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Development of a Didactical Design Based on Research and Development for Teaching Cones and Cylinders to Improve Junior High School Students' Conceptual Understanding

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ABSTRACT

Purpose of the study: This study aims to develop a didactical design based on Research and Development to improve junior high school students' conceptual understanding of cones and cylinders by addressing their learning obstacles through structured instructional materials.

Methodology: This study employed a Research and Development approach adapted from Borg and Gall and Sugiyono models. The research involved eighth-grade students, using interviews, observation sheets, validation instruments, and questionnaires. Data were analyzed using descriptive qualitative and quantitative methods with Likert scale scoring. Expert validation involved mathematics education lecturers and teachers. Small-scale and large-scale trials were conducted to evaluate the developed module's feasibility and effectiveness in mathematics learning on cones and cylinders.

Main Findings: The developed didactical design module showed significant improvement after expert validation and revision. The results indicated very good criteria in content quality, language clarity, and media design. Student responses in small-scale and large-scale trials reached 90–94%, categorized as very good. The module effectively reduced learning obstacles and improved students' conceptual understanding of cones and cylinders. The findings confirm that the instructional material is valid, practical, and effective for classroom implementation.

Novelty/Originality of this study: This study develops a didactical design module integrating learning obstacle analysis specifically for cones and cylinders using an R&D approach. The innovation lies in its structured adaptation of students' cognitive difficulties into instructional design. It contributes a context-specific mathematics learning module that enhances conceptual understanding and provides a practical model for developing geometry-based teaching materials.

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1. INTRODUCTION

Education plays a crucial role in developing high-quality human resources and shaping individuals' intellectual and personal growth. In the learning process, mathematics is a fundamental subject that supports logical, analytical, and critical thinking skills [1]. Mathematics learning is expected to facilitate students in constructing their own understanding through meaningful learning experiences. However, effective learning requires well-designed instructional materials that align with students' characteristics and needs. Therefore, the development of appropriate didactical designs becomes essential to support meaningful mathematics learning.

In practice, mathematics learning is often still dominated by conventional teaching methods, where teachers mainly rely on textbooks and emphasize procedural knowledge [2]. This condition leads students to experience difficulties in understanding mathematical concepts, particularly in abstract topics such as cones and cylinders [3]. Many students tend to memorize formulas without fully understanding the underlying concepts [4]. As a result, students struggle to solve problems when presented with variations of questions. This indicates that students' conceptual understanding in mathematics remains relatively low.

Previous studies have highlighted that learning obstacles in mathematics can arise from students' cognitive readiness, instructional approaches, and the nature of mathematical concepts. Research on didactical design has shown its potential in addressing these learning obstacles by considering students' responses during the learning process [5]. Several studies have also emphasized the importance of developing instructional materials that are tailored to students' needs. However, most existing studies focus on general mathematical topics rather than specific geometric concepts [6]. This suggests that further research is needed to explore didactical design in more specific and challenging topics.

Despite the growing attention to didactical design, there is still limited research that specifically develops instructional materials for three-dimensional curved surface geometry, particularly cones and cylinders. Moreover, many instructional materials used in schools are not designed based on an analysis of students' learning obstacles [7]. As a result, these materials are less effective in facilitating deep conceptual understanding [8]. The lack of context-specific and student-centered teaching materials creates a gap between instructional design and students' actual learning needs. Therefore, it is necessary to develop a didactical design that explicitly addresses these issues.

The development of didactical design-based instructional materials is essential to improve students' conceptual understanding in mathematics [9]. By integrating learning obstacle analysis into the design process, teaching materials can better support students in overcoming their difficulties. This approach not only enhances students' understanding but also increases their engagement in the learning process. Furthermore, well-designed instructional materials can assist teachers in implementing more effective and interactive learning strategies [10]. Thus, the development of such materials becomes a crucial step in improving the quality of mathematics education.

This study offers a novel contribution by developing a didactical design for teaching cones and cylinders using the Research and Development approach. Unlike previous studies, this research focuses on integrating learning obstacle analysis into the design of instructional materials specifically for curved surface geometry [11]. The resulting product is a module that is systematically designed based on students' needs and validated by experts. In addition, the study evaluates the effectiveness of the developed materials through field testing at different scales [12]. Therefore, this research provides both theoretical and practical contributions to the development of mathematics instructional design.

2. RESEARCH METHOD

2.1 Research Design

This study employed a Research and Development (R&D) approach to develop a didactical design for teaching cones and cylinders. The development procedure was adapted from the Borg and Gall model, which was simplified into several stages based on research needs [13]. These stages included problem identification, data collection, product design, expert validation, revision, and product testing. The study was conducted in a junior high school involving eighth-grade students as participants. A simple random sampling technique was used to select one class as the research sample.

2.2 Development Procedure

The development process began with identifying learning problems through classroom observations and interviews with teachers and students. The findings revealed that students experienced difficulties in understanding concepts due to limited and less interactive instructional materials [14]. Based on these findings, data were collected to support the development of a didactical module on cones and cylinders. The initial product design was then validated by material and media experts to ensure its quality and feasibility [15]. After validation, revisions were made, followed by small-scale and large-scale trials to evaluate the effectiveness and attractiveness of the developed product.

2.3 Data Collection and Analysis

The data in this study consisted of qualitative and quantitative data collected through interviews and questionnaires. Qualitative data were obtained from expert feedback and student responses, while quantitative data were derived from Likert-scale instruments [16]. The research instruments included interview guidelines, expert validation sheets, and student response questionnaires. Data analysis was conducted using descriptive qualitative and quantitative techniques to evaluate the developed product [17]. The feasibility of the product was calculated using percentage scores, which were then interpreted based on the criteria presented in Table 1.

Table 1. Feasibility Criteria

Percentage (P)	Category
P > 80%	Very Good
60% < P ≤ 80%	Good
40% < P ≤ 60%	Fair
20% < P ≤ 40%	Poor
P < 20%	Very Poor

3. RESULTS AND DISCUSSION

3.1 Identification of Learning Obstacles and Needs Analysis

Based on the results of interviews and preliminary tests conducted with ninth-grade junior high school students, several learning obstacles were identified in understanding the concepts of cones and cylinders [18]. The main difficulties include errors in mathematical operations, challenges in identifying key elements such as radius, height, and slant height, and low ability in solving contextual problems. In addition, students tend to memorize formulas without fully understanding the underlying concepts [19]. These findings indicate the presence of both didactical and epistemological obstacles in the learning process. Therefore, a didactical design in the form of a module is needed to address these obstacles and improve students' conceptual understanding.

Table 2. Learning Obstacles Identified

No	Type of Obstacle	Description
1	Operational	Errors in mathematical calculations
2	Conceptual	Difficulty understanding elements of cones and cylinders
3	Representational	Difficulty solving word problems
4	Epistemological	Lack of understanding of fundamental concepts and formulas

3.2 Development and Validation of the Didactical Design

The development process resulted in a didactical design module for teaching cones and cylinders, which was constructed based on the identified learning obstacles and students' needs [20]. The module includes essential components such as cover, usage instructions, contextualized materials, worked examples, and structured exercises to support conceptual understanding [21]. The product was validated by material and media experts using a Likert-scale instrument, showing significant improvement after revisions. The validation results indicate that the module achieved "good" to "very good" categories in terms of content quality, language clarity, and visual design [22]. Consequently, the developed didactical design is considered valid and appropriate for implementation in mathematics learning.

Table 3. Results of Expert Validation

Aspect	Stage I (%)	Stage II (%)	Category
Content Quality	50	85	Very Good
Content Coverage	50	85	Very Good
Language	45	87	Very Good
Media Design	55	90	Very Good

3.3 Product Testing and Students' Responses

The product testing was conducted in two stages, namely small-scale and large-scale trials, to evaluate the attractiveness and effectiveness of the developed module [23]. In the small-scale trial involving 10 students, the average response reached 90%, categorized as "very good." Meanwhile, the large-scale trial involving 30 students resulted in an average score of 93–94%, also in the "very good" category [24]. These results indicate that the module effectively enhances students' interest and supports their understanding of cone and cylinder concepts [25]. Furthermore, students provided positive feedback regarding the module's appearance, content clarity, and ease of use. Therefore, the didactical design module is considered effective and suitable for classroom implementation.

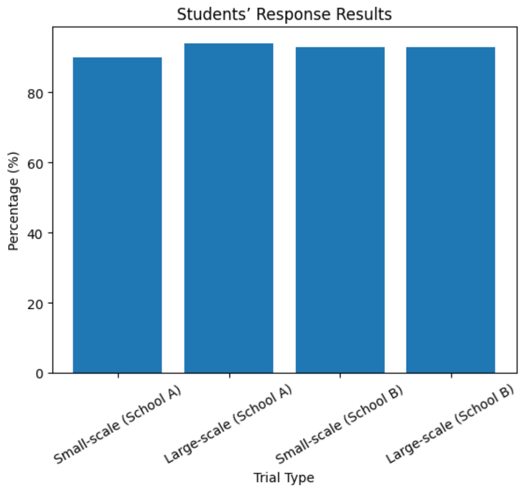

Figure 3.1 Students' Response Results

The findings of this study indicate that students experienced significant learning obstacles in understanding the concepts of cones and cylinders [26]. These obstacles include difficulties in mathematical operations, identifying geometric elements, and solving contextual problems [27]. In addition, students tended to rely on memorization rather than conceptual understanding, which limited their ability to solve non-routine problems. This condition reflects the existence of both didactical and epistemological barriers in mathematics learning. Therefore, the identification of these obstacles becomes a crucial foundation for developing an effective didactical design.

The results also show that the developed didactical design module is valid and effective for improving students' conceptual understanding. Expert validation revealed significant improvements from the initial to the revised product, particularly in content quality, language clarity, and media design [28]. Furthermore, the results of small-scale and large-scale trials demonstrate that the module received very positive responses from students. The high percentage scores indicate that the module is not only attractive but also supportive of meaningful learning [29]. Thus, the developed module can be considered a feasible instructional material for mathematics learning.

These findings are consistent with previous studies that emphasize the importance of addressing learning obstacles in mathematics through appropriate instructional design. Prior research has shown that didactical design can effectively support students' conceptual understanding by considering their cognitive difficulties [30]. However, many existing studies focus on general mathematical topics without specifically addressing curved surface geometry. This study supports the idea that integrating learning obstacle analysis into instructional design can enhance learning effectiveness. At the same time, it highlights the need for more context-specific teaching materials in mathematics education.

The novelty of this study lies in the development of a didactical design module specifically for teaching cones and cylinders based on a Research and Development approach [31]. Unlike previous studies, this research integrates learning obstacle analysis directly into the design of instructional materials. The module is systematically developed, validated by experts, and tested through empirical trials to ensure its effectiveness [32]. This approach bridges the gap between theoretical instructional design and practical classroom implementation. Therefore, this study contributes a more targeted and evidence-based approach to developing mathematics teaching materials.

The implications of this study are significant for both teachers and students in mathematics learning. For teachers, the developed module provides a structured and student-centered instructional resource that can improve teaching effectiveness [33]. For students, the module facilitates conceptual understanding by presenting materials in a contextual and interactive manner. In addition, the use of didactical design can encourage active learning and reduce students' dependence on rote memorization. This approach also supports the development of higher-order thinking skills in mathematics [34]. Therefore, the implementation of such modules can contribute to improving the overall quality of mathematics education.

Despite its contributions, this study has several limitations that should be considered. The research was conducted in a limited sample and focused only on one topic, namely cones and cylinders. As a result, the generalizability of the findings to other mathematical topics may be limited. In addition, the study primarily used descriptive analysis without incorporating more advanced statistical testing. Future research is recommended to involve larger samples and explore the application of didactical design in different mathematical topics. Furthermore, experimental studies can be conducted to examine the effectiveness of the module more rigorously..

4. CONCLUSION

The study successfully developed a didactical design module for teaching cones and cylinders using a Research and Development approach that aligns with the objectives stated in the introduction. The findings confirmed that students experienced various learning obstacles, including conceptual, procedural, and representational difficulties in understanding geometric concepts [35]. Through systematic development, validation, and revision processes, the resulting module was proven to be valid, practical, and effective in improving students' conceptual understanding. The results of expert validation and field testing demonstrated that the developed instructional material received very positive evaluations and high levels of student acceptance. These outcomes indicate that the didactical design successfully bridges the gap between instructional needs and students' learning difficulties, particularly in abstract mathematical topics. Therefore, this study is expected to contribute to improving mathematics learning quality and can be further developed for other geometric topics and broader educational contexts.

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