144**	**277%%**
Average	**92%**		
Criteria	**Highly Feasible**		

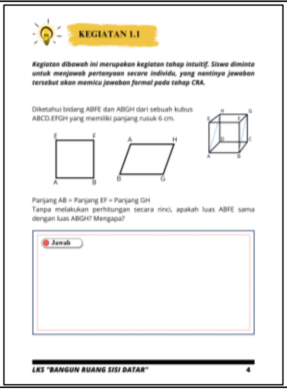
From Table 5, the average percentage rating from both validators is 92%, categorized as very feasible, meaning that the intuition-based CRA approach worksheets developed can be used as a mathematics instructional medium. Nevertheless, some feedback and suggestions were provided by the validators for improving the worksheets, including: 1) Stating the learning objectives, 2) Using contextual problems that align with the mathematical reasoning indicators, 3) Adding materials that correspond with the student activities.

c) Product Revision Results

Based on the validation results from each validator, feedback and suggestions from each validator were implemented to improve the instructional media, making it more effective and suitable for the learning process. Below are the revisions from validators (see Table 6).

Table 6. Product Revision

Aspect	Before	After
Aligning the competencies with the curriculum	 Kompetensi Dasar 3.9 Membedakan dan menentukan luas permukaan dan volume kubus 4.9 Menyelesaikan masalah yang berkaitan dengan luas permukaan dan volume kubus	 Kompetensi Dasar 3.9 Membedakan dan menentukan luas permukaan dan volume bangun ruang sisi datar (kubus, balok, prisma, dan limas). 4.9 Menyelesaikan masalah yang berkaitan dengan luas permukaan dan volume bangun ruang sisi datar (kubus, balok, prisma, dan limas).
Adding information about the colours used in the net diagrams of geometric shapes		

Aspect	Before	After
Ensuring that student activities align with the competency achievement indicators		
Stating the learning objectives		
Including contextual practice problems that align with the mathematical reasoning indicators		

4) Implementation Phase Results

After the validation phase, the product was tested with students alongside the research instruments. This test aimed to determine students' responses to the intuition-based CRA approach worksheets that had been developed. The test was conducted at SMP Negeri 13 Kota Serang with eighth-grade students. This phase included two test activities: a limited test with seven students and a field test with 21 students.

Table 7. Student Response Evaluation Results

Aspect	Data Score	Max Score	Percentage
Limited test			
Worksheet design	158	196	81%
Worksheet content	317	392	81%
Language	93	112	83%
Field test			
Worksheet design	479	588	81%
Worksheet content	956	1176	81%

Aspect	Data Score	Max Score	Percentage
Language	280	336	83%
Total	**2283**	**2800**	**490%**
Average	**82%**		
Criteria	**Highly Engaging**		

Based on Table 7, the evaluation of the student response questionnaires in both the limited and field tests, the worksheets received an average percentage rating of 82%, categorized as highly engaging, indicating that the intuition-based CRA approach worksheets on the topic of flat-sided space developed are suitable for use as a mathematics instructional medium.

5) Evaluation Phase Results

The final phase of the ADDIE development model is the evaluation phase. In this phase, the intuition-based CRA approach worksheets were refined and perfected based on feedback from expert evaluations, limited tests, and field tests. The final product is an intuition-based CRA approach student worksheet to facilitate students' mathematical reasoning abilities, comprising teaching materials, sample problems and solutions, intuitive stage activities, CRA stage activities, and practice problems aligned with the mathematical reasoning indicators. Besides being used by teachers as a teaching aid in the mathematics learning process, especially on the topic of flat-sided space, this instructional medium can also be used by students for independent study. Based on the research results, the developed product is deemed feasible, attractive, and capable of enhancing students' mathematical reasoning abilities. The feasibility validation received a percentage score of 91.37% categorized as very feasible, and student responses received a percentage score of 82% categorized as very attractive.

b. Discussion

Based on the results of the study, the development of student worksheets (LKS) utilizing an intuition-based CRA (Concrete-Representational-Abstract) approach was found to be of high quality by experts and received highly favorable responses from students, both in limited and broader field tests. The worksheet designed with the intuition-based CRA approach includes student activities tailored to the stages of the CRA approach. This approach comprises four stages: the intuitive stage, the concrete stage, the representational stage, and the abstract stage. In the worksheet, the intuition-based CRA stages are divided into two main student activities. The first activity, the intuitive stage, involves individual problem-solving tasks for students. The second activity encompasses the CRA stages, further divided into three interrelated activities: the concrete stage, the representational stage, and the abstract stage. In this second activity, students work in groups. The problems presented in the worksheet are aligned with indicators of mathematical reasoning skills, aiming to enhance students' mathematical reasoning abilities, particularly in the topic of flat-sided geometric shapes.

The indicator of mathematical reasoning chosen for the intuitive stage activities involves making conjectures and providing reasons for solutions. The conjecture indicator is selected to prompt spontaneous responses from students. These spontaneous responses during the intuitive stage are expected to trigger formal answers during the CRA stages.

Figure 5. Intuitive Stage Student Responses

Figure 5 (left side) shows a student's brief yet accurate response to the problem presented, demonstrating an understanding of the concept of the cube's surface area. This indicates the student's ability to make conjectures and provide reasons for solutions. Conversely, Figure 5 (right side) shows another student's response, indicating the ability to make conjectures but providing inaccurate reasoning unrelated to the cube's surface area.

The mathematical reasoning indicators used in the CRA stage activities are as follows:

1) Concrete Stage

At this stage, the selected indicator of mathematical reasoning ability is presenting mathematical statements through sketches. Students create learning aids as part of the learning process using concrete objects. This activity helps students to better understand the concepts related to flat-sided geometric shapes. Through hands-on learning experiences with concrete objects, students can effectively use their reasoning skills to solve problems related to flat-sided geometric shapes. Figure 6 shows the results of the concrete objects created by students in collaboration with their group members.

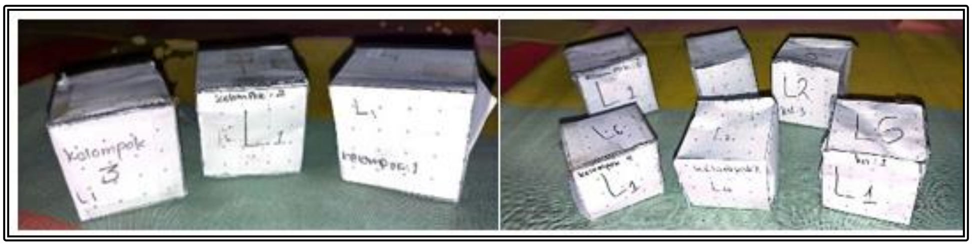


Figure 6. Concrete Stage Student Work

2) Representational and Abstract Stages

At this stage, the selected indicators of mathematical reasoning ability are validating arguments and making generalizations. After providing answers during the representation stage, students validate these answers using formulas appropriate to the given problems. They then proceed to generalize or draw conclusions based on the answers they have obtained. Below is a visual representation of the students' answers from the representation and abstraction stages, completed collaboratively with their group members.

Figure 7. Abstract and Representation Student Work during the Limited Test

In Figure 7, the left side shows the students' answers for the representation stage. The answers given are concise yet correct and relevant to the problem, conveying a clear understanding. The student also demonstrated comprehension of the concept used to determine the surface area of a cube from its nets. From these answers, it can be concluded that the students were able to make conjectures and provide justifications for their solutions. This is followed by the answers at the abstract stage, shown on the right side of Figure 11. These answers serve as validations of the responses given during the representation stage. The formulas used are appropriate, indicating that the students understood the formula for the surface area of a cube based on its nets. Additionally, the students performed generalizations or drew conclusions comprehensively and accurately. These conclusions were derived from the answers obtained in the previous stages. Therefore, it can be concluded that Group 1 was able to validate an argument and perform generalizations effectively.

Based on the above explanation, it is evident that the Student Worksheets (LKS) developed using the intuition-based CRA approach effectively stimulate students' mathematical reasoning abilities in the subject of solid geometry. These worksheets are designed to help students solve real-life problems. Through mathematical reasoning, students can enhance their problem-solving skills, construct proofs, and draw conclusions (Kotto et al., 2022). This research aligns with the findings of Zulfakri et al. (2019), which indicate that the CRA approach leads to better improvements in students' mathematical representation and problem-solving abilities compared to conventional teaching methods. This study also suggests that the CRA approach can be used as an alternative method to enhance mathematical representation and problem-solving skills, particularly for junior high school students. The findings are further supported by research from Zhang et al. (2021) and Al-Salahat (2022), which demonstrated improved student performance in learning geometric shapes using the CRA approach. The students showed enhancements in solving mathematical problems and were able to retain their learning skills after using the CRA approach. Similarly, Prosser & Bismarck (2023) found that teaching with the CRA approach, combined with the use of manipulative methods to minimize dual representations, effectively enhanced knowledge acquisition and retention at the secondary school level. This is reinforced by Yakubova et al. (2020), who concluded that the use of CRA can improve learning by providing clear, concise, and consistent mathematical language instructions that are easily understood by students.

The worksheet intuition-based CRA approach developed has several advantages, including enhancing students' mathematical reasoning abilities through intuitive and CRA stage activities, as well as exercises tailored to mathematical reasoning indicators, capturing students' interest with an attractive design and relevant, engaging images, and promoting active learning and better understanding of the material by allowing students to create visual aids. However, the worksheet intuition-based CRA approach also has some drawbacks, such as higher printing costs due to the extensive use of color in the worksheets, CRA activities in the worksheet require group collaboration, which may not be favored by all students who prefer individual work, and longer implementation time, especially if the classroom arrangement is not well-organized.

4. CONCLUSION

Referring to the research findings and discussions described, the conclusion is that the student worksheets (LKS) with an intuition-based concrete-representational-abstract (CRA) approach achieved an overall percentage of 91.37% in the "Highly Feasible" category. This percentage is derived from the media experts' evaluation, which received 90.73% in the very feasible category, and the mathematics experts' evaluation, which received 92% in the same category. Thus, the developed intuition-based CRA approach worksheets can be used in mathematics education. Student responses to the intuition-based CRA approach worksheets were "Highly Engaging," with an overall response rate of 82%, based on the limited test and field test responses, each receiving 82% in the very attractive category. Therefore, these intuition-based CRA approach worksheets can be used as a medium for mathematics instruction. The recommendations provided by the researchers based on the outlined deficiencies are as follows the CRA approach worksheets can be developed for other subjects while maintaining an attractive design that requires less funding for printing, when conducting product tests, learning groups should be formed by matching the students' abilities to ensure an even distribution of skill levels, and additionally, the student activities in the worksheets should be made more varied while considering the estimated time required for their implementation.

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