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Developing Student Worksheet of Cylinder Using Techno-Ethno-Realistic Mathematics Education Assisted by Augmented Reality

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ABSTRACT

Mastery of cylinder material is essential for strengthening students' spatial reasoning and understanding of curved 3D shapes; however, prior research indicates persistent difficulties in learning 3D shapes, one of which is the cylinder. These difficulties are often exacerbated by the limited use of innovative, contextual, and technology-supported learning materials. To address these challenges, this research applied the Techno-Ethno-Realistic Mathematics Education (TE-RME) approach to support students' learning of the cylinder. This study aims to develop a student activity sheet using the TE-RME assisted by AR. This study employs a design research approach in two stages: a preliminary study and a formative evaluation. The subjects of this study were 33 ninth-grade students of a junior high school in Semarang. Data collected through observations, tests, and interviews were analyzed descriptively. This study produced a student activity sheet on a cylinder, assisted by AR, which showed effectiveness with N-Gain at 69%, categorized as moderately effective. Based on these findings, it can be concluded that the TE-RME-based student activity sheet, assisted by AR, is effective in supporting students' conceptual understanding and problem-solving skills. The integration of AR and the TE-RME approach reflects a commitment to innovation and continuous development of effective learning designs that promote inclusive, equitable, and meaningful learning experiences

ABSTRAK

Penguasaan materi silinder sangat penting untuk memperkuat kemampuan penalaran spasial dan pemahaman siswa terhadap bangun ruang sisi lengkung; namun, penelitian sebelumnya menunjukkan kesulitan dalam mempelajari bangun ruang sisi lengkung, salah satunya adalah silinder. Kesulitan ini seringkali diperparah oleh penggunaan yang terbatas dari bahan ajar inovatif, kontekstual, dan berbantuan teknologi. Untuk mengatasi tantangan ini, penelitian ini menerapkan pendekatan Techno-Ethno-Realistic Mathematics Education (TE-RME) untuk mendukung pembelajaran siswa tentang silinder. Penelitian ini bertujuan untuk mengembangkan lembar aktivitas siswa menggunakan TE-RME yang didukung oleh AR. Penelitian ini menggunakan pendekatan penelitian desain yang terdiri dari dua tahap: studi pendahuluan dan evaluasi formatif. Subjek penelitian ini adalah 33 siswa kelas IX SMP di Semarang. Data yang dikumpulkan melalui observasi, tes, dan wawancara dianalisis secara deskriptif. Penelitian ini menghasilkan lembar aktivitas siswa tentang silinder yang berbantuan AR, yang menunjukkan efektivitas dengan

N-Gain sebesar 69%, dikategorikan sebagai cukup efektif. Berdasarkan temuan ini, dapat disimpulkan bahwa lembar aktivitas siswa berbasis TE-RME berbantuan AR efektif dalam mendukung pemahaman konseptual dan kemampuan pemecahan masalah siswa. Integrasi AR dan pendekatan TE-RME mencerminkan komitmen terhadap inovasi dan pengembangan berkelanjutan desain pembelajaran yang efektif, yang mempromosikan pengalaman belajar yang inklusif, adil, dan bermakna.

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INTRODUCTION

Understanding curved 3D shapes such as cylinders is a fundamental element of school geometry. Mastery of cylindrical concepts, including their properties, nets, surface area, and volume, is essential not only for students' spatial reasoning but also for measurement competencies and real-life applications, for example, in architecture, engineering, manufacturing, and design (Ruipérez-Valiente & Kim, 2020). 3D geometry supports many high-level mathematical concepts that rely on the ability to visualize, model, and calculate spatial quantities. In the context of global education, strengthening students' competencies in curved side spaces, such as cylinders, can support deeper mathematical literacy and help bridge the gap between abstract mathematics and real world problem-solving.

Despite this recognized importance, numerous studies indicate that many students experience difficulties in learning curved three-dimensional shapes. These difficulties are reflected in students' limited conceptual understanding, challenges in visualizing curved surfaces, and frequent errors when solving problems related to surface area and volume. However, despite its recognized importance, numerous studies indicate that many students experience difficulties in learning curved three-dimensional shapes. These difficulties are evident in students' limited conceptual understanding, challenges in visualizing curved surfaces, and frequent errors when solving problems related to surface area and volume. solid geometry problems, researchers found that students struggled with "understanding concepts, difficulties in applying principles, and challenges in process skills," particularly when problems involved curved 3D shapes (Kusuma et al., 2023). Similarly, students' conceptual and procedural understanding is often weak when transferring from two-dimensional representations, such as nets or 2D drawings, to three-dimensional objects, especially to determine the volume and area of the surface (Sudirman et al., 2023). These findings highlight the persistent learning difficulties with 3-D geometry, suggesting that conventional instruction, such as textbooks, is inadequate for building a strong understanding of the concepts.

Several factors contribute to these problems. First, the abstract nature of 3D geometry requires mental visualization, transformations between 2D and 3D, and spatial structuring, which present a high cognitive load. Epistemological barriers arise when students attempt to interpret the 3D shape of a 2D representation, identify structural elements such as base, height, and curved surface, and correctly calculate surface area or volume (Sudirman et al., 2023). Second, many students lack innovative and context-rich learning materials; teachers often rely on static drawings, formulas, or diagrams, which fail to convey the spatial structure of the curved side space concretely. As described in research on three-dimensional geometry learning, the use of ineffective or minimal media, along with the absence of interactive

visualization tools, hinders students' spatial reasoning and conceptual understanding (Cherif et al., 2017). In other words, not using carefully designed, innovative worksheets or media can be a significant factor underlying students' conceptual and procedural errors when solving problems involving curved 3D shapes, especially cylinders.

To overcome these challenges, some previous studies have attempted to develop worksheets or modules for geometry using the Realistic Mathematics Education (RME) approach. RME emphasizes learning mathematics in a context that is meaningful to students' real lives, guided rediscovery, and progressive mathematics. For example, a study developed an RME-based student worksheet on circular material and found it to be valid, practical, and effective in improving students' mathematical reasoning skills (Erita et al., 2022). Further research proposes a hypothetical learning trajectory for cylindrical materials based on the RME principle, demonstrating that 3D spatial learning using RME yields positive results that enhance students' understanding of concepts and motivation (Jannah & Amir, 2025; Nursyahidah, 2021; Nursyahidah, Albab, & Rubowo, 2023). This study shows that when geometry is embedded in a realistic context, students are more likely to engage meaningfully and build an understanding of informal to formal mathematics (Hardiyanto et al., 2024).

Despite the promising foundation, there are still gaps in integrating contextual context on ethnomathematics and modern augmented reality visualization technologies into RME-based worksheets for cylindrical materials. This gap motivated this research, which aimed to develop student activity sheets using Techno-Ethno-RME. This activity sheet relies on local wisdom/contextual realism and is assisted by augmented reality (AR) to support the visualization of curved 3D shapes. The novelty of this research lies in the incorporation of three dimensions, namely (1) culturally relevant contexts in ethnomathematics, (2) pedagogical design of RME, and (3) technology, as we know it as the TE-RME approach (Nursyahidah et al., 2025b, 2025a). The media technology used in this study is augmented reality (AR), which aims to address well-documented difficulties in understanding curved side spaces, particularly cylinders. By integrating visualization, interaction, and contextual representation, this study combines three essential components for learning about cylinders, an approach that has not been explored in previous research.

Building on this integration, the use of ethnomathematical contexts such as cultural traditions within the community provides students with meaningful entry points to learning, enabling them to connect abstract geometric concepts with their lived environment. Aided by animated videos and AR, activity sheets can help students dynamically visualize 3D shapes, mentally/visually rotate them, explore nets and surfaces, and deepen their understanding through interactive exploration (Yaniawati et al., 2023). Previous studies on the use of AR in learning curved side spaces have shown that it can improve students' spatial abilities and engagement (Gargrish et al., 2020; Winarni et al., 2023). Additionally, using AR for mathematics learning can positively support learning gains and attitude (Cai et al., 2023). Moreover, using AR can support creative thinking skills (Nusantara et al., 2025). Thus, this study aims to contribute to the field by developing an activity sheet to build curved side spaces using TE-RME in the context of traditional *rewanda* offerings, assisted by AR technology for cylindrical learning, which can strengthen students' conceptual understanding, spatial reasoning, motivation, and problem-solving skills.

Based on this background, this study aims to develop student activity sheets on the material of the curved side space using the innovative approach of TE-RME in the context of the tradition of *rewanda* offerings assisted by AR media. Its main contribution lies in its potential to improve conceptual understanding and problem-solving, as well as offering a

replicable model for mathematics education that is culturally responsive and integrated with technology.

METHOD

The purpose of this study is to design and validate student worksheets about curved 3D shapes using Augmented Reality-assisted TE-RME. This research aims to develop materials for curved 3D shapes by developing instructional resources based on the TE-RME approach, utilizing AR learning media as an educational innovation. This aligns with one of the key principles of design research, which emphasizes innovative educational practices (Siswanto et al, 2025). As part of the validation process, this study also assessed the effectiveness of student activity sheets using AR-assisted TE-RME in improving students' problem-solving abilities in the curved 3D shapes. The development process follows two main stages: initial evaluation, which includes initial analysis and design, and formative evaluation, which involves repeated testing and refinement (Gravemeijer, 1994; Treffers, 1991). The sequence of these stages is illustrated in **Figure 1**.

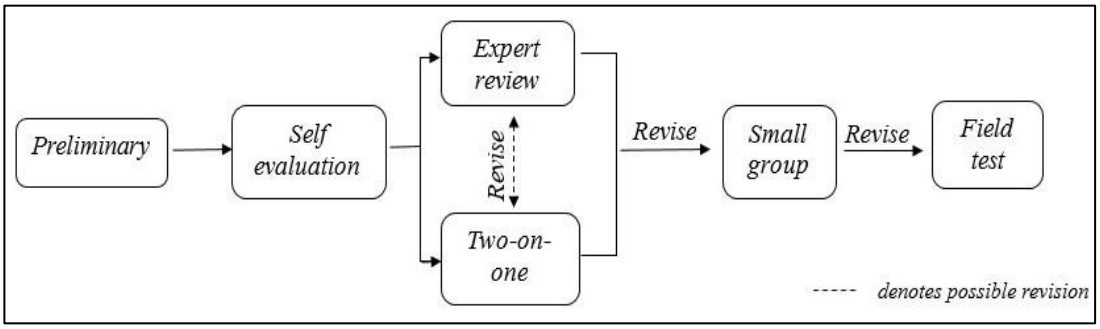


Figure 1. Research flow

Figure 1 illustrates the research flow in this study. The initial evaluation stage involves analyzing the curriculum, selecting materials for curved 3D shapes, utilizing innovative learning media, and assessing student characteristics, followed by the development of learning materials. The formative assessment phase focuses on the prototyping process, which includes expert reviews, one-on-one evaluations, small group evaluations, and field test evaluations. This research was conducted on 9th-grade students from SMPN 38 Semarang.

During the preliminary study, the researchers identified problems with curved 3D shapes in grade 9 that were relevant to the educational context. This is achieved through literature reviews, previous studies, and appropriate books, as well as curved 3D shapes. In addition, the researcher analyzed the curriculum related to curved 3D shapes, set learning objectives to improve problem-solving skills, and explored local wisdom in Semarang City as a learning context. Contextual learning is a key characteristic of the TE-RME approach. In this approach, real-life contexts relevant to students can be incorporated into the teaching materials (Bakker, 2004). For example, by integrating traditional learning contexts, students are encouraged to understand the concept of curved 3D shapes while strengthening their problem-solving skills, resulting in a more meaningful mathematics learning experience.

After completing the analysis, the researchers conducted a diagnostic assessment of the students, especially those who were the subjects of the study, to identify their characteristics in grade 9. Diagnostic assessments are conducted through observation during

classroom instruction, allowing researchers to predict students' abilities and use this information to design teaching materials for curved 3D shapes that align with their characteristics, ensuring a high-quality learning experience. This is consistent with the statement by Waheed et al. (2023) that the data obtained from the teaching process can be used to improve the effectiveness of education. Finally, researchers began to develop student activity sheets as TE-RME-based learning materials assisted by innovative AR media. The function of the student activity sheet provides a space for discussion and collaboration between students, while the innovative learning media of AR serve as a learning medium that helps students visualize abstract curved 3D shape materials, making it easier for them to understand.

In formative evaluation, the researcher conducts five phases: self-evaluation, expert review, one-to-two assessment, small group evaluation, and field test. In the self-evaluation phase, the researchers independently assessed the AR-media-assisted prototype student activity sheets developed during the preliminary study. This process involves discussions with experts and model teachers, resulting in Prototype 1, which is refined to address the identified weaknesses.

During the expert review phase, Prototype 1 went through a comprehensive evaluation process conducted by both media and content experts. Media experts are responsible for evaluating the visual and technical aspects of learning media, including the layout, readability, and overall design quality of student activity sheets integrated with microlearning comics. Meanwhile, content experts evaluated the accuracy, clarity, and pedagogical relevance of the math content, particularly related to the topic of curved 3D shapes. Their feedback contributes to the revision and improvement of the prototype before wider testing.

The one-to-two evaluation will involve two Grade 9 students working with Prototype 1. Researchers observed their interactions with the material and conducted interviews using open-ended questions to explore its strengths, limitations, and learning difficulties. These insights guide the development of Prototype 2. In a small-group evaluation, Prototype 2 was tested with 6 students divided into three groups to simulate a classroom context. This phase aims to evaluate the instructional effectiveness and efficiency of the prototype on a limited scale, increasing confidence in its implementation.

In the field test evaluation, Prototype 2, which was declared valid and efficient, was tested on 33 9th-grade students at SMPN 38 Semarang. Students are divided into eight groups, each consisting of four students. At this stage, the researchers observed how students worked on AR-assisted TE-RME-based worksheets to evaluate their effectiveness in relation to students' problem-solving abilities. Additionally, the researcher asked the model teacher, who served as an instructor, to deliver the material on curved 3D shapes. The model teacher is the actual classroom teacher.

Meanwhile, the researcher acts as an observer during the evaluation, determining how well the model teacher and pupil utilize the teaching material. This is consistent with the purpose of field test evaluation, as outlined by Tessmer (1993), which is to assess the effectiveness of the instructions. At this stage, the instructions are presented in their best form, although revision is still possible.

Data analysis was conducted to evaluate the effectiveness and efficiency of AR-RME-based student activity sheets. The researcher established the assessment range for the pretest and post-test results, as shown in **Table 1**. This score is then compared to determine the extent of the student's improvement in the problem-solving ability of the curved 3D shape

material. In this way, the researcher can identify the appropriate follow-up actions for the students.

Table 1. Assessment score

Interval	Information
86 - 100	Excellent
71 – 85,99	Good
56 – 70,99	Enough
40 – 55,99	Less
< 40	Poor

As can be seen in **Table 1**, there are five categories of assessments applied by researchers, according to the range in which each student's scores fall. Each category represents a different level of student performance, allowing for a more detailed analysis of the student's problem-solving abilities. This classification guide helps researchers identify specific areas where pupils may need additional assistance or intervention.

RESULTS AND DISCUSSION

During the preliminary study, the researchers formulated learning objectives that were in line with the learning outcomes set out in the curriculum: (1) students determine various forms of cylinder nets; (2) the students determine the surface area and volume of the tube; (3) the students solve contextual problems related to the cylinder. Next, the researchers developed Prototype 1, which consisted of two activities in the student activity sheet (SAS). Previously, Augmented Reality media was created as a learning medium, provided on students' activity sheets, to help visualize the curved 3D shapes of a cylinder.

Each of these SAS was developed within the context of the tradition of offering rewanda, a traditional practice from Semarang, which is expected to stimulate active student involvement because it utilizes real-life problems. In addition to using AR, the SAS is also equipped with an animated video that describes the history and origin of the *rewanda* offerings tradition. The presence of videos, images, and AR media in SAS is expected to enhance understanding and provide a fun learning experience. The SAS display is shown in **Figure 2**.

Figure 2. Video Design on SAS

As shown in **Figure 2**, the animated video used can represent the history of the *rewanda* offering tradition, the properties used in carrying out the tradition, and the meaning

contained in it. Using real-world contexts can help students focus on a single source of information while also improving their understanding of the subject matter.

In the expert review phase, Prototype 1 was evaluated by media and content experts to identify its strengths and weaknesses. Media expert lecturers carry out media validation, while content validation involves experts in the field of Mathematics Education. At this stage, several components are reviewed (**Table 2**). The feedback provided by these experts serves as a crucial guide in refining the prototype and enhancing its overall quality.

Table 2. Summary of the results of the survey by the media

Assessment Aspects	Valuation
Display design	Good
Technical Quality	Good
Media Suitability with Material	Good
Language and Usage Factors	Good
Creativity and Novelty	Good

As shown in **Table 2**, the assessment of AR media is conducted across five aspects. All these aspects are well rated. However, there is a minor input, namely the placement of media in the SAS, which allows feedback to be provided after the student has learned the concepts independently. The medium can serve as a booster. In addition to the media, expert assessments were obtained on student activity sheets, as shown in **Table 3**.

The assessment of this activity sheet aims to evaluate the effectiveness of the activity sheet in strengthening students' understanding of the concept of curved 3D shapes. Experts provide feedback on the clarity, usability, and alignment of the activity sheet with the learning objectives, which helps refine the activity sheet. This feedback is then carefully analyzed before revisions are made.

Table 3. Summary of the results of the expert review of the student activity sheet

No	Validated Objects	Commentar
1.	Fill out the student's activity sheet.	
	a. Does the TE-RME-based student activity sheet contain mathematics material that is aligned with the curriculum?	Yes
	b. Does the TE-RME-based student activity sheet contain mathematics material that must be taught to junior high school students?	Yes
2.	The characteristics of TE-RME are reflected in the student's activity sheet.	
	Do the student activity sheets reflect the following characteristics of RMEs?	Yes
	a. Apply real-world problems	Yes
	b. Using models as a bridge from informal to formal mathematics	Yes
	c. Value linguistic diversity and student participation	Yes
	d. Promote two-way interaction	Yes
	e. Combined with other instructional topics	
3.	Media perspective and significance	
	a. Have the media aspects of the student activity sheet been included correctly?	Yes
	b. Do student activity sheets effectively reflect intended learning outcomes?	Yes

Based on **Table 3**, the contents of Prototype 1 align with the curriculum used in schools. Content about curved 3D shapes, with a focus on the sub-topics of tubes. The contents of the student's activity sheet align with the five characteristics of RME. First, applying real-world problems with the tradition of *rewanda* offerings used as a context. Second, using a model that emphasizes informal solutions before using formal methods. In this case, students can create their own models to solve contextual problems posed to them. Third, it values linguistic diversity and student participation. The media used is relevant to the learning objectives. In addition, the questions presented in the student activity sheet provide an opportunity for students to propose answers based on the results of each of their group's thought processes, demonstrating some level of respect for diversity among them. Fourth, promote interactivity. The researchers designed the student activity sheet in a way that required students to collaborate in groups to complete it. Students engage in discussions and collaborations to work on examples of curved 3D shape problems. Fifth, supporting integration with other learning topics. In this case, curved 3D shape, in studying the surface area of the cylinder requires the prerequisite material of the circle, radii, diameter, the area and perimeter of the circle, so that the material of curved 3D shapes can be integrated with other topics, as well as the use of the context of the tradition of *rewanda* offering can be associated with history subjects.

The media aspect and its relevance to the student's activity sheet are well assessed. In addition, the content of the student activity sheet is considered relevant to the learning objectives that have been formulated. During the two-to-one evaluation, the researchers analyzed how two selected students worked on prototype 1. Neither student will be among the study subjects involved in the field test. The assessment was focused on identifying usability issues and assessing student engagement with Prototype 1. Feedback from students provides valuable insights to refine teaching materials for better learning outcomes. The two students worked on the activity sheet independently. The researchers observed the process as it unfolded and noted several key findings.

Additionally, records are compiled based on observations and interviews. The researchers analyzed these findings to identify the learning difficulties of the students. The data is then used to refine the design of the activity sheet, ensuring that it will further support students' learning and understanding, especially in terms of their problem-solving abilities.

Based on observations, it was found that the two students provided answers with different results: one student obtained two models, while the other received only one model (**Figure 3**). These differences in answer indicate that the use of context can stimulate various solutions, and both students use different cognitive approaches to problem-solving. Recognizing these differences can help researchers improve the instructional material contained in the activity sheet.

As illustrated in **Figure 3**, a video QR code in the context of the traditional offering of the *rewanda* offering and an AR code are provided that direct students to the medium of animated and AR videos. Following the barcode, the first step is for students to understand the material in the context of local wisdom from Semarang, providing a means for discussion and collaboration among students. Animated videos and AR media, which serve as learning media, help students learn about a cylinder using the context of the *rewanda* offering tradition. **Figure 3** presents student responses related to the concept of a cylinder. They first became involved with animated videos and AR media, which served as learning media, where the concept of a cylinder was introduced using the context of the *rewanda* offering tradition from Semarang. The three guided questions provided facilitate discussion and collaboration, helping students develop a deeper understanding of the concept of a

cylinder. Students A and B recorded all the properties used in the traditional tradition of the *rewanda* offering, which represented a cylinder. Student A could mention more than three tools in the form of a tube, namely a bedug, a kendang, and a replica of teak wood and bamboo used to carry mountains, while Student B only mentions three tools. The problems posed can measure students' conceptual understanding of a cylinder, as well as their reasoning skills. Students were asked to determine how much paper is used to coat the teak wood replica. To determine the area needed, students carried out an activity to find the surface area of the tube using a paper model in the form of a tube for guidance. They opened the tube model to determine various shapes of tube nets. From this activity, different forms of tube nets were obtained. Furthermore, students were able to derive the formula for surface area by adding up all the components that make up the tube nets, namely the areas of two circles and one rectangle. This allowed them to calculate the surface area of the tubes in activity 2, as designed by the researchers.

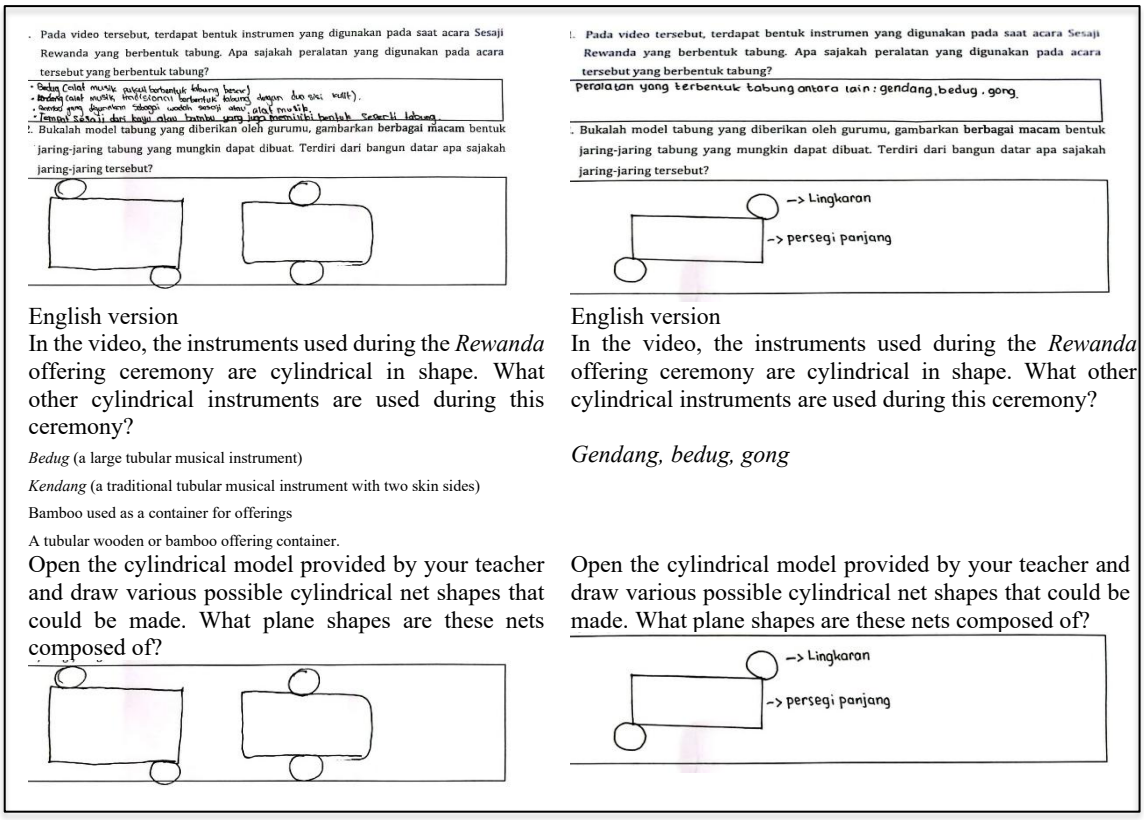


Figure 3. Sample student answer

Based on **Figure 3** students found the volume of the cylinder by arranging or stacking 10 coins provided by the teacher. From this activity, they were able to see the formula for the volume of the tube. After discovering the formulas for surface area and volume, they were asked to apply the concepts to solve contextual problems related to tubes. From these observations, the researchers noticed the doubts that arise in students when solving problems. This doubt stems from their tendency to solve mathematical problems directly using formulas.

Additionally, they are rarely exposed to contextual problems that require reasoning, which further complicates the difficulties students face. Mathematics learning is typically

very textbook-centric, containing procedural content. These challenges are a reflection for students and researchers.

Based on the findings of the expert review and the two-on-one evaluation, the researchers revised Prototype 1 to improve its quality, adding context video to the SAS so that students could replay it as needed. This revision is presented in **Figure 4**.

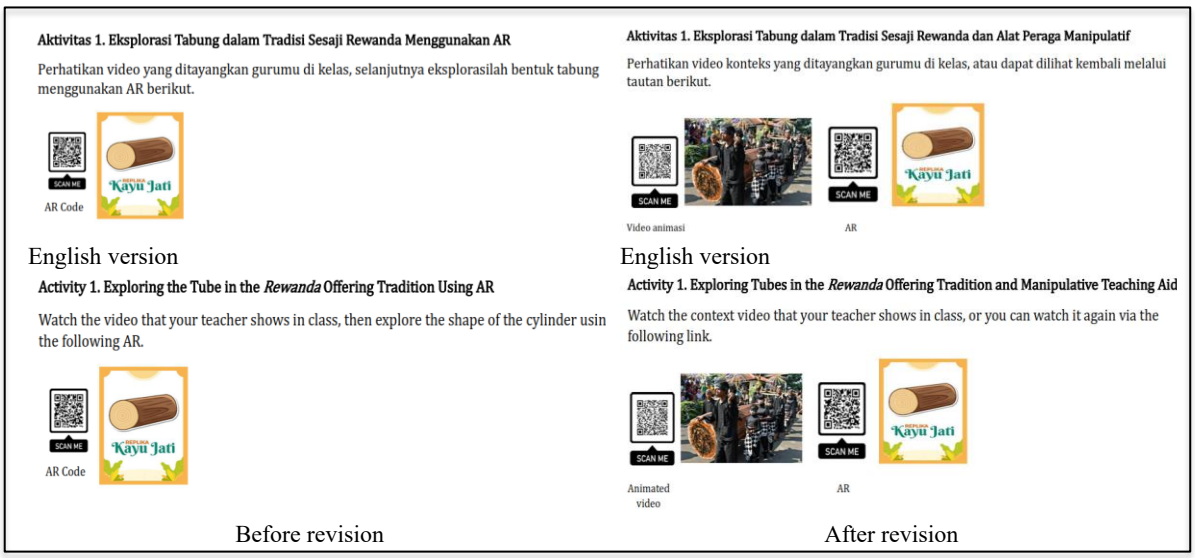


Figure 4. Media revision on SAS

Figure 4 depicts a revised version of the media used in the SAS. Initially, there was no context video in the SAS; the video was only shown together and then revised and added to the SAS with additional images as a stimulus. In this study, the researchers adapted the tradition of *rewanda* offerings from the city of Semarang. This change was made to emphasize the abstraction of the tube material. In making these modifications, the researchers realized the importance of a designer understanding how math material is taught to students, as it will help students understand concepts more effectively. One of the benefits we gain from this understanding is that it enables students to understand better the concepts and principles that accompany the theory. In addition to the media, revisions were also made to the student activity sheet.

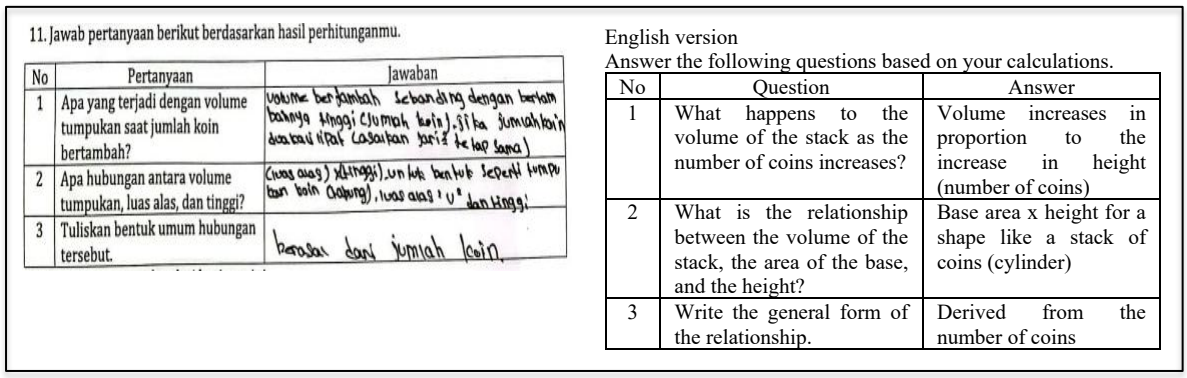
Furthermore, the changes made were to the original activity of discovering the volume of the tube, based on the volume of the flat-sided space, which was revised in the SAS by providing an activity that involved finding the formula for the volume of the tube through an experiment involving the arrangement of coins. The results of the revision resulted in Prototype 2 (**Table 4**). These adjustments ensure that student activity sheets are more effectively aligned with revised video and media content, thereby improving student understanding and engagement. By combining elements from updated media and activities, activity sheets create a more relatable learning experience. The refinements made to produce Prototype 2 were informed by feedback from previous evaluations, ensuring improved instructional quality and better student understanding.

Table 4. Modification of prototype 1 to create prototype 2

Prototype 1	Prototype 2
a. No video context b. Tube volume discovery activity using the 3D shapes volume approach	a. Included QR code video context b. Tube volume discovery activity using coin arranging activity

As shown in **Table 4**, the researchers designed activities to facilitate students' learning of tube material. These experiments reinforce students' reasoning skills, helping them determine the volume of tubes in a given experiment. The refinement of Prototype 1 yielded a valid Prototype 2, which was subsequently tested during a small-group evaluation.

During the small-group evaluation, the researchers tested Prototype 2 on a group of four students, except for one group that had three students. Each student focuses on completing their own activity sheet. The researchers observed their progress during the activity and conducted interviews with them afterwards. Observations show that students complete the activity sheet. In addition, the results of the interviews revealed that the students found the use of the context of the *rewanda* offering tradition, packaged in the form of videos and visualization assistance in the form of AR media, helpful in helping them understand the concept of a cylinder, and solving the problems presented in the student activity sheet (**Figure 5**).


11. Jawab pertanyaan berikut berdasarkan hasil perhitunganmu.

No	Pertanyaan	Jawaban
1	Apa yang terjadi dengan volume tumpukan saat jumlah koin bertambah?	volume bertambah sebanding dengan bertambahnya tinggi (jumlah koin). jika jumlah koin ditambah (alas tabung tetap sama)
2	Apa hubungan antara volume tumpukan, luas alas, dan tinggi?	(luas alas) x (tinggi). untuk bentuk seperti tumpukan koin (tabung), luas alas, πr^2 dan tinggi
3	Tuliskan bentuk umum hubungan tersebut.	berasal dari jumlah koin.

English version
Answer the following questions based on your calculations.

No	Question	Answer
1	What happens to the volume of the stack as the number of coins increases?	Volume increases in proportion to the increase in height (number of coins)
2	What is the relationship between the volume of the stack, the area of the base, and the height?	Base area x height for a shape like a stack of coins (cylinder)
3	Write the general form of the relationship.	Derived from the number of coins

Figure 5. Student answers from small group discussions

Figure 5 presents the answers from the group of students, demonstrating successful problem-solving. The students accurately determine the surface area and volume of the tube. This shows that they have strong reasoning skills. From these answers, it can be concluded that the students have understood the concept of a tube. To determine the surface area of the tube, the student's reasoning ability is essential. The students can give the correct answer to the problem.

The contextual problems presented reveal the flexibility of the student's thinking, which generates various methods. This aligns with Arifin et al. (2021), who consider that flexibility of thinking is reflected in the possibility of different ideas and the ability to change methods or approaches to problem-solving quickly. The students can devise the correct solutions, demonstrating that they are able to apply their reasoning skills to solve the problems at hand.

Animated video media and AR can increase students' motivation to learn to build spaces, as evidenced by their answers on the activity sheet. These findings also demonstrate that learning about cylinders is efficacious in improving students' reasoning skills. The students have shown a good understanding of the concept of a cylinder. The appeal of animated videos lies in their ability to awaken students' enthusiasm for learning due to the alignment of content relevant to their lives. This enthusiasm is key to understanding the material being studied.

Observation and analysis of students' answers revealed that Prototype 2 was effective and efficient in teaching curved side room builds, making it suitable for field tests. As stated by Tessmer (1993), small group evaluations focus on student performance data to confirm previous revisions and provide a more accurate measure of student performance.

At the field test stage, the learning process was conducted by a model teacher, involving 34 9th-grade students, who were then divided into eight groups. The model teacher conveyed the material to the students, using the developed activity sheet of a cylinder. Throughout the evaluation, the researchers acted as observers, assessing how effectively teachers and students engaged with the instructional materials provided through the student activity sheets. Instructions are done in the best possible way, although some improvements may be necessary.

Based on the researcher's observations, students appeared enthusiastic during the learning process. A number of students scanned animated videos and displayed AR media with their respective groups. They cut out the given tube models to find various possible shapes of tube nets and derived formulas for the surface area of the tubes. They also conducted experiments by arranging the coins to determine the formula for the volume of the tube. The students' answers to the activity sheet also demonstrated good performance, as they successfully determined the various possible shapes of the nets, the surface area, and the volume of the curved side space. An example of the student's work can be presented in **Figure 6**.

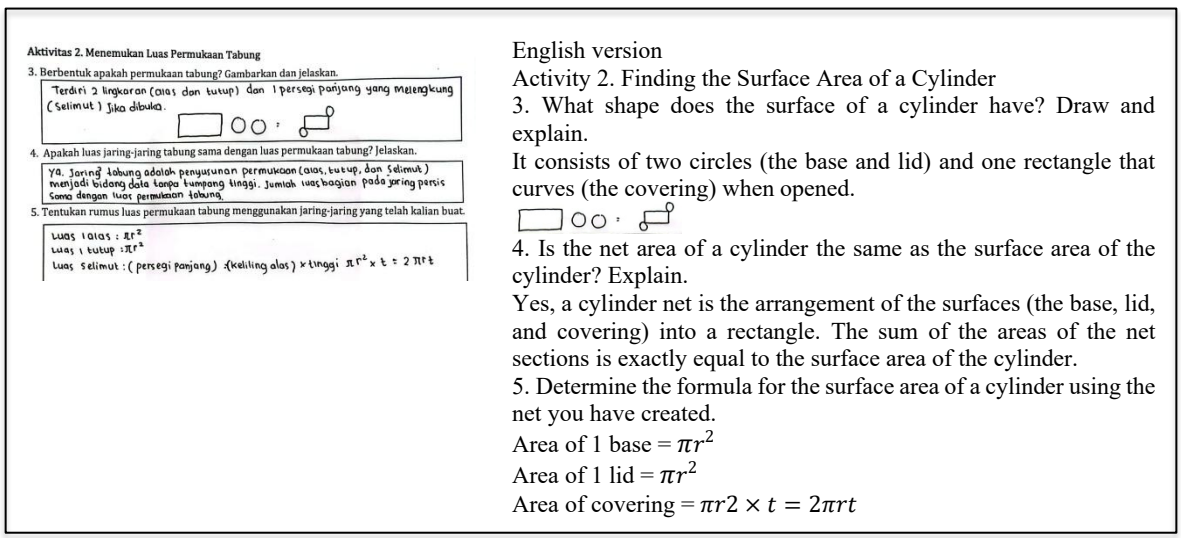


Figure 6. Student answers in the activity sheet

Figure 6 shows the students' responses in Activity 2 on the activity sheet. Students were asked to find the surface area and volume of the tube. The answers given demonstrate the student's understanding of the concept of a cylinder and the ability to identify problems.

This answer also shows that the students have been able to use their reasoning skills and understand the concept of a cylinder.

Post-test student achievement also showed an improvement compared to pretest results. The researchers found that the performance of students' answers differed significantly between the pretest and post-test, as shown in **Table 6**. This improvement demonstrates that the instructional materials and teaching strategies implemented during the study contributed to the students' enhanced understanding of the cylinder. The difference in students' responses shows a positive impact on their problem-solving skills.

The questions on the post-test are slightly similar to the pretest questions, except that the researchers modified the numerical values. The students' answers on the post-test were significantly better than their answers on the pretest. Students were able to determine the surface area and volume of the cylinder in a given problem. Field tests were conducted with 33 students. The students involved were those who did not participate in the two-on-one and small group evaluations. The questions are designed to evaluate students' understanding of the concepts of surface area and volume of tubes, as well as their ability to solve real-life situation problems.

The research results were further analyzed using N-Gain analysis to determine the effectiveness of the student activity sheets, which utilized TE-RME assisted by animated video and AR, as presented in **Table 5**.

Table 5. N-Gain Analysis Results

Description	Value	Category
N-Gain Score	0,69	Moderate
N-Gain Score (%)	69	Moderately Effective

Table 5 shows an N-Gain of 0.69, or 69%. Based on the N-Gain interpretation, it falls into the moderate category, and the effectiveness interpretation (Meltzer & David, 2002) indicates that it falls into the moderately effective category.

The improvement in student learning outcomes from pretest to post-test demonstrates the effectiveness of student activity sheets integrated with animated videos and AR in enhancing students' understanding of the concept of a cylinder. This finding aligns with previous research, which has highlighted that the use of animated video media can enable learners to access learning content by engaging multiple senses, aiding visualization, and promoting retention and flexible learning (Nursyahidah, Albab, & Rubowo, 2023). In addition, visual elements and 3D effects on AR serve as effective cognitive scaffolding that supports the understanding of abstract mathematical concepts (Pujiastuti & Haryadi, 2024). As previous researchers have confirmed, AR media in mathematics teaching can increase student engagement and foster future-ready learning competencies (Zou et al., 2025), particularly when designed to align with curricular goals (Koparan et al., 2023).

In addition, the use of ethnomathematics can support students in constructing their knowledge (Ramadhan et al., 2025). Moreover, the ability of students to transfer their conceptual understanding to new contexts, such as solving problems involving everyday life contexts, demonstrates the growth of problem-solving skills (Çakiroğlu & Şahın, 2026; Nursyahidah, Albab, & Mulyaningrum, 2023). This supports the perspective that emphasizes the importance of cultivating problem-solving skills, enabling students to solve real-life problems with a variety of possible solutions. The different nature of instructional materials accommodates diverse learning preferences, contributing to a more inclusive and equitable learning environment, in line with the principles of RME, which emphasize contextual and

mathematical learning (Zulkardi & Setiawan, 2020; Zulkardi & Putri, 2020). The use of an innovative approach, TE-RME, assisted by animated video and AR media, allows students to engage meaningfully with a cylinder through realistic scenarios, thereby strengthening their conceptual understanding and problem-solving skills.

CONCLUSION

In this study, the researchers developed a student activity sheet on a cylinder for grade IX students with a TE-RME approach based on animated videos and *Augmented Reality media*, in the context of the *rewanda* offerings tradition from Semarang. The product exhibits the following characteristics. First, the construction is designed according to the TE-RME approach. The students' activity sheet consists of 4 essential activities: starting with activity 1, exposing the context of the *rewanda* offering tradition from Semarang through animated videos and AR to determine the various shapes of cylinder net, activity 2 determines the surface area of a cylinder, and activity 3 to determine volume of the tube, and activity 4 solving contextual problem related to the cylinder. Second, the answers to the issues are presented as student contributions. This helps students understand the concept of a cylinder while strengthening their problem-solving skills. Third, as a learning medium, animated video and AR present concise and engaging material on the topic. Fourth, animated videos and AR media integrated into student activity sheets are easy to use, effective, and efficient, making them valuable tools to improve students' understanding of concepts and problem-solving skills. Based on the research results, animated videos and AR media can enhance students' learning; thus, integrating them into student activity sheets can further develop students' problem-solving skills. Students can identify various shapes of cylinder nets, calculate the surface area of a cylinder, determine the volume of a cylinder, and solve contextual problems related to cylinders.

A limitation of this study is that it was conducted in only one school. It is expected that future research will include several schools to provide a more precise assessment of the effectiveness and efficiency of instructional activity sheets. By integrating relevant contexts into learning materials, student activity sheets contribute to increasing equity and educational engagement, as well as advancing the quality of mathematics teaching by utilizing the context of local wisdom, a nation's cultural treasure, and integrating it with AR technology.

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