Jurnal Elemen, 10(2), 324-340, May 2024
https://doi.org/10.29408/jel.v10i2.25244

e- ISSN: 2442 - 4226

Didactical design to overcome learning obstacles in cuboid volume

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Abstract

This study aims to produce an empirical didactic design designed to overcome didactic barriers experienced by students on beam volume material. Didactical design research is a design in this study that contains three stages of analysis, namely prospective analysis, metapedadidactic analysis, and retrospective analysis. 25 9th-grade junior high school students and one mathematics teacher were selected using purposive sampling techniques to become subjects. Observation, tests using diagnostic tests, and interviews are techniques in data collection. The collected data is analysed and interpreted qualitatively using interpretive and critical paradigms. The results of this study show that through three stages of analysis, an empirical didactic design was obtained that contains four didactic situations: action situations, formulation situations, validation situations, and institutionalisation situations. However, the limitations of presenting problems in institutionalisation situations have an impact on the occurrence of other learning barriers, namely epistemological concepts. Thus, this limitation becomes an improvement material in empirical didactic design.

Keywords: cuboid volume; didactic design; learning obstacle

How to cite: Jamilah, Priskila, & Oktaviana, D. (2024). Didactical design to overcome learning obstacles in cuboid volume. *Jurnal Elemen, 10*(2), 324-340. https://doi.org/10.29408/jel.v10i2.25244

Received: 31 January 2024 | Revised: 24 April 2024
Accepted: 2 May 2024 | Published: 1 June 2024

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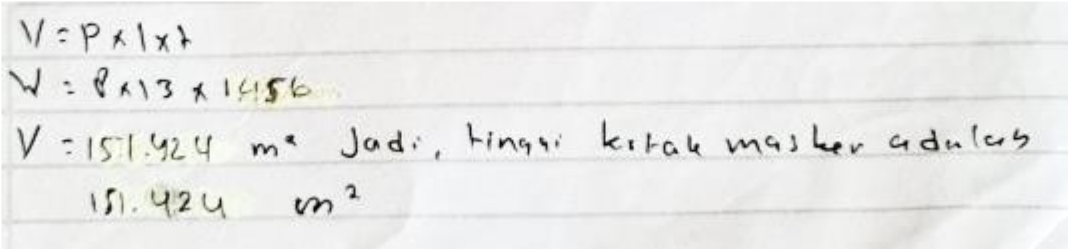
Introduction

The goal of mathematics learning is that students can obtain complete knowledge from the learning process. When students can acquire knowledge, it means that students can demonstrate the systematicity of their thinking processes and can demonstrate the accuracy of the knowledge they have built. However, one factor that can hinder the process of acquiring this knowledge is the existence of learning obstacles. The nation of obstacles appears fundamental to the consideration of the problem of scientific knowledge (Brousseau, 2002). A learning obstacle is a condition where a person cannot follow the learning process properly, which is characterized by the presence of certain obstacles in achieving learning outcomes (Brousseau, 2002; Suryadi, 2019).

Suryadi (2019) states that learning obstacles are caused by three factors. First, ontogenic obstacle, namely a learning obstacle related to mental readiness and cognitive maturity in receiving knowledge. Suryadi (2019) revealed that ontogenic obstacle can be indicated through three factors which include: (a) ontogenic psychological, namely learning obstacles related to students' psychological aspects such as motivation and interest in certain topics, (b) ontogenic instrumental, namely learning obstacles related to technical processes in learning, and (c) ontogenic conceptual, namely learning obstacles related to concepts in the learning process that are not by students' experiences in learning. Second, epistemological obstacles, namely learning obstacles caused by limitations in certain contexts due to not obtaining complete knowledge. According to Nuban, et al. (2020), epistemological obstacles are caused by three indicators which include: (a) epistemological conceptual obstacles, namely obstacles where students are unable to explain and demonstrate a basic concept, (b) epistemological procedural obstacles, namely obstacles where students cannot solve problems in their simplest form and the way to solve the questions instructed is not appropriate, and (c) epistemological operational technique, namely obstacles where students make mistakes in writing and calculating the value of an arithmetic operation. Third, didactical obstacles are obstacles caused by errors in teaching materials that are not by students' thinking processes.

The study of learning obstacles is one of the research topics that is often carried out by several researchers, such as Sari et al (2019) in their research conducting learning obstacle analysis on triangle material, Andani et al (2021) in their research regarding learning obstacle analysis on the concept of geometric series, as well as other researchers like Purnama (2023), and Mahmud et al. (2023). Analysis of learning obstacles for 9^{th}-grade students in cuboid volume material has also been carried out by Priskila et al (2023) in their preliminary study. A total of 2 diagnostic test questions have been given: (1) If the block-shaped mask box is known to have a length of 13 cm, a width of 8 cm, and a volume of 1.456 cm^3, then what is the height of the block?; and (2) A block-shaped pool has a length of 80 dm, a width of 75 dm, and a depth of 10 dm. If 3/4 of the pool is filled with water, then what is the volume of water in the pool?

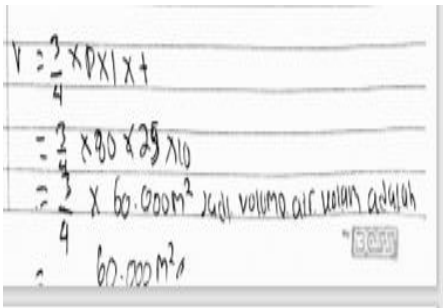
Based on the diagnostic test results, the following results were obtained:



$v = l \times w \times h$
$v = 8 \times 13 \times 1456$
$v = 151{,}924\ m^2$
So, the height of the box is $151{,}924\ m^2$

Figure 1. Student answer to question number 1.

Based on the results of the interview, it was found that the low motivation and ability of students in learning mathematics, and the limitations of students in carrying out the completion procedure were caused by limited understanding of the concept of block volume. From the results of tests and interviews, it was obtained that there are obstacles to student learning, namely ontogenic psychological and epistemological concepts.



$v = \frac{3}{4} \times l \times w \times h$
$= \frac{3}{4} \times 80 \times 75 \times 10$
$= \frac{3}{4} \times 60{,}000 m^2$
So, the volume of water in the pool is $60.000 m^2$.

Figure 2. Student answer to question number 2

Based on the results of the interview, it was found that students' limitations in completing the completion procedure correctly were caused by students not knowing how to simplify number counting operations. In addition, it was also found that there was an inability of students to associate this material with material on number counting operations caused by the limited presentation of prerequisite material, namely number counting operations. This information indicates learning barriers in the form of epistemological concepts, epistemological operational techniques, and didactic obstacles.

To overcome or minimize the occurrence of these learning obstacles, it is necessary to develop a didactic design that is based on these needs. This is in line with the opinion of Khoeruroziqin (2019), Rahmawati et al. (2021), and Jamilah and Winarji (2021), who found that didactical designs designed based on analysis of learning obstacles were proven to be successful in overcoming and minimizing the occurrence of learning obstacles, both ontogenic obstacles, didactical obstacles, and epistemological obstacles.

Similarly, in learning cuboid volumes, it is necessary to develop a didactic design to overcome or minimize the occurrence of learning obstacles. Therefore, in this follow-up study, researchers conducted research, namely the development of a didactic design on cuboid volume material which could not only overcome or minimize learning obstacles but could also facilitate students in gaining knowledge of the concept of cuboid volume as a whole. In contrast to the research of Khoeruroziqin (2019) and Rahmawati et al. (2021), the DDH designed in this research is based on the didactic situation theory which presents 4 didactic situations (Brousseau, 2002) and the theory of didactic transposition through analysis of the transposition of knowledge from scholarly knowledge and knowledge to be taught to taught knowledge (Chevallard & Bosch, 2014).

Methods

Didactical Design Research (DDR) was chosen as the design in this research. This research design was relevant to the needs of this research, where with an interpretive and critical paradigm, the researcher designs a hypothetical didactic design based on the results of the analysis of students' learning obstacles and after implementation the researcher will again carry out an analysis of the students' learning obstacle so that in the end suggestions for improvement will be obtained. To formulate an empirical didactic design, DDR contains 3 steps (Suryadi, 2010; 2013), as in Figure 3.

At the prospective analysis stage, the preparation of a hypothetical learning trajectory (HLT) and hypothetical didactic design (DDH) is carried out. The preparation of HLT and DDH is based on the findings of student learning barriers in previous beam volume learning. DDH was developed to overcome or minimize the occurrence of obstacles for students. Furthermore, DDH implementation was carried out on cuboid volume learning. At the metapedadidactic analysis stage, an analysis of the results of DDH implementation is carried out based on the didactic triangle point of view. This analysis is carried out by looking at the relationship between teacher and student (pedagogic relationship), the relationship between student and material (didactic relationship), and the relationship between teacher and material (pedagogic didactic anticipation). In the final stage, namely the retrospective analysis stage, an analysis is carried out based on the results of reflection and evaluation by looking at the relationship between prospective analysis and metapedadidactic analysis. Specifically, an analysis was carried out to see the suitability between the didactic situation designed in the hypothetical didactic design with the didactic situation that occurred during the implementation of the didactic design, as well as to see the compatibility between the HLT design and the learning trajectory (LT) that occurred during implementation (Jamilah, 2021). The final result of this analysis will be obtained from empirical didactic design formulation (DDE).

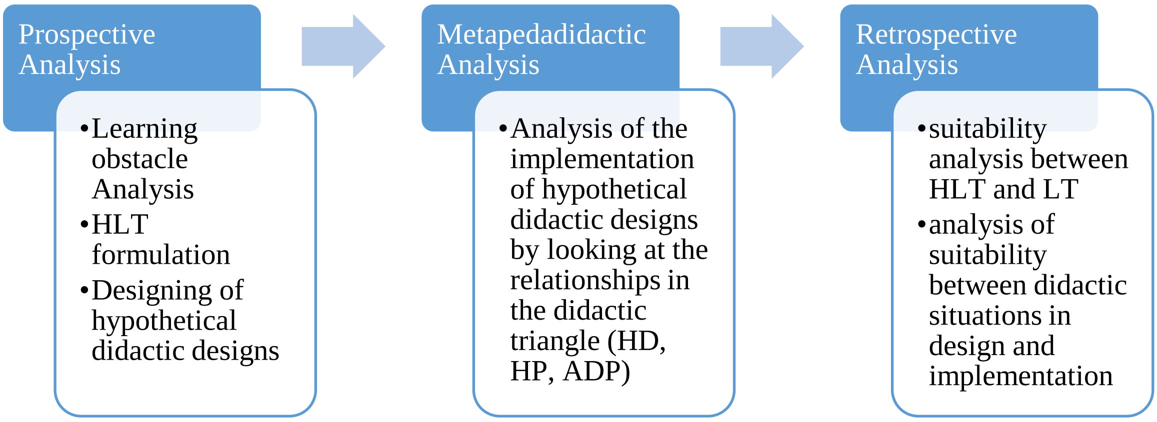


Figure 3. DDR research design chart

Furthermore, using the principle of positive sampling, 25 9th-grade students were obtained as the subjects of this research and a mathematics teacher who taught volume of cubes and cuboids (Moleong, 2012; Creswell, 2012; Freankel et al. 2012). Data collection techniques consist of observation, in-depth interviews (Marshall & Rossman, 2016; Moleong, 2012), and tests (Cohen et al, 2007) with data collection tools consisting of observation guidelines, interview guidelines, and diagnostic tests. Furthermore, the data was processed through the managing and transcription process, analyzed, and then interpreted (Marshall & Rossman, 2016). The data validity technique used is data and theory triangulation techniques (Mok & Clarke, 2015).

Results

The results of this research are presented based on the steps of this research, namely: prospective analysis, metapedadidactic analysis, and retrospective analysis.

Prospective analysis

The results of the analysis in a preliminary study previously carried out by Priskila et al. (2023) became the basis for this researcher in formulating a hypothetical learning trajectory (HLT) and hypothetical didactic design (DDH). After conducting a study of the concept of cuboid volume based on scholarly knowledge and the material presented in the curriculum, the HLT was then formulated as presented in Table 1.

Table 1. Hypothetical Learning Trajectory (HLT)

Concept	Didactic Step	Learning Activity	Learning Objectives
Prerequisite Concepts	Explore initial understanding of the concept of number calculation operations and algebraic calculation operations.	Through question-and-answer activities, students are presented with problems related to number calculation operations and algebraic calculation operations.	Students can recall and understand the concept of number calculation operations and algebraic calculation operations and relate them to the concepts they will study next.

Concept	Didactic Step	Learning Activity	Learning Objectives
Prerequisite Concepts	Exploring students' initial understanding of the concept of volume, the concept of cuboid based on the differences in characteristics with cubes.	1. Through question-and-answer activities, students are presented with problems regarding the definition of volume. 2. Through group discussions, students are presented with a problem (**Problem I**) to understand the concept of cuboids based on their characteristics and differences with cubes.	Students can recall and understand the concepts of volume and cuboid and use this understanding in studying the concept of volume of cuboid.
Core concept	Determining the Volume of a Cuboid	Students are presented with a problem (**problem II**), namely determining the volume of block ABCD.EFGH if the length, width, and height are known.	Students can determine the cuboid volume.
Core concept	Determine the formula for the length of one edge of the cuboid.	Students are presented with a problem (**problem III**) namely determining the length of edge BF of beam ABCD.EFGH if the volume, edges AB, and BC are known.	Students can reduce the formula for the volume of a block into a formula for the length, width, or height of a block using algebraic operations.
Core concept	Resolving contextual problems related to cuboid volume	Students are presented with contextual problems (**problem IV and problem V**) and are asked to solve the problem using the concept of cuboid volume that has been studied.	Students can develop their knowledge of the concept of cuboid volume by solving a variety of relevant contextual problems.

The HLT created is the basis for formulating DDH (see Figure 4). This DDH is presented in the form of a Learning Implementation Plan which is equipped with a Student Worksheet. The didactic situations presented in this lesson plan contain 4 didactic situations, namely action situations, formulation situations, validation situations, and institutionalization situations. In action situations and formulation situations, students are presented with 3 problems (problems I, II, and III) which guide students to construct their knowledge about the cuboid volume and implement them in solving problems.

The Hypothetical Learning Trajectory (HLT) map is presented in Figure 4.

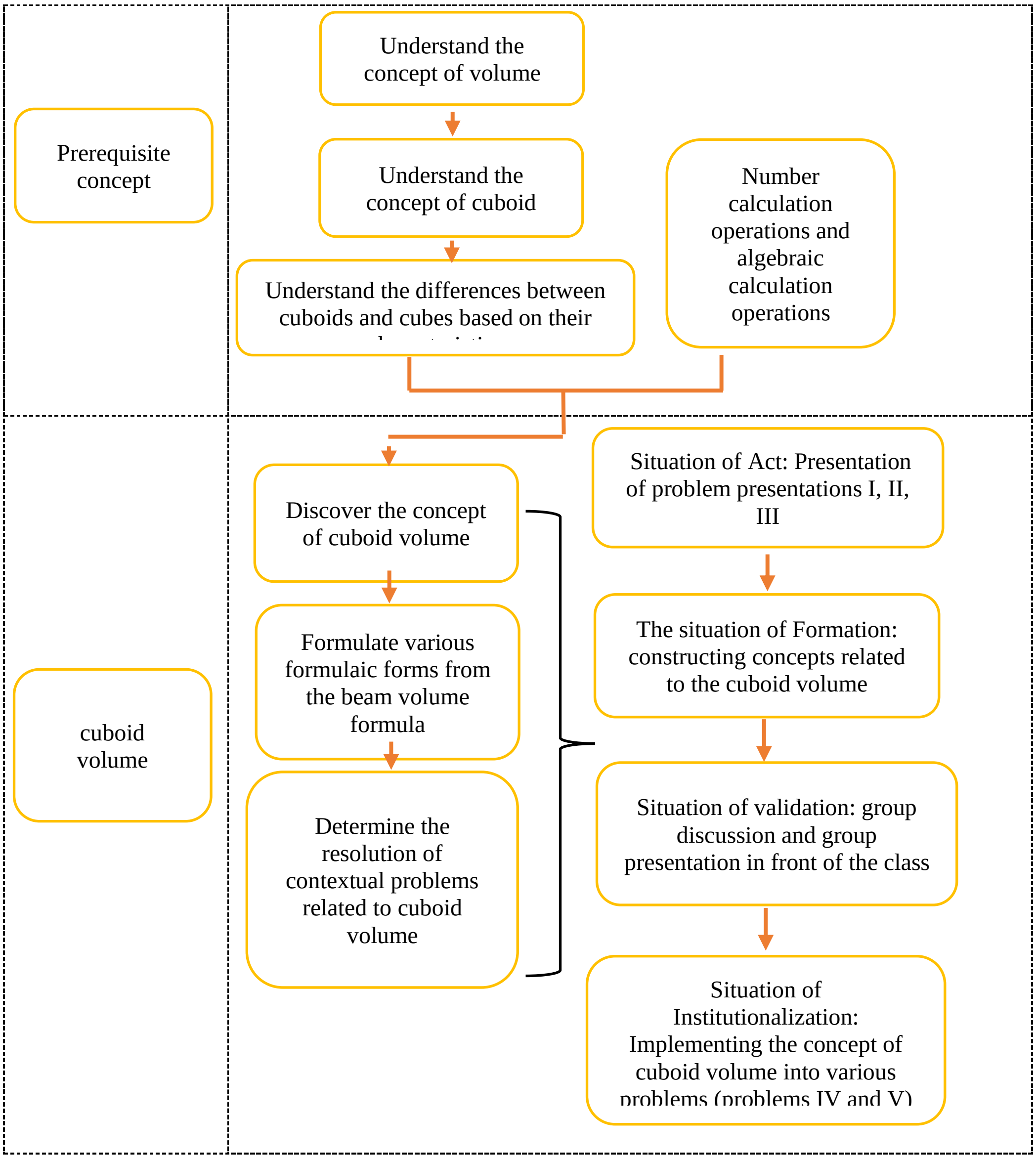
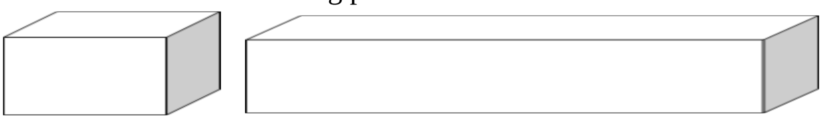


Figure 4. Hypothetical Learning Trajectory (HLT)

Problem I. Look at the following picture!



(a) (b)

Based on the two pictures above, determine which of the objects above is a block? Determine the reason!

Problem I is given to explore the basic concept of cuboids by identifying the differences between cuboids and cubes based on their characteristics.

Problem II. If one of the image objects in problem I is block ABCD.EFGH which is known to be AB = 2 cm, BC = 3 cm, and BF = 4 cm, then how to determine the volume of block ABCD. EFGH?

Problem II is given to stimulate students in constructing the concept of cuboid volume.

Problem III. If a block ABCD.EFGH has a volume of 120 cm^3, length AB = 5 cm, and BC = 6 cm, so what is the length of BF?

Problem III is given to stimulate students' thinking to determine the length of one edge on a beam if the volume is known and the length of the other 2 edges using the concept of algebraic arithmetic operations. This problem is presented to minimize the occurrence of epistemological concepts as happened in previous research, where students had difficulty solving problems like this due to the limitations of the concepts being studied.

In the validation situation, students are asked to present their learning results in solving problems I, II, and III given. This didactic situation is presented to validate the concept construction process that students have carried out. The validation process is also carried out after students have completed problems IV and V.

Furthermore, in the institutionalization situation, students are presented with 2 new problems, namely problems IV and V.

Problem IV. A block-shaped bathtub is 3/4 filled with water. If the length of the pool is 80 cm, the width is 75 cm, and the height is 10 cm. So, what is the volume of water in the bathtub?

Problem V. A tub in the form of a block measuring 150 cm x 75 cm x 60 cm, filled to the brim with water. It turns out that the bathtub was leaking so the water level was 35 cm, so how much water was lost?

Problems IV and V are given to stimulate students' thinking processes in implementing the concept of cuboid volume in solving problems with a variety of contextual problems.

Metapedadidactic analysis

At this step, an analysis of the didactic situation during the implementation of DDH was carried out by looking at the didactic triangle relationships, namely: didactic relationships (HD), pedagogic relationships (HP), and pedagogical didactic anticipation (ADP).

Action situation

In this situation, students are given 3 problems, namely problems I, II, and III as explained in the previous section.

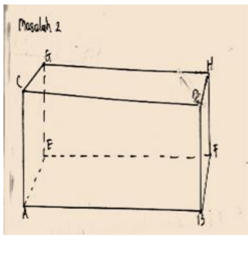
Formulation situation

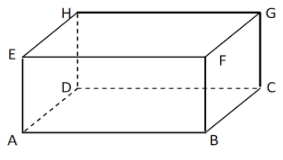
In this situation, students in groups are asked to solve 3 given problems. The problem I am given with the aim is that with the initial knowledge they have regarding the concept of a cube, students can understand the concept of cuboids by comparing the different characteristics of cuboids and cubes. Furthermore, Problem II is given to make students able to construct their knowledge regarding the concept of cuboid volume. Meanwhile, problem III is given with the aim that students can develop their knowledge using the knowledge they have regarding the concept of cuboid volume. In this case, students are asked to be able to determine the formula to calculate one edge length if the volume and length of the other edge are known.

Validation situation

To ensure the accuracy of problem-solving and the accuracy of the concepts constructed by students, the results of student work need to be validated. This validation process is carried out both during group discussions and during presentations. In solving problem I, students did not experience difficulties. This is possible because, before the problem I was given, the teacher had first explored students' initial knowledge about the concept of cubes and their characteristics. This didactic situation can help students to more easily identify the characteristics of cuboids based on their differences with the characteristics of cubes. From the validation process carried out, it was found that students understood: "A cuboid is a 3-dimensional geometric shape that has 3 pairs of opposite sides, and each pair of opposite sides is the same size."

Furthermore, based on the validation process in solving problem II, it was found that students understood that volume is the amount of space contained in an object. Based on their initial knowledge of the concept of cube volume, students understand that the volume of a block is the product of the length, width, and height of the geometric figure. However, in the process of solving problem II, student responses showed that students were still wrong in naming spatial shapes as seen in Figure 2, resulting in errors in determining the cuboid volume both conceptually and procedurally. In the question, the length of BC is the width of the beam, but based on the representation of students' answers, the length of BC is the diagonal of the plane of the beam. Based on the student's responses, the teacher provides scaffolding as ADP by conducting questions and answers to help students represent the ABCD.EFGH block image according to the correct writing rules, as in Figure 5.





(a) **(b)**

Figure 5. (a) Representation of the ABCD.EFGH cuboid according to students; (b) Representation of the expected ABCD.EFGH cuboid

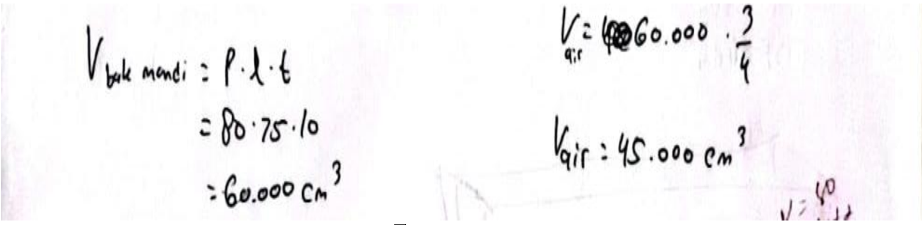
Based on the validation process for solving problem III, it was found that students did not experience problems in solving the problem. This is possible because at the beginning of the lesson, the teacher reminded us of the concept of algebraic calculation operations which is the basic concept for solving problem III. By using the concept of algebraic arithmetic operations, students can modify the formula:

$$v = p \times l \times t \text{ to become } t = \frac{v}{p \times l} \text{ or } p = \frac{v}{t \times l} \text{ or } l = \frac{v}{p \times t}, \quad (1)$$

with v: cuboid volume, p: cuboid length, t: cuboid height, and l: cuboid width.

Institutionalization situation

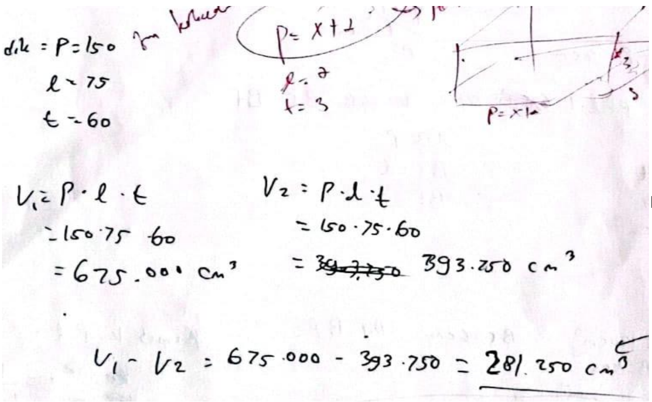
After students can formulate the concept of cuboid volume and validate it as knowledge, in this situation the teacher gives problems IV and V which aim to develop students' thinking abilities in implementing the concept of cuboid volume in various problems. From the results of solving problems IV and V, there were no difficulties experienced by students. This condition can be seen from the students' answers as in Figure 6. This condition is because the potential difficulties that students can experience in solving problems IV and V have been anticipated by the teacher by providing scaffolding in the form of questions and answers to stimulate students' reasoning.



$$\begin{aligned} Vpool &= p.l.t \\ &= 80.75.10 \\ &= 60.000\ cm^3 \end{aligned}$$

$$\begin{aligned} Vwater &= 60.000.\frac{3}{4} \\ Vwater &= 45.000\ cm^3 \end{aligned}$$

(a)



Known : $p = 150$
$l = 75$
$t = 60$

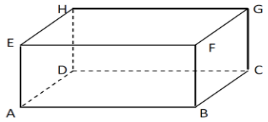
$$\begin{aligned} v_1 &= p.l.t \\ &= 150.75.60 \\ &= 675.000\ cm^3 \\ v_2 &= p.l.t \\ &= 150.75.60 \\ &= 393.750\ cm^3 \\ v_1 - v_2 &= 675.000 - 393.750 \\ &= 281.250\ cm^3 \end{aligned}$$

(b)

Figure 6. (a) Results of solving problem IV; (b) Results of solving problem V

After implementing the DDH, a diagnostic test was carried out to measure students' understanding of the knowledge they had on the concept of cuboid volume, as well as to measure the extent to which the hypothetical didactic design minimized the occurrence of learning obstacles. 2 description questions are given as the diagnostic test.

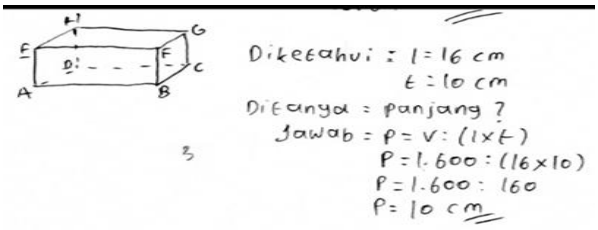
Question 1. Look at the picture below!



If the volume of block ABCD.EFGH is 1,350 cm^3, the length of AE = 15 cm, and the length of EH = 9 cm. What is the length of the HG?

Problem 2. If a block-shaped tub has a width of 16 cm, a height of 10 cm, a volume of 1,600 cm^3, and half of the tub is filled with water, then what is the length of the tub of water?

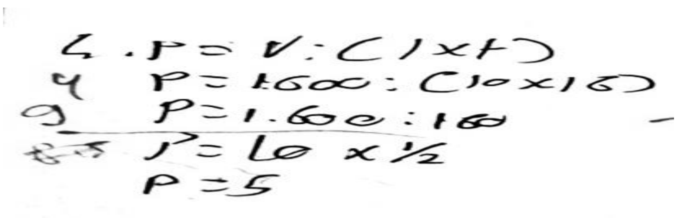
The results of diagnostic tests given to 25 of 9th-grade students after learning showed results related to student understanding. Based on the test results, students can solve the problem in question number 1. This is because, in the learning process, students have gained learning experience to be able to solve similar problems. However, it is different from the problem in question number 2. Students still found difficulties in solving question number 2. Some student test results are shown in Figures 7 and 8.



Known: $w = 16\ cm$
$h = 10\ cm$
Asked: length?
Answer: $l = v : (w \times h)$
$l = 1.600 : (16 \times 10)$
$l = 1.600 : 160$
$l = 10\ cm$

Figure 7. Diagnostic test results for undergraduate students on question number 2

Figure 7 shows that students are not yet complete in solving the problems given. Even though the final result is that the student's work shows the correct answer, conceptually there are still errors. S1 is limited to determining the length of the water tank with a normal (full) volume size. After conducting interviews, information was obtained that S1 was not detailed enough in identifying the information provided from the questions and S1 had not optimally represented the editing of the questions into mathematical sentences. S1 does not understand how long the water tub is by using the information "half of the tub is filled with water". Based on this, it was found that the learning obstacle that occurred was the epistemological concept.



$l = v : (w \times h)$
$l = 1.600 : (16 \times 10)$
$l = 1.600 : 160$
$l = 10\ \times 1/2$
$l = 5$

Figure 8. S2 student diagnostic test results on question number 2

Furthermore, Figure 8 also shows errors in solving the given problem, both conceptually and procedurally. In the context of this problem, the length of the water tank should remain 10 cm. If the water tank is half filled with water, then the variables that remain constant in value are width and length, while the variables that change in value are volume and height. If the water tank is only half filled, then the initial volume (V_0) is 1,600 cm^3 to V_a = 800 cm^3, and the height of the tank (t_0) 10 cm becomes t_a = 5 cm. Thus, the length of the water tank after being filled with water up to half the tub is

$$P_a = \frac{V_0}{(l \times t_a)} \tag{2}$$

After conducting interviews, information was obtained that this student's difficulties were caused by never having faced such a problem. This shows the existence of epistemological concepts and also didactic obstacles.

Retrospective analysis

At this step, an analysis is carried out to see the suitability between the didactic situation in the hypothetical didactic design (prospective analysis) and the didactic situation during the implementation of the hypothetical didactic design (metapedadidactic analysis), as well as an analysis to see the suitability between HLT (prospective analysis) and the existing learning trajectory (LT) arise during the implementation of a hypothetical didactic design (metapedadidactic analysis).

Learning obstacle

At prospective analysis, learning obstacles occur when given a diagnostic test with problem types such as problems III and IV: Ontogenic physical, epistemological concept, epistemological operational technique, and didactic obstacle. While at metapedadidactic analysis, learning obstacles that occur when given problems I, II, III, IV, V: none. Learning obstacles that occur when given a diagnostic test with a higher level of difficulty (test question number 2): epistemological concept and didactic obstacle

Learning trajectory

Overall, the LT that occurred was by the HLT that had been designed. However, to improve the prerequisite concepts, it is necessary to check and re-understand how to write the names of geometric shapes correctly (eg block ABCD.EFGH), as well as how to change word problems into mathematical sentences.

Didactic situation

Overall, the didactic situation that occurred during implementation was the designed didactic situation. During implementation, 4 didactic situations (action situation, formulation situation, validation situation, and institutionalization situation) went according to design. However, in preparing improvements to the empirical didactic design, several things need to be added: 1) response predictions and ADP are added according to the student responses that emerge when implementing the hypothetical didactic design, 2) if the didactic situation and problems presented in the hypothetical didactic design are successful in overcoming learning. obstacles that occurred previously, then for didactic situations and problem presentation in empirical didactic design it is necessary to present more complex problems and non-routine problems so that students get a more complete learning experience and can encourage students to develop reasoning abilities as well as an effort to minimize the emergence of new learning obstacles

Discussion

This research was carried out through three steps of analysis contained in DDR. At the prospective step, HLT and DDH have been designed based on the need to minimize the occurrence of obstacles to student learning, as occurred in the previous learning of cuboid volumes. In previous cuboid volume learning, it was found that there were student learning obstacles including ontogenic physiological obstacle, epistemological concepts, epistemological operational technique obstacle, and didactic obstacle. This learning barrier is considered to be the cause of students' learning obstacles in obtaining complete knowledge.

Apart from being based on the need to overcome students' learning obstacles, HLT and DDH were also designed based on the results of researchers' studies on the presentation of concepts according to scholarly knowledge and the presentation of material according to the school curriculum through a didactic transposition process. This is important so that the concepts learned and understood by students do not have gaps with their formal concepts. This is in line with what was stated by Jamilah et al (2021) who stated that didactic transposition analysis became the basis for compiling a new HLT which will serve as a framework for designing didactic situations in the form of didactic designs.

The designed DDH contains four didactic situations which refer to the didactic situations proposed by Brousseau (2002), namely action situations, formulation situations, validation situations, and institutionalization situations. Jamilah & Winarji (2021) found that through four didactic situations, students were facilitated to carry out the triadic cycle, and students were able to build mathematical objects consisting of concepts and proof of the concept of the arc length of a circle. On the other hand, Sumita et al. (2022) found that not implementing four didactic situations properly had an impact on the occurrence of epistemological obstacles. So by presenting 4 didactic situations in DDH, students are facilitated in gaining knowledge of the cuboid volume.

After HLT and DDH were designed and implemented, findings were obtained which showed that the four didactic situations presented were able to present didactic situations that could help students to construct their knowledge on the concept of cuboid volume well. These results can be seen from the student's ability to understand the concept of cuboid volume, modify the cuboid volume formula, and solve various problems (problems I to problem V) given during the learning process. Another finding is that the implementation of DDH can overcome learning obstacles that occurred in previous cuboid volume learning. In other words, in learning the cuboid volume there are no ontogenic physiological obstacles, epistemological concepts, epistemological operational technique obstacles, and didactic obstacles. The results of this research are in line with research proposed by Pramuditya et al (2021) which found that didactical situations designed through didactic design can anticipate students' learning obstacles in algebraic form material and facilitate students' thinking process.

After presenting the 2 problems in the diagnostic test again, it was found that students were able to understand and solve the first problem using the concept of cuboid volume that had been studied, but students had difficulty solving the second problem. Where in solving the second problem, students are faced with a didactic situation that requires them to carry out a thinking and reasoning process. Meanwhile, in the learning process, students have not been intensively exposed to these didactic situations. This shows that there are learning obstacles caused by limited problem contexts presented during the learning process yang (epistemological concept) and limited didactic situations that can facilitate students to develop high-level thinking skills (didactical obstacle) (Sulastri, et al. 2022; Sidik, et al. 2021).

Therefore, to complement the didactic design that was developed, the empirical didactic design was supplemented with the presentation of a variety of more complex problems to facilitate students developing high-level thinking skills.

Conclusion

This research has shown that DDR obtained an empirical didactical design (DDE) which contains four didactic situations including action situations, formulation situations, validation situations, and institutionalization situations. This DDE has facilitated students to construct their knowledge on the concept of beam volume. The implication of implementing DDE is that student learning barriers such as ontogenic psychological, epistemological operational techniques, and didactical obstacles can be overcome.

The results of this study also show that there are still limitations in the presentation of problems in institutionalization situations which then have an impact on limitations on students in developing their knowledge, especially in solving various problems related to block volume. In other words, the limited presentation of this problem is a factor causing the occurrence of epistemological concepts. The limitation of the presentation of this problem is a supplementary note for improvements in the formulation of this DDE.

Acknowledgment

The authors would like to thank all parties who have helped in this research, especially mathematics teachers and 9th-grade students who have been sources of data in this research.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completed by the authors.

Funding Statement

This work received no specific grant from any public, commercial, or not-for-profit funding agency.

Author Contributions

Jamilah: Conceptualization, writing - original draft, editing, and visualization; **Priskila:** Writing - review & editing, formal analysis, and methodology; **Dwi Oktaviana:** Validation and supervision.

References

Andani, M, Jamilah, & Hartono. (2021). Didactical obstacle siswa kelas ix pada materi deret geometri [Didactical obstacles of 9th-grade students on geometric series material]. *Journal of Innovation Research and Knowledge*, *1*(5), 887-894. https://doi.org/10.53625/jirk.v1i5.482

Brousseau, G. (2002). *Theory of didactical situations in mathematics*. Kluwer Academic Publisher.

Chevallard, Y. & Bosch, M. (2014). Didactic transposition in mathematics education. In Lerman S. (Eds.), *Encyclopedia of Mathematics Education (pp.170-174)*. Springer, Dordrecht.

Cohen, L., Manion, L. & Morrison, K. (2007). *Research methods in education (6th ed.)*. Routledge.

Creswell, J. W. (2012). *Educational research. planning, conducting, and evaluating quantitative and qualitative research (4th ed.)*. Pearson Education, Inc.

Freankel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education (8th ed.)*. McGrow-Hill Componies, Inc.

Jamilah & Winarji, A. (2021, Desember 11). *Pengorganisasian situasi didaktis dalam pembelajaran panjang busur lingkaran [Organizing didactic situations in the learning of the length of the circle arc*] [Conference session]. Didactical Design Research Conference, Semarang, Indonesia.

Jamilah. (2021). *Proses transposisi didaktik mahasiswa calon guru matematika melalui didactical design research pada materi himpunan [The process of didactic transposition of prospective mathematics teacher students through didactical design research on set material]* [Unpublished doctoral dissertation]. Universitas Pendidikan Indonesia.

Jamilah, Suryadi, D., & Priatna, N. (2021). Analysis of didactic transposition and hlt as a rationale in designing didactic situation. *Proceedings of 4th Sriwijaya University Learning and Education International Conference*. Advances in Social Science, Education, and Humanities Research. Atlantis Press. Vol 513: 567-574.

Khoeruroziqin, E. M. (2019). Desain didaktis materi luas permukaan dan volume balok mts n 1 majalengka kelas 8 [Didactic design of material surface area and volume in 8th grade MTs N 1 Majalengka]. *PEDIAMATIKA: Journal of Mathematical Science and Mathematics Education*, *1*(3), 55-64. https://www.syekhnurjati.ac.id/jurnal/index.php/pmat/article/viewFile/5865/2848

Lutfi, M. K., Juandi, D. & Jupri, A. (2021). Student ontogenic obstacle on the topic of triangle and quadrilateral. *Journal Of Physics. Conference Series*. *1806*(1), 012108. https://doi.org/10.1088/1742-6596/1806/1/012108

Mahmud, M. R., Turmudi, Sopandi, W., Rohimah, S. M., & Pratiwi, I. M. (2023). Learning obstacles analysis of lowest common multiple and greatest common factor in primary school. *Jurnal Elemen*, 9(2), 440-449. https://doi.org/10.29408/jel.v9i2.12359

Marshall, C. & Rossman, G. B. (2016). *Designing qualitative research (6th Ed.)*. Sage Publication.

Moleong, L. J. (2012). *Metodologi penelitian kualitatif [Qualitative research methodology]*. Penerbit PT Remaja Rosdakarya Bandung.

Mok, I. A. C., & Clarke, D. J. (2015). The contemporary importance of triangulation in a post-positivist world: examples from the learner's perspective study. In Bikner-Ahsbahs et al. (Eds.), *Approaches to Qualitative Research in Mathematics Education.* Springer.

Nuban, A., Sugiatno, & Nursangaji, A. (2020). Hambatan siswa dalam menyelesaikan soal bentuk pangkat berdasarkan kriteria kesalahan Watson di SMA [Student barriers in solving rank form questions based on Watson's error criteria in high school]. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa*, 9(7), 1-10. https://doi.org/10.26418/jppk.v9i7.41746

Pramuditya, S. A., Noto, M. S., & Handayani, V., D. (2021). Desain didaktis konteks fabel berbasis pemahaman matematis siswa pada materi aljabar [Didactic design of fable contexts based on students' mathematical understanding of algebraic material]. *Jurnal Elemen, 7*(1), 68-83. https://doi.org/10.29408/jel.v7i1.2730

Priskila, Jamilah, & Oktaviana, D. (2023). analisis learning obstacle siswa smp pada materi volume kubus dan balok [Analysis of learning obstacles of junior high school students on cube and block volume material]. *Journal of Comprehensive Science*, *2*(6),1656-1663.

Purnama, S. D., Fadillah, S., & Jamilah. (2023). Analisis learning obstacle siswa pada materi pembelajaran himpunan siswa kelas 7 SMP Negeri 4 Sungai Ambawang [Analysis of student learning obstacles on learning materials for 7th grade student association of SMP Negeri 4 Sungai Ambawang]. *Juwara Jurnal Wawasan dan Aksara*, *3*(1), 43-56. https://doi.org/10.58740/juwara.v3i1.46

Rahmawati, E., Pranata, O. H., & Lidinillah, D. A. M. (2021). Desain didaktis materi volume kubus dan balok berbasis teori van hiele untuk mengatasi learning obstacle siswa [Didactic design of volume materials, cubes and blocks based on van Hiele theory to overcome student learning obstacles]. *Pedadidaktika: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar*, *8*(3), 780-791.

Sari, W., Fauziah, F., & Jayanti, J. (2019). Analisis learning obstacle materi segitiga pada siswa SMP Kelas 7 [Analysis of learning obstacle triangle material in junior high school of 7th-grade students]. *Jurnal Inovasi Pendidikan Matematika*, *2*(1), 21-29. https://doi.org/10.31851/indiktika.v2i1.3394

Sidik, G. S., Suryadi, D., & Turmudi.(2021). Learning obstacle on addition and subtraction of primary school students: analysis of algebraic thinking. *Education Research International*, 5935179. https://doi.org/10.1155/2021/5935179

Sulastri, R., Suryadi, D., Prabawanto, S., & Cahya, E. (2022). Epistemological obstacles on limit and functions concepts: a phenomenological study in online learning. *Mathematics teaching research journal*, *14*(4), 84-106.

Sumita, W., Jamilah, & Muchtadi. (2022). analisis situasi didaktis berdasarkan teory of didactic situation materi kubus dan balok [Analysis of didactic situation based on the theory of didactic situation cube and beam material]. *Jurnal Pendidikan Matematika Indonesia*, *7*(2), 67-72. http://dx.doi.org/10.26737/jpmi.v7i2.3414

Suryadi, D. (2010, November 13). *Didactical Design Research (DDR) dalam pengembangan pembelajaran matematika [Didactical Design Research (DDR) in the development of* *mathematics learning]* [Conference Session]. Seminar Nasional Pembelajaran MIPA UM Malang, Indonesia.

Suryadi, D. & Suratno, T. (2013). *Metapedadidaktik dan Didactical Design Reseach (DDR) dalam implementasi kurikulum dan praktik lesson study [Metapedadidaktik and Didactical Design Research (DDR) in curriculum implementation and lesson study practice]*. Seminar Nasional FMIPA Universitas Negeri Surabaya, Indonesia.

Suryadi, D. (2019). *Landasan filosofi penelitian desain didaktis [Foundations of didactic design research philosophy]*. Pusat Pengembangan DDR Indonesia.