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# Overcoming learning obstacles in cylinder and cone volume: A didactic design research approach

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## Abstract

Many students encounter learning obstacles when understanding the volume of cylinders and cones; however, few studies have explicitly integrated these obstacles into didactic design. This study aimed to develop a didactic design to address specific learning obstacles in understanding the volume of cylinders and cones. Using a Didactic Design Research (DDR) approach grounded in Brousseau's Theory of Didactic Situations, the study involved 28 seventh-grade students and a mathematics teacher from a junior high school in Pontianak, selected through purposive sampling. Data were collected through observations, diagnostic tests, and interviews and then analyzed qualitatively using interpretative and critical techniques. The didactic design consisted of four didactic situations: action, formulation, validation, and institutionalization, implemented in classroom practice. The institutional phase revealed several limitations, particularly a lack of sufficient scaffolding and inadequate visual support for students' spatial reasoning. The findings indicate that addressing epistemological obstacles, such as misconceptions regarding the interpretation of height and base area in three-dimensional solids, can enhance students' conceptual understanding. The study suggests that integrating learning obstacle analysis into didactic design helps refine future implementations to better anticipate students' cognitive development.

**Keywords:** cylinder and cone volume; didactic design; learning obstacles

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## Introduction

Diagnostic data revealed that 21 of 28 students (75%) exhibited procedural errors when solving cylinder and cone volume problems involving unit conversions and fraction operations (Agustini & Fitriani, 2021). Furthermore, students do not fully understand the underlying concepts and formulas related to these two solids (Solin et al., 2023). When teaching the volume of cylinders and cones, teachers tend to emphasize memorizing formulas rather than understanding their conceptual meanings (Aisyah et al., 2024). Consequently, students frequently make errors when solving related problems, which can be categorized as learning obstacles (Abouelenein & Elmaadaway, 2023; Widodo et al., 2023).

Learning obstacles refer to difficulties that hinder students from fully engaging in learning activities, preventing them from achieving the intended learning outcomes (Pebriyanti et al., 2017; Suryadi, 2019). According to Suryadi (2019), learning obstacles consist of three interrelated categories: didactic obstacles, which arise from mismatches between instructional methods and students' learning conditions (Brousseau in Ramli and Sufyani (2020); ontogenic obstacles, which relate to psychological or developmental factors influencing students' readiness to learn; and epistemological obstacles, which stem from a limited understanding or inappropriate conceptualization of mathematical ideas (Jamilah et al., 2024). These obstacles manifest as errors in applying formulas, misinterpreting geometric relationships, or lacking motivation and prior knowledge.

Although numerous studies have investigated learning obstacles in topics such as triangles (Sari et al., 2019), geometric sequences (Andani et al., 2021), and the volume of cubes and cuboids (Mahmud et al., 2023; Priskila et al., 2023; Purnama et al., 2023), research addressing curved surface solids, particularly the volume of cylinders and cones, remains limited. Prior Didactical Design Research (DDR) studies have predominantly focused on flat or polyhedral solids, leaving a gap in understanding how students conceptualize solids with curved boundaries and their composite relationships. This study addresses this gap by focusing on the conceptual and procedural difficulties that arise in learning the volume of cylinders and cones.

Preliminary findings from Suryani et al. (2025), involving seventh-grade students at Al-Mumtaz Middle School in Pontianak, revealed persistent difficulties in solving problems related to cylinder and cone volumes, especially when involving fractions or formula application. The interviews indicated that these challenges stemmed from insufficient understanding of prerequisite concepts, computational inaccuracies, and limited variation in problem types. These findings reflect the presence of didactic, ontogenic, and epistemological obstacles (Ramli & Sufyani, 2020).

Developing a didactic design, a term derived from the *French didactique des mathématiques* and distinct from the more general "instructional design" is an essential step toward overcoming these barriers. A didactic design aims not merely to plan teaching sequences but to model and analyze the dynamic relationship between the teacher, student, and mathematical knowledge (Brousseau, 1997; Chevallard, 1985). Prior research has shown that didactic designs informed by learning obstacle analysis improve both learning effectiveness and students' conceptual understanding (Habibah et al., 2021; Jamilah & Winarji, 2021; Rahmawati et al., 2021).

To strengthen the theoretical foundation, this study systematically integrates Suryadi's Learning Obstacle Framework with Brousseau's Theory of Didactic Situations and Chevallard's Didactic Transposition Theory (Brousseau, 1997; Chevallard, 1985; Suryadi, 2019). Each type of learning obstacle informs the construction of classroom tasks and teacher interventions. For instance, didactic obstacles were addressed through action situations emphasizing the contextual exploration of real objects (e.g., estimating cylinder volume through measurable containers), while epistemological obstacles were targeted in the formulation and validation phases, where students verbalized and justified their reasoning. Ontogenic obstacles related to motivation and readiness were mitigated during the institutionalization phase through adaptive questioning and reinforcement of conceptual distinctions, such as recognizing the perpendicular height of cones.

This integration illustrates how each obstacle is systematically connected with corresponding didactic situations, thereby providing a coherent theoretical basis for the development of a Hypothetical Didactic Design (HDD) focused on the volume of cylinders and cones. The present study also draws on Simon's Learning Trajectory Theory (Simon, 1995), emphasizing the iterative refinement between hypothetical and actual learning pathways (HLT and ALT, respectively). Moreover, global perspectives on geometric cognition (Battista, 2007; Fischbein, 1987) highlight that understanding three-dimensional figures requires the reconstruction of spatial reasoning through visual and experiential engagement, an aspect directly aligned with this study's approach.

International applications of Didactical Design Research (e.g., Even and Ball (2009); Prévost et al. (2022)) have demonstrated its effectiveness in fostering mathematical reasoning and conceptual fluency in diverse educational contexts. By extending this framework to curved-surface solids, this study contributes both theoretically and practically to the growing body of DDR literature in mathematics education.

Finally, the selection of Grade 7 students is pedagogically justified. In the Indonesian Merdeka Curriculum, the concept of the volume of solids, including cylinders and cones, is introduced at this level, aligning with international benchmarks such as the Common Core State Standards for Mathematics (CCSSM), which also introduce measurement and volume reasoning for early secondary learners. Therefore, this study aimed to develop and evaluate a hypothetical didactic design (HDD) that can help students overcome learning obstacles in understanding the volume of cylinders and cones through the Didactical Design Research (DDR) approach.

## Methods

This study employed the Didactical Design Research (DDR) method, a localized form of Design-Based Research (DBR) developed within the Indonesian mathematics education context (Suryadi, 2019), as follows. While DBR generally emphasizes iterative cycles of design, implementation, and reflection to improve learning environments (Gravemeijer &

Cobb, 2006), DDR focuses specifically on the didactical dimension, identifying, anticipating, and overcoming learning obstacles encountered by students. The methodological legitimacy of DDR has also been recognized internationally, as seen in studies such as Prévost et al. (2022), which adapted DDR principles across diverse classroom contexts. The DDR framework in this study consisted of three main stages: prospective, metapedadidactic, and retrospective analyses (Figure 1).

The term metapedadidactic analysis refers to a reflective process in which researchers and teachers analyze classroom interactions and instructional decisions from a meta-level perspective to understand how didactical relationships evolve during implementation (Suryadi, 2019; Suryadi & Prabawanto, 2020). Although uncommon internationally, this concept serves a similar function to meta-didactical reflection, as discussed in the international DBR literature (e.g., Prediger et al. (2015)).

According to Suryadi (Sitanggang et al., 2024), in the learning process, there are three types of relationships that must be established: the pedagogical relationship (HP) between the teacher and the students, the didactical relationship (HD) between the students and the learning materials, and the relationship between the teacher and the learning materials, known as didactical–pedagogical anticipation (ADP).

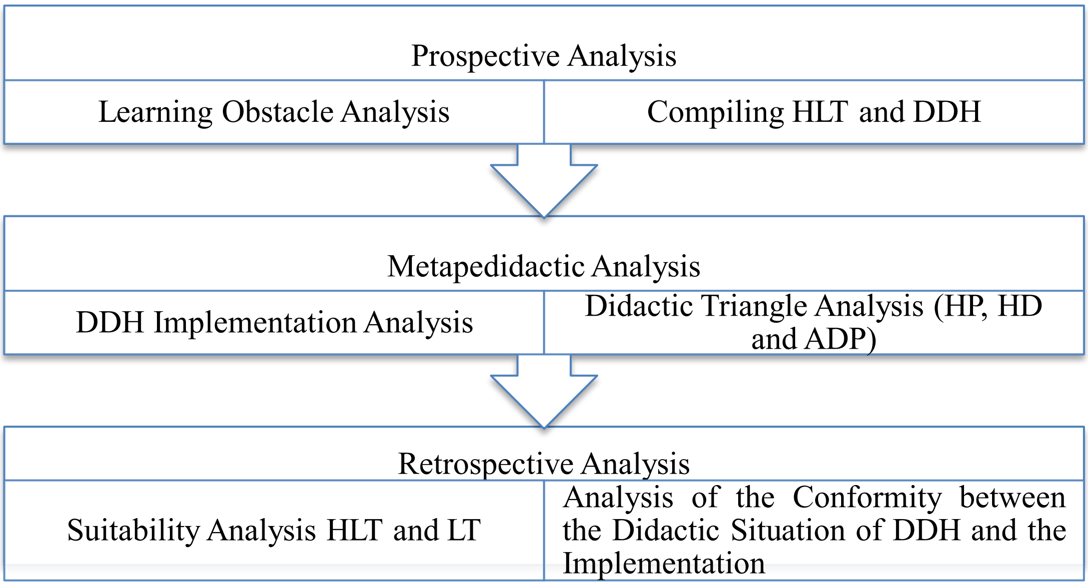


**Figure 1.** Stages of didactical design research (adapted from Suryadi, 2019).

In the prospective analysis stage, the researchers designed a Hypothetical Learning Trajectory (HLT) and a Hypothetical Didactical Design, referred to as Desain Didaktik Hipotetik (DDH), based on diagnostic findings regarding students' learning obstacles in understanding the concept of cylinder and cone volumes (Jamilah et al., 2024). The design aimed to reduce the emergence of didactic, epistemological, and ontogenic obstacles during instruction (Putra & Setiawati, 2018; Shabrina et al., 2022). The implementation was carried out in two 90-minute sessions under the supervision of the researcher and the classroom teacher.

The metapedadidactic analysis stage examined the implementation of this design through the didactic triangle framework, focusing on the relationships between (1) teacher and student (pedagogical), (2) student and learning content (didactical), and (3) teacher and content (didactical anticipation). This framework is grounded in Brousseau's Theory of Didactical Situations (Brousseau, 1997) and was later expanded by Suryadi (2019) to include anticipatory elements in DDR. Data from classroom observations, teacher reflections, and video recordings were analyzed to explore how teachers responded to emergent learning difficulties.

The retrospective analysis stage compared the Hypothetical Learning Trajectory (HLT) with the Actual Learning Trajectory (ALT) observed during the implementation (Jamilah, 2021). This comparison identified discrepancies between the intended and enacted learning processes, providing insights for refining didactic design for future classroom applications.

The participants included 28 seventh-grade students (aged 12–13) and one mathematics teacher from SMP Al-Mumtaz Pontianak, a private Islamic junior high school located in an urban area of West Kalimantan, Indonesia. The school was selected through purposive sampling as it represents a typical urban Indonesian context implementing the Merdeka Curriculum, which emphasizes contextual, competency-based, and meaningful mathematics learning (Turner, 2020). According to teacher reports, students had prior experience with basic fraction operations but limited exposure to applying them in geometric or contextual problem-solving, which often led to procedural and epistemological obstacles.

Data were collected through classroom observations (Wahyono, 2018), diagnostic tests (Triyono et al., 2023), and semi-structured interviews (Kamaria, 2021). The instruments included observation guidelines, diagnostic test items and interview protocols. To ensure validity, the diagnostic test items were validated by two doctoral-level mathematics education faculty members specializing in geometry instruction and didactical design. Validation followed international standards using a content validity index (CVI) approach, in which each item was rated for relevance, clarity, and cognitive alignment. Revisions were made based on expert feedback and the results of a small-scale pilot test with students of similar characteristics. The sample test items and scoring rubrics are provided in the Appendix.

Data were analyzed qualitatively through three stages: (1) data reduction and coding based on the types of learning obstacles (didactic, ontogenic, and epistemological); (2) thematic and constant comparative analysis across DDR stages to identify recurring patterns of student difficulties and teacher responses; and (3) drawing conclusions through cross-verification of data from observations, tests, and interviews.

To ensure trustworthiness, this study employed data and theory triangulation (Alfansyur & Mariyani, 2020; Nurfajriani et al., 2024). Additionally, intercoder reliability was established by involving two independent coders with expertise in mathematics education who discussed and reconciled differences in coding until reaching full consensus

Prior to data collection, ethical clearance and informed consent were obtained from both students and their parents through written agreements outlining the study objectives, procedures, and confidentiality measures. Participation was voluntary, and all the data were anonymized. The researcher did not act as a classroom teacher during the implementation. To maintain implementation fidelity, the teacher received detailed instructional guidelines and short training for each phase of didactic design. The researcher functioned solely as an observer, documenting the process through video recordings, field notes, and post-lesson reflective discussions to ensure alignment between the intended and enacted learning trajectories.

## Results

The research results are presented based on the three stages of Didactic Design Research (DDR): prospective analysis, metapedadidactic analysis, and retrospective analysis. Each stage is supported by rich empirical data from diagnostic tests, learning observations, student responses, and interviews. Figures and tables are embedded to support the explanations.

### Prospective analysis

A preliminary study conducted by Suryani et al. (2025) identified learning obstacles faced by seventh-grade students at Al-Mumtaz Junior High School in Pontianak on the topic of cylinder and cone volume. Two diagnostic questions were administered:

1. A cylindrical paint can has a radius of 10 cm and a height of 15 cm. What is the volume of the can?
2. A cone-shaped ice cream container has a diameter of 14 cm and a volume of 1540 ml. Calculate its height.

Student answers to Question 1 (see Figure 2) revealed calculation errors due to procedural misunderstanding, particularly in operations involving fractions. Of 28 students, 19 students (68%) made similar errors, mostly caused by incorrect order of operations. Interviews showed that although they considered the question easy, they admitted to "forgetting to complete the division step." These findings reflect epistemological obstacles related to procedural fluency (Ramli & Sufyani, 2020).

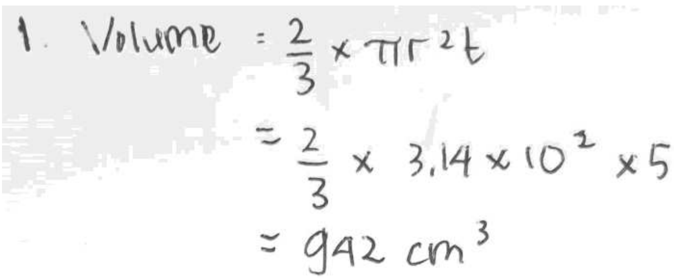


**Figure 2.** Student's written response showing error in fraction operation (epistemological obstacle).

For Question 2 (see Figure 3), 11 students (39%) were confused about the correct mathematical operation and unsure whether to multiply or divide. Their limited conceptual understanding indicated overlapping ontogenic, epistemological, and didactic obstacles.

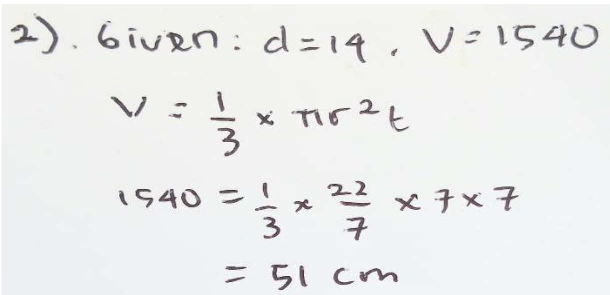


**Figure 3.** Misinterpretation of the phrase "two-thirds full" illustrating combined didactic and ontogenic obstacles.

Based on these findings, a Hypothetical Learning Trajectory (HLT) was designed (Figure 4) as the foundation for the Hypothetical Didactic Design (DDH). The HLT mapped specific tasks to identified learning obstacles, with contextual problems to strengthen representation and reasoning skills.

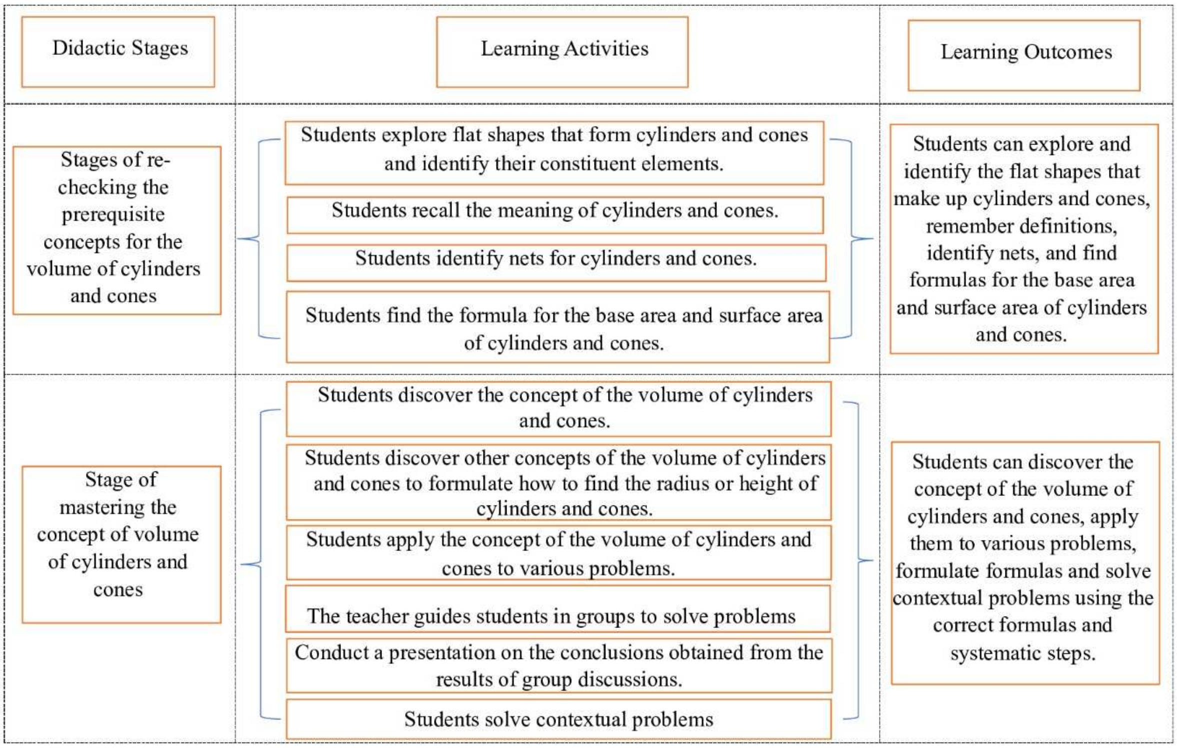


**Figure 4.** Hypothetical learning trajectory (HLT) mapping tasks to specific learning-obstacle categories.

The design included four didactic situations (Brousseau, 1997): action, formulation, validation, and institutionalization. In the *action* and *formulation* phases, students worked on contextual tasks to address prior misconceptions such as writing the incorrect formula $V = \pi \times r + t$ instead of $V = \pi r^2 t$.

## Metapedadidactic analysis

During the implementation of DDH, the metapedadidactic analysis focused on didactic relationships (HD), pedagogical relationships (HP), and anticipatory didactical phenomena (ADP). Students were presented with the following problems:

1. Cylinder Problem I: A cylindrical water pipe is 2 m long and has an inner diameter of 20 cm. How much water can flow through it?
2. Cone Problem I: A cone-shaped container has a base radius of 14 cm. Two-thirds of the container is filled with boiled peanuts. If the height is 27 cm, determine the volume of the peanuts.

In the *validation* phase, group discussions occurred, but peer-to-peer dialogue was limited. The teacher provided scaffolding through reflective questioning, such as, “Why did your group choose this method?”

**Table 1.** Didactic triangle analysis on the volume of cylinders and cones material

| Problem Context | HP (Teacher-Student Relationship) | HD (Student-Material Relationship) | ADP (Teacher Anticipation and Scaffolding) | Student Response (Empirical Evidence) |
|---|---|---|---|---|
| Volume of the cylinder | Teacher presents problem using mixed units (m and cm). | Students confuse unit conversion and treat diameter as radius. | The teacher emphasizes the uniformity of units through scaffolding in the form of conversion examples, such as 5 m = 500 cm, so that the units of length correspond to the radius. | “I forgot to change m to cm, that’s why my result was too small.” |
| Volume of a cone | Teacher gives problem about a cone container two-thirds filled with peanuts. | Students misinterpret “two-thirds” and apply wrong operation.. | The teacher explains the meaning of 'two-thirds of the volume' through simple examples and scaffolding that fractions, such as , demonstrate the operation of multiplication. | “I divided by 3 instead of multiplying by $\frac{2}{3}$.” |
| Composite Shape | Teacher assigns problem combining cone and cylinder. | Students identify both heights but confuse which applies to each formula. | Teacher reinforces concept of corresponding height through questioning and diagram comparison. | “I know the cone is smaller, but I used the cylinder’s height for both.” |

In the *institutionalization* phase, students solved new contextual problems, such as calculating the remaining tank volume or estimating materials for decorative cones. A post-test was then given to measure learning improvement.

Quantitative comparison showed a notable improvement. Procedural accuracy increased from 32% (pre-test) to 79% (post-test), and the number of students confusing the cone height decreased from 8 to 3. However, spatial misconceptions remained among a small group of students.

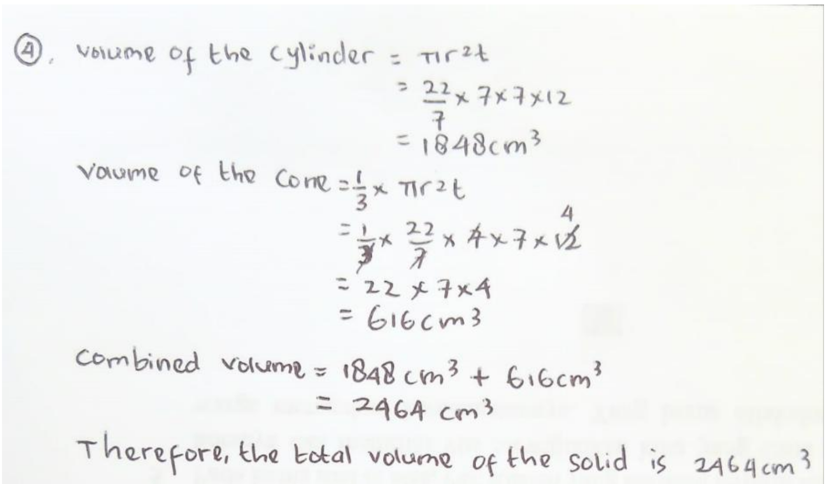


**Figure 5**. Post-test response showing confusion between cone and cylinder height (ontogenic obstacle).

Interviews revealed that students confused the cylinder and cone heights in composite shapes. Although they applied formulas correctly, the misunderstanding stemmed from inadequate conceptual grasp of geometric components. One student said:

*"I just use the formula, I didn't think which height was for the cone."*

This reflects procedural tendencies and ontogenic obstacles due to internal readiness (Jamilah, 2021).

## Retrospective analysis

The retrospective analysis compared the Hypothetical Learning Trajectory (HLT) with the Actual Learning Trajectory (ALT) observed during implementation. Overall, the ALT closely aligned with the HLT, though several key deviations provided valuable insight.

1. Systematic Comparison between HLT and ALT
   a. Action Phase: All 28 students participated actively in model observation, following the planned trajectory.
   b. Formulation Phase: 8 students (29%) incorrectly identified the cone's height as equal to the cylinder's height or slant height an error unanticipated in the HLT.
   c. Validation Phase: Most groups (9 of 11) verified calculations correctly, though 2 groups relied solely on formulas without understanding the base height relationship.
   d. Institutionalization Phase: Despite reinforcement, 4 students (14%) still struggled with cone height, suggesting insufficient visual scaffolding.
2. Empirical Data Triangulation
   Three data sources strengthened interpretation:
   a. Student Work: Errors (see Figure 5) showed confusion between cylinder and cone height (entered 7 cm instead of 6 cm).
   b. Validation Discussion:
      1) S-12: "I thought the cone's height was the same as the cylinder's height, Ma'am."
      2) Teacher: "Please observe carefully. The cone's height is always perpendicular to its base."
   c. Teacher Reflection: The teacher observed persistent confusion in distinguishing height from slant, recommending increased use of 3D models and cross-sectional visuals.
3. Implications for Learning Obstacles Analysis
   Initially, this confusion was identified as an ontogenic obstacle, as it appeared to stem from students' internal readiness. However, triangulation of evidence (student work, reflection, and task analysis) indicated that the root cause was insufficient visual support within the instructional design. Consequently, the obstacle was reclassified as a didactic obstacle. This reclassification was based on teacher reflection and task analysis, showing that the design rather than individual student readiness caused the difficulty.

## Discussion

The post-intervention analysis revealed an important theoretical insight: several difficulties initially identified as ontogenic were, in fact, didactic in nature, arising not from students' internal readiness but from limitations in instructional design. This reclassification underscores a key principle in learning obstacle theory, as described by Suryadi (2019), who distinguishes ontogenic obstacles as stemming from cognitive or motivational readiness, while didactic obstacles emerge from mismatches between instructional approaches and learner needs. By recognizing that some student challenges were triggered by the learning design itself, this study highlights the dynamic nature of obstacle classification within Didactical Design Research (DDR), where understanding evolves through iterative implementation and reflection.

The findings demonstrate that the Hypothetical Didactic Design (DDH), grounded in learning obstacle analysis, effectively supported students' construction of the cylinder and cone volume concepts. The structured progression through the action, formulation, validation, and institutionalization phases enabled the students to systematically develop conceptual understanding and gradually overcome both epistemological and didactic barriers. However, this facilitation was only partially successful; conceptual confusion persisted, particularly in distinguishing between slant height and vertical height, a well-documented epistemological obstacle in three-dimensional geometry (Battista, 2007). These findings suggest that students' spatial reasoning and embodied visualization of three-dimensional structures remain limited, requiring sustained pedagogical interventions that emphasize spatial relationships and visualizations.

This interpretation aligns with previous studies that emphasize the role of well-structured didactic designs in reducing learning barriers and enhancing mathematical reasoning (Gravemeijer & Cobb, 2006; Pramuditya et al., 2021). Likewise, Sulastri et al. (2022) and Sidik et al. (2021) observed that conventional classroom instruction often lacks non-routine and spatially demanding problem types, which may explain the persistence of procedural tendencies among students in the current study. As emphasized by Boaler (2016), students conceptual engagement increases significantly when instruction focuses on meaningful exploration rather than repetitive calculation. In this study, despite the integration of visual and contextual learning aids, many students still relied on memorized procedures instead of conceptual reasoning. Although the DDH incorporates visualizations of formula derivations and connects them to the idea of volume as an accumulation of space, reinforcement during the early learning stages remains essential for deeper internalization of these conceptual connections.

From an international perspective, the present findings contribute to the broader discourse on geometry learning and spatial reasoning. Data from the PISA and TIMSS consistently reveal that students across various countries experience difficulties in tasks requiring three-dimensional understanding. In this regard, the DDH model developed in this study provides a contextually grounded yet potentially transferable framework for improving geometry instruction beyond the Indonesian context, particularly in fostering the shift from procedural recall to conceptual comprehension.

Furthermore, this study extends the DDR methodology by demonstrating that obstacle classification is not static but evolves through empirical implementation and reflective analysis. The process of identifying and reclassifying obstacles from ontogenic to didactic forms a methodological contribution that enhances the adaptability of DDR in addressing complex learning phenomena. Guided by Brousseau's theory of didactical situations (Yunarti, 2017) and further supported by Jamilah and Winarji (2021), the iterative enactment of the four learning situations was crucial for fostering robust mathematical understanding. Nonetheless, the study acknowledges its limitations, such as being conducted in a single classroom and within a short implementation duration, which may restrict the generalizability of its findings.

Thus, future didactic designs should aim to incorporate non-routine contextual problems that promote reasoning flexibility and adaptive thinking. The validation phase can be strengthened by embedding peer questioning, justification prompts, and collaborative reflection activities to deepen students' metacognitive engagement. Moreover, conceptual understanding should be reinforced through spatial visualization, dynamic representations, and narrative explanations of geometric volumes. To support future DDR cycles, systematic documentation through student work samples, interview excerpts, and teacher observation journals is vital for tracing the evolution of students' reasoning and refining subsequent design iterations.

## Conclusion

This study demonstrates that learning obstacles are not static student deficits but dynamic interactions among task design, instructional approaches, and students' prior knowledge. Through the Didactical Design Research (DDR) approach, the developed didactic design effectively supported students' understanding of cylinder and cone volumes. However, limitations in the institutional phase revealed that several difficulties previously assumed to be ontogenic were, in fact, didactic, arising from insufficient scaffolding and task sequencing rather than students' internal readiness.

This insight emphasizes that what appears to be ontogenic obstacles may often originate from design gaps, highlighting the need for continuous reflection and refinement in the instructional design. Accordingly, future iterations should integrate concrete and technology-supported interventions, such as dynamic geometry software, physical manipulatives, and cross-sectional modeling, to strengthen students' spatial reasoning and conceptual coherence.

Aligned with the principles of Indonesia's *Merdeka* Curriculum, this study underscores the role of DDR in fostering teacher autonomy and evidence-based pedagogical decision making. By embedding adaptive and reflective elements, teachers can iteratively develop responsive didactic designs that evolve with classroom realities, thereby promoting a deeper mathematical understanding and sustained learner growth.

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## Conflicts of Interest

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

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## Author Contributions

**Titin Suryani:** Conceptualization, methodology, investigation, writing original draft, and editing; **Jamilah:** Validation, supervision and formal analysis; **Reni Astuti:** Supervision, visualization, and project administration.

## References

Abouelenein, Y. A. M., & Elmaadaway, M. A. N. (2023). Impact of teaching a neuro computerized course through VLE to develop computational thinking among mathematics pre-service teachers. *Journal of Educational Computing Research*, *61*(6), 1175–1206.

Agustini, W. A., & Fitriani, N. (2021). Analisis kesulitan siswa SMP pada materi bangun ruang sisi lengkung [Analysis of junior high school students' difficulties in curved surface solids. *Jurnal Pembelajaran Matematika Inovatif*, *4*(1), 91–96.

Aisyah, A. P., Prabandari, A. R., Natalia, E., Rahmadhani, N., Susanti, E., Meryansumayeka, M., Zulkardi, Z., & Yukans, S. S. (2024). Pengembangan alat peraga Prolucc pada materi volume tabung dan kerucut [Development of Prolucc teaching aids on the topic of cylinder and cone volume. *Jurnal Borobudur Educational Review*, *4*(1), 50–60.

Alfansyur, A., & Mariyani, M. (2020). Seni mengelola data: Penerapan triangulasi teknik, sumber dan waktu pada penelitian pendidikan sosial [The art of managing data: Application of technique, source, and time triangulation in social education research. *Jurnal Kajian, Penelitian & Pengembangan*, *5*(2), 146–150.

Andani, M., Jamilah, J., & Hartono, H. (2021). Didactical obstacle siswa kelas IX pada materi deret geometri [Didactical obstacles of ninth-grade students on geometric sequences. *Journal of Innovation Research and Knowledge*, *1*(5), 887–894.

Battista, M. T. (2007). The development of geometric and spatial thinking. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 843–908). Information Age Publishing.

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching.

Brousseau, G. (1997). *Theory of didactical situations in mathematics: Didactique des mathématiques, 1970–1990*. Kluwer Academic Publishers.

Chevallard, Y. (1985). *La transposition didactique: Du savoir savant au savoir enseigné*. La Pensée Sauvage.

Even, R., & Ball, D. L. (2009). *The professional education and development of teachers of mathematics: The 15th ICMI study*. Springer.

Fischbein, E. (1987). *Intuition in science and mathematics: An educational approach*. D. Reidel Publishing Company.

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 17–51). Routledge.

Habibah, U., Santika, R., Setiono, P., Yuliantini, N., & Wurdjinem, W. (2021). Analisis kesulitan belajar siswa SD dalam pembelajaran matematika secara daring [Analysis of elementary students' learning difficulties in online mathematics learning. *Jurnal Ilmiah Matematika Realistik*, *2*(2), 1–6.

Jamilah, J. (2021). *Proses transposisi didaktik mahasiswa calon guru matematika melalui didactical design research pada materi himpunan [Didactical transposition process of preservice mathematics teachers through didactical design research on set theory* [Ph.D. Thesis, Universitas Pendidikan Indonesia].

Jamilah, J., Priskila, P., & Oktaviana, D. (2024). Didactical design to overcome learning obstacles in cuboid volume. *Jurnal Elemen*, *10*(2), 324–340.

Jamilah, J., & Winarji, A. (2021). Pengorganisasian situasi didaktis dalam pembelajaran panjang busur lingkaran [Organization of didactical situations in teaching arc length. In *Konferensi Penelitian Desain Didaktik*.

Kamaria, A. (2021). Implementasi kebijakan penataan dan mutasi guru pegawai negeri sipil di lingkungan dinas pendidikan Kabupaten Halmahera Utara [Implementation of civil servant teacher transfer and placement policies in the Department of Education of North Halmahera. *Jurnal Ilmiah Wahana Pendidikan*, *7*(3), 82–96.

Mahmud, M. R., Turmudi, T., Sopandi, W., Rohimah, S. M., & Pratiwi, I. M. (2023). Analisis hambatan belajar kelipatan persekutuan terkecil dan faktor persekutuan terbesar di sekolah dasar [Analysis of learning obstacles on LCM and GCF topics in elementary school. *Jurnal Elemen*, *9*(2), 440–449. https://doi.org/10.29408/jel.v9i2.12359

Nurfajriani, W. V., Ilhami, M. W., Mahendra, A., Sirodj, R. A., & Afgani, M. W. (2024). Triangulasi data dalam analisis data kualitatif [Data triangulation in qualitative data analysis. *Jurnal Ilmiah Wahana Pendidikan*, *10*(17), 826–833.

Pebriyanti, G. W., Sari, D., & Hadi, M. (2017). Profil hambatan belajar epistemologis siswa pada materi asas Bernoulli kelas XI SMA berbasis analisis tes kemampuan responden [Profile of students. *6*, 1–8.

Pramuditya, S. A., Noto, M. S., & Handayani, V. D. (2021). Desain didaktis konteks fabel berbasis pemahaman matematis siswa pada materi aljabar [Didactical design using fable contexts based on students' mathematical understanding of algebra. *Jurnal Elemen*, *7*(1), 68–83.

Prediger, S., Bikner-Ahsbahs, A., & Arzarello, F. (2015). Networking theories in mathematics education. In S. Prediger (Ed.), *ICME-13 topical survey: Networking of theories as a research practice in mathematics education*. Springer.

Prévost, P., Mary, C., & Martin, R. (2022). Applying Didactical Design Research to foster algebraic reasoning: An international classroom-based study. *International Journal of Science and Mathematics Education*, *20*(3), 551–573.

Priskila, P., Jamilah, J., & Oktaviana, D. (2023). Analisis learning obstacle siswa SMP pada materi volume kubus dan balok [Analysis of junior high school students' learning obstacles on cube and cuboid volume. *Journal of Comprehensive Science*, *2*(6), 1656–1663.

Purnama, S. D., Fadillah, S., & Jamilah, J. (2023). Analisis hambatan belajar siswa pada materi pembelajaran himpunan siswa kelas 7 SMP Negeri 4 Sungai Ambawang [Analysis of students' learning obstacles on set learning material among seventh graders of SMP Negeri 4 Sungai Ambawang. *Juwara: Jurnal Wawasan dan Aksara*, *3*(1), 43–56. https://doi.org/10.58740/juwara.v3i1.46

Putra, R. W. Y., & Setiawati, N. (2018). Pengembangan desain didaktis bahan ajar persamaan garis lurus [Development of didactical design for straight-line equation teaching materials. *Jurnal Penelitian dan Pembelajaran Matematika*, *11*(1), 139–148.

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. *8*, 780–791.

Ramli, R., & Sufyani, P. (2020). Kesalahan dan learning obstacle dalam menyelesaikan permasalahan matematis [Errors and learning obstacles in solving mathematical problems. *Juring: Journal for Research in Mathematics Learning*, *3*(3), 233–246.

Sari, W., Fauziah, F., & Jayanti, J. (2019). Analisis kendala pembelajaran materi segitiga pada siswa SMP kelas 7 [Analysis of learning difficulties on triangle material among seventh-grade students. *Jurnal Inovasi Pendidikan Matematika*, *2*(1), 21–29. https://doi.org/10.31851/indiktika.v2i1.3394

Shabrina, F. A., Sumiaty, E., & Sudihartinih, E. (2022). Kajian learning obstacle pada materi peluang untuk jenjang SMP ditinjau dari literasi matematis PISA 2021 [Study of learning obstacles in probability material for junior high school based on PISA 2021 mathematical literacy. *Jurnal Pendidikan Matematika: Judika Education*, *5*(2), 152–165.

Sidik, G. S., Suryadi, D., & Turmudi, T. (2021). Learning obstacle on addition and subtraction of primary school students: Analysis of algebraic thinking. *Education Research International, Article*, *ID*, 5935179.

Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*, *26*(2), 114–145.

Sitanggang, A. K., Lubis, A., & Elisa, T. S. (2024). Pengembangan model Design Didactic Research (DDR) untuk mengatasi hambatan belajar (learning obstacle) matematika [Development of the Didactical Design Research (DDR) model to overcome mathematics learning obstacles. *Jurnal Handayani*, *15*(1), 1–6.

Solin, T. A., Fitria, N., Sitorus, S. F., & Angkat, D. K. A. (2023). Analisis kesulitan siswa dalam menyelesaikan soal bangun ruang sisi lengkung [Analysis of students' difficulties in solving curved surface solid problems. *Relevan: Jurnal Pendidikan*, *3*(4), 458–465.

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.

Suryadi, D. (2019). *Landasan filosofis penelitian desain didaktis (DDR) [Philosophical foundations of didactical design research*. DDR)]. Pusat Pengembangan DDR Indonesia.

Suryadi, D., & Prabawanto, S. (2020). Metapedadidaktik dalam penelitian desain didaktis [Metapedadidactics in didactical design research. *Jurnal Didaktik Matematika*, *7*(1), 1–12.

Suryani, T., Jamilah, J., & Astuti, R. (2025). Analisis learning obstacle konsep volume tabung dan kerucut siswa kelas VIII [Analysis of learning obstacles on the concept of cylinder and cone volume among eighth-grade students. *JRPMS: Jurnal Riset Pembelajaran Matematika Sekolah*, *9*(1), 75–85.

Triyono, T., Masrukan, M., & Mulyono, M. (2023). Pengembangan tes diagnostik matematika kurikulum Merdeka [Development of a diagnostic mathematics test for the Merdeka curriculum. *Jurnal Prisma*, *12*(2), 560–569.

Turner, D. P. (2020). Sampling methods in research design. *Headache: The Journal of Head & Face Pain*, *60*(1), 8–12.

Wahyono, I. (2018). Implementasi nilai-nilai Pancasila dalam kegiatan pembelajaran di SDN 1 Sekarsuli [Implementation of Pancasila values in learning activities at SDN 1 Sekarsuli. *Jurnal Pendidikan Guru Sekolah Dasar*, *7*(2), 133–139.

Widodo, S. A., Wijayanti, A., Irfan, M., Pusporini, W., Mariah, S., & Rochmiyati, S. (2023). Effects of worksheets on problem-solving skills: Meta-analytic studies. *International Journal of Educational Methodology*, *9*(1), 151–167.

Yunarti, T. (2017). *Desain didaktis berbasis masalah untuk teori peluang SMA [Problem-based didactical design for probability theory in senior high school*. Media Akademi.