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Research articles

Students' conceptual difficulties in learning curved-surface solids: The needs for RME-based interactive e-module

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Abstrak Penelitian ini bertujuan untuk mengidentifikasi kesulitan belajar dan menganalisis pemahaman konsep siswa pada materi bangun ruang sisi lengkung, serta mengeksplorasi kebutuhan mereka terhadap konten dan fitur e-module sebagai landasan pengembangan e-module berbasis *realistic mathematics education* (RME). Penelitian ini menggunakan pendekatan *mixed-method* dengan desain *sequential explanatory*. Partisipan terdiri atas 94 siswa kelas IX dari salah satu SMP swasta di Kota Surakarta, Indonesia. Data diperoleh melalui angket dan wawancara mendalam. Analisis data kuantitatif dilakukan secara deskriptif, sedangkan data kualitatif dianalisis melalui proses reduksi, penyajian, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa siswa masih mengalami kesulitan dalam memvisualisasikan bentuk tiga dimensi, memahami struktur dan penerapan rumus volume serta luas permukaan, serta mengidentifikasi komponen bangun ruang sisi lengkung. Pemahaman konsep siswa berada pada kategori cukup dengan kecenderungan ketidakpastian dalam menjelaskan, menghubungkan, dan menerapkan konsep. Selain itu, siswa membutuhkan konten berupa penjelasan konseptual yang mendalam, contoh prosedural bertahap, dan latihan kontekstual yang menunjukkan perlunya integrasi pendekatan RME pada e-module. Siswa juga mengharapkan fitur digital seperti visualisasi 3D, video tutorial, manipulasi objek interaktif, dan asesmen otomatis.

Kata kunci *Bangun ruang sisi lengkung, E-module interaktif, Pemahaman konsep, Realistic mathematics education*

Abstract This study aims to identify students' difficulties in learning curved-surface solids, analyze the key aspects of their conceptual understanding, and explore their needs regarding content and digital features for an RME-based e-module. A mixed-method approach with a sequential explanatory design was employed. The participants consisted of 94 ninth-grade students from a private junior high school in Surakarta, Indonesia. Data were collected using a questionnaire as well as in-depth interviews. Quantitative data were analyzed descriptively, while qualitative data were processed through reduction, display, and conclusion drawing. The findings reveal that students continue to struggle with visualizing three-dimensional shapes, understanding the structure and use of formulas for volume and surface area, and identifying components of curved-surface solids. Their conceptual understanding falls within the "moderate" category, with noticeable uncertainty in explaining, connecting, and applying concepts. Moreover, students require content that offers deeper conceptual explanations, step-by-step procedural examples, and contextualized exercises, highlighting the need for integrating the RME approach into the e-module. They also expect digital features such as 3D visualizations, tutorial videos, interactive object manipulation, and automated assessments.

Keywords *Curved-surface solids, Interactive e-module, Conceptual understanding, Realistic mathematics education*

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Introduction

Curved-surface solids are important parts of spatial geometry in mathematics. They are three-dimensional objects with at least one curved surface (Marasabessy et al., 2021). In primary and secondary education in Indonesia, the curved-surface solids studied include cylinders, cones, and spheres (Kemendikbudristek, 2024; Mendikbud RI, 2018). Learning about curved-surface solids serves as a means for students to develop skills in analyzing and interpreting various everyday phenomena, and helps them understand and operate other mathematical concepts (Dana-Picard & Hershkovitz, 2019). Furthermore, studying curved-surface solids is important because the concepts form the foundation for understanding the shapes and properties of three-dimensional objects, which in turn supports the mastery of other mathematical concepts such as surface area, volume, and the relationships between elements of spatial geometry (Puig et al., 2022; Rohendi & Wihardi, 2020). Therefore, students need to improve their understanding of curved-surface solids and possess adequate skills in relating them to other geometry topics.

Various studies indicate that students still encounter numerous difficulties in learning curved-surface solids (Agustini & Fitriani, 2021; Marasabessy et al., 2021; Özerem, 2012; Solin et al., 2023). Observations and a preliminary interview with a ninth-grade mathematics teacher at a private junior high school in Surakarta City highlight these findings. The teacher revealed that the motivation of ninth-grade students towards learning curved-surface solids remains low, leading to a lack of enthusiasm during lessons. Students often struggle to understand the basic concepts and properties of curved-surface solids, as evidenced by their poor performance in answering simple questions about the shapes and characteristics of these objects. This problem is linked to the predominantly conventional teaching methods, such as lectures, which fail to actively engage students in the learning process. Additionally, the teaching media and materials used by the teacher are generally manual and have not used interactive technology, thus failing to facilitate the visualization of the abstract concepts inherent in curved-surface solids. These factors are suspected to contribute to the low conceptual understanding of students on this topic. The problems of underutilized interactive learning media and low student conceptual understanding can be addressed through the implementation of electronic teaching materials (Hariyono & Ulia, 2020; Nurjanah et al., 2017; Putri et al., 2021; Sari et al., 2019). One form of electronic teaching materials that can be used is an e-module.

An e-module is a digital teaching material that integrates multimedia elements and interactive features to enhance the student learning experience (Mariskha et al., 2022; Vrcek & Magdalenic, 2011). As part of e-learning, e-modules utilize technological advancements to support the learning process (Ramadanti et al., 2021). Compared to printed modules, e-modules can incorporate videos, audio, animations, and other interactive features that students can access and replay, thereby enriching their learning experience (Holisoh et al., 2023; Suarsana & Mahayukti, 2013). Research shows that the use of e-modules is effective in improving students' conceptual understanding of mathematics (Sumliyah et al., 2023; Ramli, 2022). To help students understand abstract mathematical concepts, such as those in curved-surface solids, the application of a suitable learning approach in e-module development is necessary. One relevant approach is Realistic Mathematics Education (RME).

The application of RME is essential for teaching abstract mathematical concepts. This approach is designed to relate abstract mathematical concepts to real-life experiences and situations that are more easily understood by students (Samritin et al., 2023; Santoso, 2017; Siregar, 2021). Through RME, students are guided to reinvent mathematical ideas, concepts, and principles by solving contextual problems derived from the real world (Santosa et al., 2026; Suparni, 2020; Yuanita et al., 2018). Thus, RME encourages active student engagement in the learning process, ensuring that their understanding of mathematical material is not merely mechanistic or based on memorization, but develops through a process of constructing meaning that is deep and relevant to everyday life. Therefore, developing an RME-based e-module is necessary so that students can learn mathematics more contextually, interactively, and meaningfully. Before development is undertaken, a needs analysis must be conducted to identify students' learning difficulties, perceptions of learning challenges, and suitable e-module characteristics from students' perspectives, as they are the primary users of the learning materials (Leong et al., 2020).

Studies on needs analysis prior to e-module development have been widely conducted. Several studies on mathematics e-module needs analysis were carried out in the Indonesian context. For example, Purwoko et al. (2020) conducted a needs analysis for an e-module based on Central Javanese ethnomathematics. Asrowiah et al. (2021) conducted a needs analysis for developing an e-module in distance learning during the Covid-19 pandemic. Meanwhile, Bikoir et al. (2022) carried out a needs analysis for developing a mathematics e-module for students of sixth grade. Pirma and Caswita (2023) conducted a needs analysis in the development of an ethnomathematics-based flipbook e-module, while Qomalasari et al. (2021) carried out a needs analysis for developing an e-module on fractions at elementary school level. However, studies specifically analyzing students' needs for developing an RME-based e-module, particularly on the topic of curved-surface solids at the junior high school level, are still limited.

Based on this background, a study to identify the needs for the development of an RME-based e-module on curved-surface solids at the junior high school level is needed. This study aims to obtain a detailed description of students' needs from their perspectives in learning curved-surface solids so that the developed RME-based e-module can be effective and suited to the characteristics and difficulties faced by students. Specifically, this research aims to identify: (1) students' difficulties in learning curved-surface solids, (2) aspects of students' conceptual understanding of the topic, (3) the e-module content required by students, and (4) the e-module features needed to support learning.

Methods

Research design

This study employed a mixed-methods approach with a sequential explanatory design (Creswell & Creswell, 2017). This design was chosen because the research began with the collection and analysis of quantitative data, then followed by the collection and analysis of qualitative data to elaborate on and explain the quantitative findings. The integration of these two data types was expected to provide a more comprehensive overview of student needs for the development of an e-module on curved-surface solids.

Participants and data collection

The participants of this study comprised 94 ninth-grade students from a private junior high school in Surakarta who had previously studied the topic of curved-solids geometry. A total sampling technique was employed, wherein the entire population of ninth-grade students familiar with the subject matter was included in the study. This approach was utilized to obtain comprehensive quantitative data regarding students' learning difficulties, levels of conceptual understanding, and their needs concerning RME-based e-module.

In the quantitative phase, all 94 students completed a needs questionnaire distributed via Google Form. The data from this phase were used to identify student difficulties, levels of conceptual understanding, and needs regarding the content and features of an RME-based e-module.

In the qualitative phase, three students were selected using purposive sampling based on the variance in their questionnaire responses, representing high, medium, and low levels of conceptual understanding and learning difficulties (Arikunto, 2006). The selection of these students aimed to capture diverse student characteristics, thereby enabling an in-depth exploration of their experiences and needs. The limited number of participants in the qualitative phase was deemed adequate, as qualitative inquiry prioritizes rich, in-depth information over statistical generalization (Patton, 2014). Consequently, these students were interviewed to gain a deeper understanding of their requirements for the RME-based e-module, specifically concerning learning difficulties, conceptual understanding, and the necessary content and features.

Instrument

The primary instrument in this study was a questionnaire on student needs for the development of an RME-based e-module on curved-surface solids. The questionnaire consisted of four dimensions: (1) student difficulties in learning curved-surface solids, (2) aspects of conceptual understanding, (3) needs regarding e-module content, and (4) needs regarding e-module features. Each statement item was constructed using a 5-point Likert scale, ranging from Strongly Disagree (1) to Strongly Agree (5). This scale was used to measure students' perceptions of statements reflecting their learning experiences and needs for the development of an RME-based e-module (Caia et al., 2018; Wu & Leung, 2017). Prior to being used, the questionnaire was validated by two experts in mathematics education. Content validity analysis was performed using the Content Validity Index (CVI) with Aiken's V formula, yielding a result of 0.86, which indicates high validity (Aiken, 1980). Furthermore, the reliability of the questionnaire was tested using Cronbach's Alpha coefficient, which produced a value of α = 0.945, indicating that the questionnaire has very high reliability (Taber, 2018).

Additionally, a semi-structured interview guide was used to elaborate on the findings from the quantitative data. The interview questions were developed based on the dimensions measured in the questionnaire, such as student difficulties, conceptual understanding, and e-module content and feature needs. Sample questions included: "Which part of the curved-surface solids topic did you find most difficult to understand?", "In your opinion, what should an e-module look like to be engaging and helpful for learning?", and "What interactive features would you like to have in this e-module?"

Data analysis

Data analysis in this study was conducted in stages, following the sequential explanatory design. The first stage involved the analysis of quantitative data obtained from the student needs questionnaire. The data were analyzed using a percentage formula, calculated by comparing the number of respondents in each response category (SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree) with the total number of respondents, then multiplied by 100%. The results were presented in a table to illustrate the tendency of student responses for each statement. Score interpretation referred to the criteria by Riduwan (2012), as presented in Table 1.

Table 1. Interpretation criteria of percentage scores

Score	Category
0% – 20%	Very weak
21% – 40%	Weak
41% – 60%	Moderate
61% – 80%	Strong
81% – 100%	Very Strong

The second stage involved the analysis of qualitative data obtained through semi-structured. The second stage involved the analysis of qualitative data obtained through semi-structured interviews with three students selected via purposive sampling. The analysis was performed using the model by Miles et al. (2014), which includes three main steps: (1) data reduction, the process of selecting and focusing on relevant data from the interview results; (2) data display, organizing the data into systematic narratives; and (3) conclusion drawing, the process of interpreting the meaning of the data to verify and explain the quantitative findings. The results from both analytical stages were then integrated to gain a comprehensive understanding of student needs for the development of an RME-based e-module on curved-surface solids.

Findings and Discussion

The questionnaire was administered to 94 ninth-grade students at a private junior high school in Surakarta City. Based on demographic data, many respondents were male (58.5%), while female students accounted for 41.5%. The questionnaire responses were subsequently analyzed across four main components: (1) student difficulties in learning curved-surface solids, (2) aspects of student conceptual understanding of the topic, (3) e-module content needs, and (4) e-module feature needs.

Students' difficulties in learning curved-surface solids

Based on the questionnaire results from 94 students, it was found that most students still experienced difficulties in learning the topic of curved-surface solids. As Table 2 indicates, most responses fell into the Neutral (N) to Agree (A) categories for almost all statements. For instance, regarding the statement on the difficulty of learning the elements of a cylinder, 47.7% of students responded Neutral and 41.5% responded Agree. According to the interpretation criteria in Table 1, the combined percentage for the tendency of difficulty (combined A and SA) falls into the "Moderate" category (47.7%). A similar pattern was observed for the elements of a cone (49.2% N; 38.5% A) and a sphere (43.1% N; 44.6% A), which also fall into the "Moderate" category.

Table 2. Students' response

Statement	Response options				
	SD	D	N	A	SA
I experience difficulties when learning the elements of a cylinder in the instruction of curved-surface solids.	3.1 %	1.5%	47.7%	41.5%	6.2%

Statement	Response options				
	SD	D	N	A	SA
I experience difficulties when learning the elements of a cone in the instruction of curved-surface solids.	1.5%	6.2%	49.2%	38.5%	4.6%
I experience difficulties when learning the elements of a sphere in the instruction of curved-surface solids.	1.5%	7.7%	43.1%	44.6%	3.1%
I experience difficulties when learning the volume of a cylinder in the instruction of curved-surface solids.	4.6%	6.2%	40%	44.6%	4.6%
I experience difficulties when learning the surface area of a cylinder in the instruction of curved-surface solids.	3.1%	3.1%	44.6%	41.5%	7.7%
I experience difficulties when learning the volume of a cone in the instruction of curved-surface solids.	3.1%	9.2%	44.6%	40%	3.1%
I experience difficulties when learning the surface area of a cone in the instruction of curved-surface solids.	3.1%	4.6%	47.7%	41.5%	3.1%
I experience difficulties when learning the volume of a sphere in the instruction of curved-surface solids.	1.5%	12.3%	40%	40%	6.2%
I experience difficulties when learning the surface area of a sphere in the instruction of curved-surface solids.	1.5%	7.7%	41.5%	44.6%	4.6%
I experience difficulties in understanding cylinder-related material due to insufficient visualization or supporting media.	3.1%	6.2%	38.5%	46.2%	6.2%
I experience difficulties in understanding cone-related material due to insufficient visualization or supporting media.	4.6%	9.2%	36.9%	43.1%	6.2%
I experience difficulties in understanding sphere-related material due to insufficient visualization or supporting media.	3.1%	10.8%	40%	41.5%	4.6%

These findings indicate that students have not yet fully mastered the basic structure of curved-surface solids. The relatively high proportion of Agree and Strongly Agree responses indicates that these difficulties are experienced by a significant number of students, albeit not in the "Strong" category. Similar difficulties are apparent in the aspects of volume and surface area, with the combined proportion of Agree and Strongly Agree responses reaching 40–52.4%. Based on the interpretation criteria in Table 1, these values again fall into the "Moderate" category, meaning that obstacles remain in understanding the relationships between variables, applying formulas, and visualizing three-dimensional shapes. Furthermore, students also acknowledged a lack of support from media or visualizations in their learning. For example, a total of 52.4% of students responded Agree and Strongly Agree, indicating that they found it difficult to learn about cylinders due to a lack of visualization.

These questionnaire results are consistent with the interview findings from the qualitative phase. In general, students expressed that the main difficulties lay in the ability to visualize three-dimensional shapes, fully understand the concepts of volume and surface area, and find meaningful contexts for curved-surface solids. The following is a summary of their statements.

S1: "Actually, I understand what cylinders and cones look like, but when it comes to surface area or volume, I start getting confused about which parts need to be counted. Especially when the shape is rotated or shown as a net. Sometimes I just memorize the formulas without really understanding where they come from."

S2: "I struggle the most with imagining the 3D shapes. When the book only shows flat pictures, it's hard for me to figure out which part is the base, which part is the curved surface, and what it looks like when it's opened. When the teacher explains the formula for volume or surface area, I just follow along, but afterward I still can't solve the problems if the numbers are different."

S3: "I can actually follow the lessons on curved-surface solids, but there are some parts that make me unsure. For example, choosing the right formula or understanding the context of word problems. Sometimes I need real examples or some kind of visualization to feel more confident about the steps I take."

Overall, the questionnaire and interview findings demonstrate that the primary sources of student difficulty lie in visualizing three-dimensional shapes, understanding the concepts of volume and surface area, and identifying the elements of curved-surface solids. These obstacles are closely related to the limitations of available visual media and supporting explanations in the current learning process. Figure 1 presents a visual mapping of the overall pattern of these difficulties.

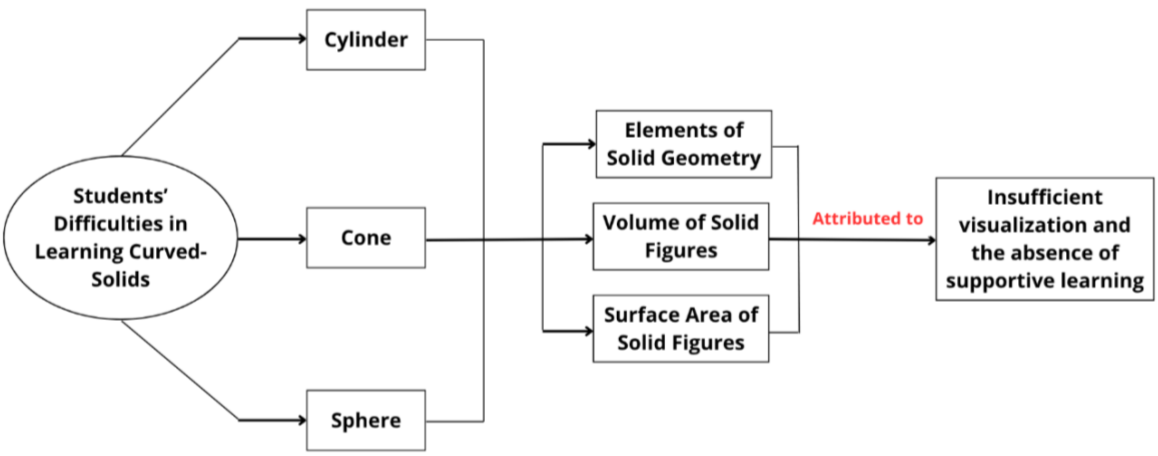

Figure 1. Conceptual map of students' difficulties in learning curved-surface solids

The findings regarding student difficulties with the volume and surface area of curved-surface solids align with the results of a study by Arifin et al. (2017), who revealed that students often struggle to understand formulas and apply them to solve problems related to curved solids. These difficulties are closely linked to low conceptual understanding, as noted by Khoirunnisa et al. (2020), who found that a weak understanding of the structure of three-dimensional shapes and calculation errors are primary factors preventing students from solving problems correctly. Furthermore, limitations in visualization, whether in the form of learning media or pictorial representations, constitute a dominant reason hindering the students' comprehension. This finding corroborates the results of Ismail et al. (2020), who affirmed that a lack of visual representation results in students' difficulty in distinguishing and recognizing the characteristics of three-dimensional shapes, consequently leading to conceptual errors and incorrect formula selection.

Students' conceptual understanding of curved-surface solids

The indicators of conceptual understanding used in this study refer to the framework proposed by Sumarmo (2014). Based on the questionnaire results presented in Table 3, the understanding of concepts related to curved-surface solids tends to be in the Moderate category. In general, most of student responses fell into the Neutral (N) to Agree (A) categories across almost all indicators of conceptual understanding.

Table 3. Students' response

Indicators	Statements	Response options				
		SD	D	N	A	SA
Stating Examples and Non-Examples of Concepts	I can provide examples of objects around me that represent a cylinder.	0%	3.1%	46.2%	36.9%	13.8%
	I can provide examples of objects around me that represent a cone.	1.5%	4.6%	40%	40%	13.8%
	I can provide examples of objects around me that represent a sphere.	1.5%	4.6%	38.5%	35.4%	20%
	I can provide non-examples of objects around me that are not cylinders.	1.5%	4.6%	38.5%	41.5%	13.8%
	I can provide non-examples of objects around me that are not cones.	3.1%	6.2%	40%	38.5%	12.3%
	I can provide non-examples of objects around me that are not spheres.	1.5%	4.6%	43.1%	33.8%	16.9%
Restating Concepts	I can explain the elements of a cylinder using my own words.	1.5%	10.8%	60%	21.5%	6.2%
	I can explain the elements of a cone using my own words.	1.5%	9.2%	61.5%	23.1%	4.6%
	I can explain the elements of a sphere using my own words.	3.1%	9.2%	67.7%	16.9%	3.1%
Classifying Objects Based on Specific Attributes	I can distinguish between cylinders and prisms based on their properties.	1.5%	13.8%	52.3%	30.8%	1.5%
	I can distinguish between cones and square pyramids based on their properties.	0%	18.5%	50.8%	27.7%	3.1%
Presenting Concepts in Various Mathematical Representations	I can identify the components of the formulas for the volume and surface area of a cylinder.	3.1%	24.6%	50.8%	16.9%	4.6%
	I can identify the components of the formulas for the volume and surface area of a cone.	3.1%	23.1%	58.9%	10.8%	6.2%

Indicators	Statements	Response options				
		SD	D	N	A	SA
Using, Applying, or Choosing Appropriate Procedures	I can identify the components of the formulas for the volume and surface area of a sphere.	4.6%	21.5%	60%	10.8%	3.1%
	I can choose the correct formulas to calculate the volume and surface area of curved-surface solids.	3.1%	23.1%	55.4%	13.8%	4.6%
Applying Concepts or Algorithms to Solve Problems	I can apply formulas for the volume and surface area of curved-surface solids to solve problems related to everyday life.	1.5%	20%	61.5%	15.4%	1.5%

For the indicator of providing examples and non-examples of curved-surface solids, students showed a higher level of certainty compared to other indicators. This is evident from the combined proportion of Agree and Strongly Agree responses, which reached approximately 50–55% (categorized as Moderate), indicating that they felt reasonably capable of implementing this indicator.

Conversely, for the indicators of restating a concept and classifying objects, student responses were mostly in the Neutral category, reflecting a high degree of uncertainty in assessing their own abilities. Regarding restating concepts, 60–68% of students selected Neutral, suggesting that the majority were unsure of their ability to explain the elements of three-dimensional shapes in their own words. A similar pattern was observed for the classification indicator, where over 50% of students chose Neutral. These findings indicate that while students can intuitively recognize differences in shapes, they lack the confidence to perform classifications accurately.

The dominance of Neutral responses was also strongly evident in the aspects of mathematical representation and the use of procedures or algorithms. For the indicator of identifying the components of volume and surface area formulas for curved-surface solids, 50–60% of students selected Neutral, while the proportion of Agree and Strongly Agree responses was relatively low (13–22%). This shows that students' understanding of the formula structures remains superficial and unstable. A similar condition was observed in the ability to select and apply procedures, with 55–61% of students again selecting Neutral. This prevalence of uncertainty signifies a lack of student confidence and fluency in correctly using formulas to solve contextual problems, indicating that their procedural skills are not yet optimally developed.

For the final indicator, applying a concept or algorithm in problem-solving, the Neutral category was even more dominant (61.5%), while the combined Agree and Strongly Agree accounted for only about 16.9%. This finding indicates that students lack confidence in their ability to apply volume or surface area formulas in real-life contexts. Consequently, their mathematical application and connection skills can be considered underdeveloped (Purnomo et al., 2024; Sisman & Aksu, 2016).

The questionnaire analysis results are consistent with the findings from the qualitative interview stage. In general, students reported that their greatest uncertainty lay in the ability to explain concepts in their own words, recognize the structure of volume and surface area formulas, and apply procedures to contextual problems. The dominance of Neutral responses in the questionnaire was reflected in students' admissions of feeling "unsure" about their own conceptual and procedural abilities. The following is a summary of their statements:

S1: “I can recognize cylinders, cones, and spheres, but when I try to explain their parts in my own words, I’m not really confident. I usually remember the formulas, but I don’t fully understand what each part means. So, when I face word problems, I’m not sure which formula I should use.”

S2: “I can tell the shapes apart most of the time, but I still feel unsure when I have to classify them or give my own examples. I follow the teacher’s explanation about volume and surface area, but later I still don’t know where to start when solving different kinds of problems.”

S3: “There are still many things I don’t completely understand. For example, choosing the right formula or figuring out the context in word problems. That’s why I often feel uncertain, and I usually pick the neutral option because I’m not confident about my own ability.”

Overall, students' conceptual understanding of curved-surface solids remains in the Moderate category, with a dominance of Neutral responses indicating uncertainty in assessing their own conceptual understanding. Both the questionnaire and interview results affirm that students' conceptual and procedural understanding is not fully developed, particularly in explaining concepts, recognizing formula structures, and applying procedures to contextual problems. Furthermore, an overview of students' conceptual understanding of curved three-dimensional shapes is visualized in Figure 2.

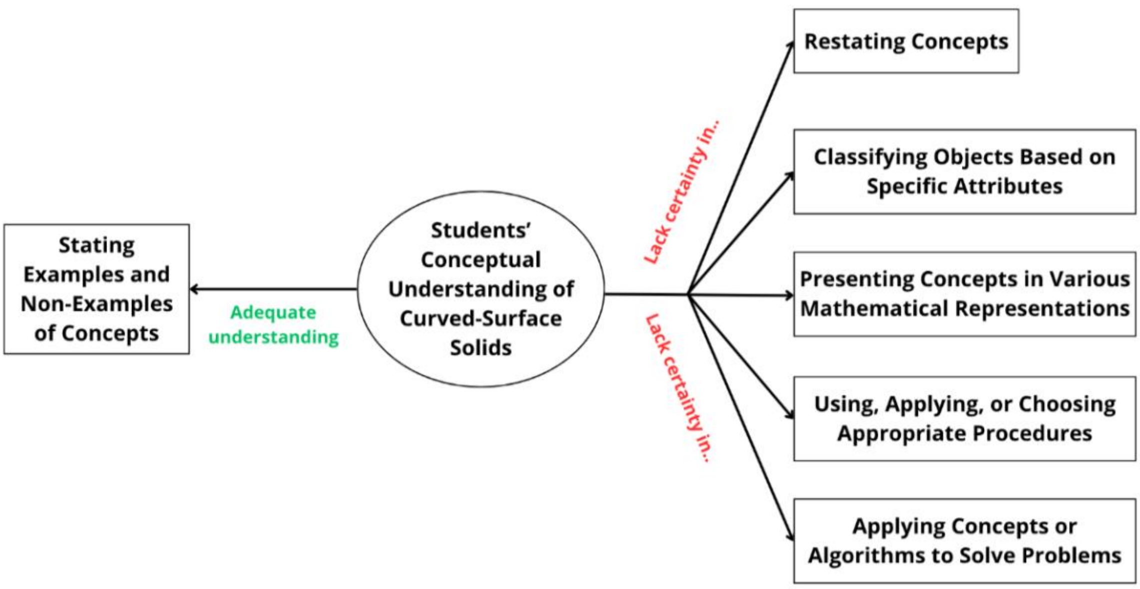

Figure 2. Conceptual map of students’ understanding on curved-surface solids

The dominance of uncertain responses suggests that students lack metacognitive clarity regarding their own abilities (Preheim et al., 2023). Such uncertainty typically arises when conceptual understanding is still at an initial stage or has not been adequately internalized (Lu et al., 2023; Santosa et al., 2025). Furthermore, the low proportion of Agree and Strongly Agree responses on indicators related to identifying volume and surface area formulas indicates that students' knowledge structures remain fragmented. This finding aligns with the view of Borji et al. (2021), that procedural understanding unsupported by strong conceptual understanding tends to be fragile and short-lived. This condition impacts students' weak ability to apply procedures and connect concepts to real-world contexts, supporting the argument of Hoffman et al. (2018) that the application of concepts requires the integration of representation, understanding, and strategy. Thus, these findings underscore the need for learning strategies that emphasize strengthening conceptual understanding, utilizing multiple representations, and developing metacognitive reflection to enhance students' confidence and accuracy in applying mathematical concepts and algorithms.

Criteria for e-module content

This section delineates students' responses regarding the e-module content they require for the topic of curved-surface solids. Table 4 indicates that students need more comprehensive and structured learning support for this topic. For all statements, most students selected the Agree and Strongly Agree categories, signifying a clear need for more in-depth conceptual explanations, guided sample problems, and real-world applications within the e-module.

Table 4. Students' response

Statement	**Response options**				
	SD	**D**	**N**	**A**	**SA**
I need an in-depth explanation of the components of a cylinder in the electronic module.	0%	1.5%	36.9%	38.5%	23.1%
I need an in-depth explanation of the components of a cone in the electronic module.	1.5%	0%	33.8%	36.9%	27.7%
I need an in-depth explanation of the components of a sphere in the electronic module.	1.5%	1.5%	30.8%	43.1%	23.1%
I need sample problems that include explanations of the formulas for the volume and surface area of a cylinder.	0%	6.2%	30.8%	38.5%	24.6%
I need sample problems that include explanations of the formulas for the volume and surface area of a cone.	1.5%	0%	30.8%	44.6%	23.1%
I need sample problems that include explanations of the formulas for the volume and surface area of a sphere.	1.5%	1.5%	30.8%	40%	26.2%
I need examples of how the concept of a cylinder is applied in everyday life.	1.5%	1.5%	36.9%	35.4%	24.6%
I need examples of how the concept of a cone is applied in everyday life.	1.5%	1.5%	38.5%	36.9%	21.5%
I need examples of how the concept of a sphere is applied in everyday life.	0%	3.1%	38.5%	33.8%	24.6%
I need practice problems arranged at varying levels of difficulty to help strengthen my understanding of curved-surface solids.	3.1%	7.7%	35.4%	36.9%	16.9%

Statement	Response options				
	SD	D	N	A	SA
I need examples of applications of curved-surface solids in everyday life.	0%	3.1%	38.5%	40%	18.5%
I need examples of how concepts of curved-surface solids are applied in everyday life.	0%	1.5%	43.1%	36.9%	18.5%

Furthermore, students expressed a strong need for detailed explanations of the components of cylinders, cones, and spheres, with the combined Agree and Strongly Agree proportions ranging between 61% and 68%. This indicates that the students' understanding of the elements of curved-surface solids remains inadequate and requires further elaboration in the e-module. Similarly high proportions, ranging from 63% to 68%, were observed for students' need for sample problems accompanied by explanations of the volume and surface area formulas. This finding reveals that students do not merely require exposure to formulas but also need explicit guidance on how these formulas are derived and applied in problem-solving.

Additionally, students emphasized the importance of examples applying the concepts of cylinders, cones, and spheres in everyday life, with the Agree and Strongly Agree proportions ranging from 58% to 61%. They also stated the need for practice questions with progressively increasing difficulty levels, reflected by over 55% of respondents selecting Agree or Strongly Agree. Moreover, approximately 58% to 62% of students expressed the need for examples of curved-surface solids applications in real-world contexts, further underscoring the importance of providing contextual tasks to support the reinforcement of conceptual understanding.

The interview results reinforce these questionnaire findings, indicating that students indeed require more comprehensive explanations, sample problems accompanied by formula derivations, and real-world application contexts to understand curved-surface solids. In general, students conveyed that they often need additional explanations regarding the components of cylinders, cones, and spheres because the explanations available during lessons have not provided a complete picture. The following is a summary of student statements:

S1: “Sometimes I know the formula for volume or surface area, but I don't really understand why the formula works. If the teacher only shows the formula, I get confused when the question changes a little. I think examples with step-by-step explanations would help me understand better.”

S2: "I can recognize cylinders, cones, and spheres, but I still feel unsure about explaining their parts. If the module gives clear explanations with pictures and examples from daily life, I think it will be easier to understand the concepts."

S3: "I learn better when there are real-life examples. For example, when I see how a cone or a cylinder is used in real objects, the formula makes more sense. I also need practice questions that start from easy to difficult so I can build my understanding slowly."

Overall, these findings indicate that students require an e-module that provides detailed conceptual explanations, guided practice, progressive scaffolding, and contextual applications. These characteristics are deemed capable of supporting the development of both conceptual and procedural understanding in students learning about curved-surface solids (Pamungkas et al., 2024).

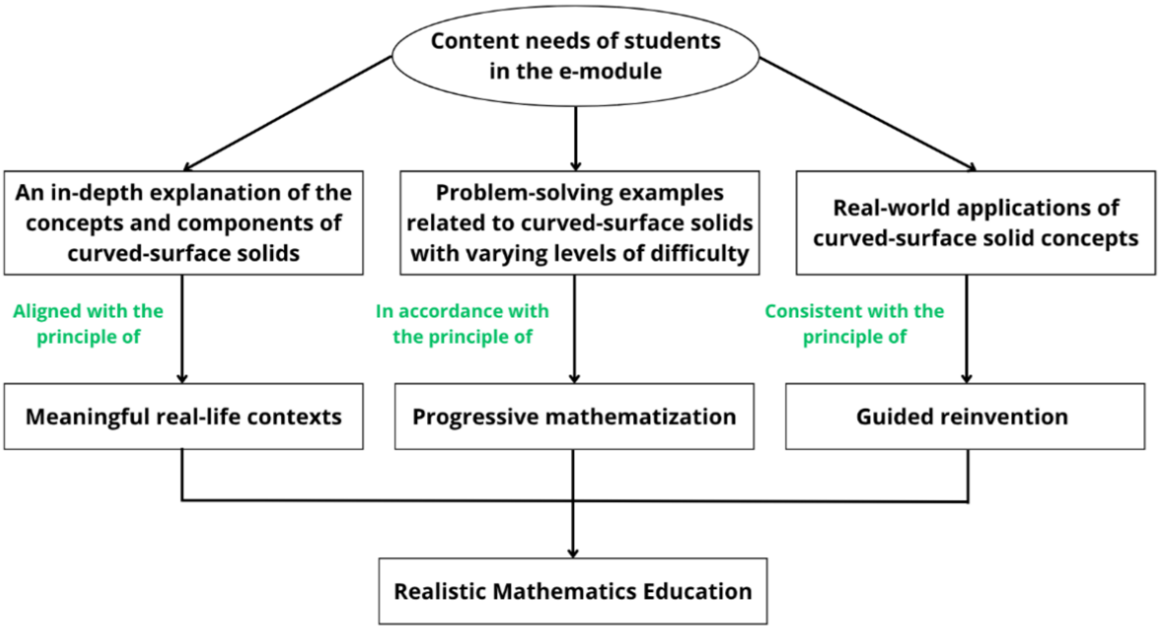

Figure 3. Conceptual map for e-module content based on RME principles: Students' needs

The findings regarding students' needs for e-module content demonstrate that they require more in-depth conceptual explanations, sample problems accompanied by formula reasoning, and real-world applications, all of which align with the principles of RME (Aulia & Prahmana, 2022; Rodi'ah et al., 2024). Figure 3 visualizes how each student need corresponds to several core components of the RME approach. The high proportion of Agree and Strongly Agree responses regarding the need for explanations of cylinder, cone, and sphere components indicates that students require a learning starting point grounded in meaningful real-life contexts, as emphasized by Freudenthal (2005). The need for examples of the application of these solids in daily life shows that students rely on context to understand conceptual structures, supporting the process of guided reinvention which allows them to reconstruct concepts through situational exploration (Solomon et al., 2021). Furthermore, the students' need for structured sample problems and progressive practice reflects the need for scaffolding that facilitates progressive mathematization, the shift from concrete representations towards formal mathematical forms (Warsito et al., 2018). Therefore, the needs identified in the questionnaire affirm the importance of developing an RME-based e-module that incorporates real-world contexts, robust visual representations, and sequential activities to build conceptual and procedural understanding more meaningfully.

Criteria for e-module features

Students' responses regarding the required e-module features for learning curved-surface solids are presented in Table 5. The questionnaire results indicate that the majority of students need visual, interactive, and automated feedback support to strengthen their understanding of curved-surface solids.

Table 5. Students' response

Statement	Response options				
	SD	D	N	A	SA
I need 3D visualizations or animations of a cylinder to help me understand the concept of a cylinder.	1.5%	3.1%	36.9%	44.6%	13.8%
I need 3D visualizations or animations of a cone to help me understand the concept of a cone.	1.5%	4.6%	35.4%	46.2%	12.3%
I need 3D visualizations or animations of a sphere to help me understand the concept of a sphere.	0%	4.6%	36.9%	44.6%	13.8%
I need tutorial videos in the module that explain the steps for calculating the volume and surface area of curved-surface solids.	1.5%	1.5%	35.45	44.6%	16.9%
I need interactive features that allow me to manipulate the size and shape of curved-surface solids to make the concepts easier to understand.	0%	0%	35.4%	47.7%	16.9%
I need automatic assessment features that provide immediate feedback on the practice questions I complete.	3.2%	1.5%	33.8%	47.7%	13.8%

The students' demand for visual and multimodal support in the e-module is very high. Approximately 58% (combined Agree and Strongly Agree) of students stated a need for 3D visualizations or animations to understand the concepts of cylinders, cones, and spheres, highlighting the importance of visual representation in helping them build a mental picture of the forms and components of three-dimensional shapes. Furthermore, 61.5% of students require tutorial videos that explain the procedures for calculating volume and surface area step-by-step, signifying the need for structured procedural explanations to reduce misconceptions. Interactive features are also a primary need, with 64.6% of students requiring manipulative facilities to change the size or shape of the solids to explore the relationships between dimensions more intuitively. On the other hand, 61.5% of students emphasized the importance of automated assessment features with immediate feedback, enabling them to conduct self-evaluation and quickly understand their errors, thereby making learning more adaptive.

The interview results reinforce these questionnaire findings. In general, students expressed that they need clearer visual, interactive, procedural explanation, and automated feedback features to understand curved-surface solids. The following is a summary of statements from three students:

S1: "When I only look at 2D images, I sometimes find it difficult to imagine what a cylinder or a cone actually looks like. If there were 3D animations that I could rotate or zoom in on, it would definitely be easier to understand. I also need a video that explains the steps for calculating volume, so I don't misunderstand them."

S2: "I feel that I understand better when I can try it myself. For example, if there is a feature that allows the size of a cylinder to be adjusted, I can see how it affects the volume. When learning in class, sometimes I memorize the formula, but if the problem changes slightly, I get confused. That's why I need clear and gradual examples."

S3: "I like it when there are practice questions that immediately show where I went wrong, so I can see which parts I haven't understood. Also, using examples from everyday objects, such as bottles or balls, makes the formulas more meaningful. I usually only understand when there are real-life examples."

Overall, the dominant tendency across the various features needed by students confirms that an effective e-module must integrate 3D visualizations, procedural explanations via video, interactive manipulation, and automated feedback to comprehensively meet their learning needs. These findings are further illustrated in the conceptual diagram shown in Figure 4.

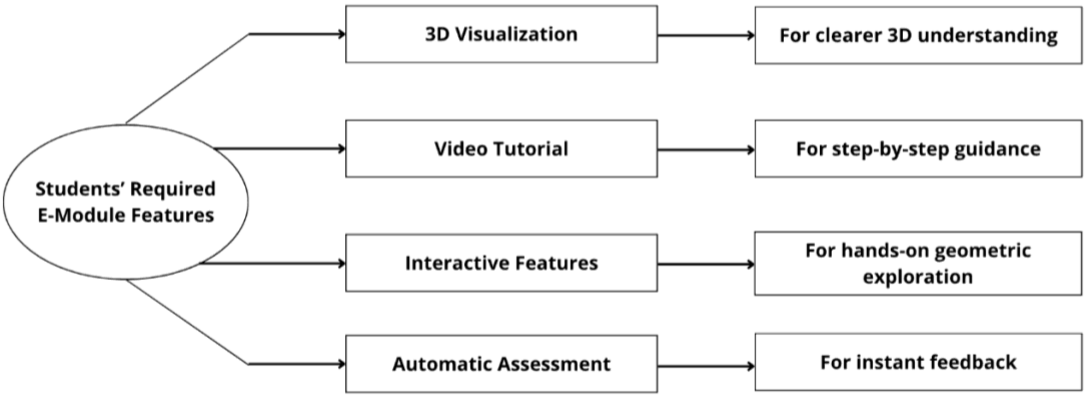

Figure 4. Conceptual map for e-module features: Students' needs

3D visualization is one of the most needed features in the e-module for curved-surface solids. This finding aligns with the view of Rahmawati et al. (2021), who affirmed that three-dimensional visual representations can enhance the understanding of geometric concepts by helping students internalize abstract objects through more concrete visual experiences. Furthermore, the need for tutorial videos explaining the procedures for calculating volume and surface area is consistent with Mayer's (2009) multimedia learning theory, which states that the integration of visuals and audio strengthens understanding through dual-channel information processing.

Interactive features enabling the manipulation of solid shapes are also deemed important by students, and this support is consistent with the findings of Ha and Fang (2017), which showed that the direct manipulation of objects can enhance spatial ability and the understanding of geometric relationships. Meanwhile, the need for automated evaluation features providing immediate feedback is reinforced by the findings of Sary (2021), who stated that instant feedback not only helps students identify errors quickly but also increases learning motivation. Collectively, these findings emphasize that an effective e-module for curved-surface solids must integrate a combination of 3D visualization, multimodal procedural explanations, interactive manipulation, and automated feedback to optimally support learning.

Conclusion

This study demonstrates that students still encounter difficulties in learning curved-surface solids, particularly in visualizing three-dimensional shapes, understanding the concepts of volume and surface area, and identifying their elements. Students' conceptual understanding was at a moderate level, characterized by the predominance of Neutral responses reflecting uncertainty in explaining concepts, recognizing formula structures, and applying procedures to contextual problems. Furthermore, students expressed a strong need for an e-module that provides in-depth conceptual explanations, guided sample problems, progressive practice, and real-world application contexts. They also emphasized the importance of visual and interactive features, including 3D visualizations, procedural tutorial videos, object manipulation, and automated assessments with immediate feedback. Overall, these findings confirm that the developed e-module needs to present visual, conceptual, procedural, and interactive support to help students build a more comprehensive understanding of curved-surface solids.

This study is subject to several limitations. Firstly, the data were derived exclusively from questionnaires and interviews without direct measurement of students' cognitive abilities. Consequently, the interpretation of students' conceptual understanding remains contingent upon self-reporting and perception. Secondly, the study sample was restricted to a single school; therefore, caution must be exercised when generalizing these findings to a broader population. Thirdly, the scope of this research was confined to the needs analysis phase and did not extend to the evaluation of the developed e-module's effectiveness. Fourthly, the needs analysis was conducted exclusively from the students' perspective, excluding the insights of teachers. Teachers could have offered distinct perspectives regarding pedagogical challenges, curriculum alignment, and practical considerations for the implementation of the e-module in the classroom.

Future research is recommended to develop and test the e-module designed based on the findings of this needs analysis. Employing experimental or quasi-experimental designs would allow for a rigorous investigation into the module's impact on students' conceptual understanding. Subsequent studies should also involve samples from multiple schools to enhance external validity. Furthermore, a more in-depth examination is required to determine how specific interactive features, such as three-dimensional (3D) object rotation, simulations, or adaptive feedback, influence students' learning strategies and cognitive processes. Finally, longitudinal studies are essential to assess the sustained impact of e-module utilization on students' problem-solving abilities and mathematical literacy.

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