

## Development of RME Learning Media Based on Virtual Exhibition to Improve Students' High Order Thinking Skills (HOTS)

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*Abstract: Students' higher-order thinking skills (HOTS) in Indonesia are still low and have not experienced significant development. To enhance HOTS, modern technology-based learning media are needed to support realistic mathematics learning. Innovative learning media can enhance realistic learning and students' thinking abilities. Therefore, the authors aim to develop virtual exhibition-based Realistic Mathematics Education (RME) learning media and evaluate its quality in improving students' high-level thinking abilities. The results of this research are significant in bridging the gap by providing flexible and easily accessible alternative learning materials, addressing the shortage of interactive technology-based mathematics learning media for boosting students' HOTS. This research was conducted at Widiatmika Middle School, with classes 8A and 8B participating. The authors employed the Borg and Gall Research and Development (R&D) method to develop the learning media. Several data collection instruments were used, including interviews, observations, questionnaires, validation sheets, and tests. Data analysis was carried out to determine whether the product met the criteria for validity, effectiveness, and practicality. The validation results indicated that the virtual exhibition-based RME media achieved an ideal total average percentage of 87.27% in media expert validation and 91% in material expert validation. Thus, it can be concluded that the virtual exhibition-based RME media developed falls within the 'very good' criteria for use in mathematics learning. The students' HOTS test results in the Limited Test showed a completion rate of 60%, which increased to 79% in the Field Test. The average student opinion score regarding the quality of virtual exhibition-based RME media is 83%. The application of RME learning combined with technology has a positive impact on enhancing students' HOTS. RME learning using virtual exhibition media provides students with a modern, effective, and enjoyable approach to learning mathematics.*

## INTRODUCTION

Mathematics is crucial for the development of a nation's human resources (HR). Higher-order thinking skills (HOTS) are essential for successfully understanding and enhancing mathematical abilities, as well as comprises a series of learning competencies that progressively evolve into a specialized skill that students must master in today's education (Arifin & Retnawati, 2017). HOTS is indispensable for students because the real-world problems they encounter are often complex, unstructured, novel, and demand more advanced thinking skills than mere application of previously acquired knowledge (Riadi & Retnawati, 2014).

The importance of students' HOTS is inversely proportional to the fact that students' mathematical thinking skills are low in Indonesia (Mandini & Hartono, 2018). Data from the Trends International Mathematics and Science Study (TIMSS) in 2015 showed that Indonesia's ability in mathematics was ranked 48 out of 50 countries where Indonesian students lack high-level mathematical thinking skills (Mullis et al., 2015). In addition, Tanudjaya and Doorman (2020) stated that the low achievement of Indonesian students in HOTS has not improved over the years. Furthermore, the low HOTS of students cause problems in ongoing mathematics learning and does not support meaningful mathematics learning, especially its application in real life (Pangestika & Cahyaningsih, 2022). Because of this, the problem of the lack of HOTS students must be addressed using mathematics learning that emphasizes real world contexts.

Realistic Mathematics Education (RME) is a learning approach that prioritizes real-world contexts and was developed in 1971 by a group of mathematicians at the Freudenthal Institute, Utrecht University in the Netherlands (Heuvel et al., 2014). This approach offers a potential solution to address students' lack of Higher-Order Thinking Skills (HOTS). According to RME, the mathematics classroom isn't merely a place for transferring mathematical knowledge from teacher to student. Instead, it serves as an environment where students can rediscover mathematical ideas and concepts by engaging with authentic problems. In the context of realistic mathematics learning, students start with real problems before entering a more formal setting. With guidance from their teacher, they're encouraged to reconstruct their understanding of mathematical concepts and then apply these concepts to everyday problems or other fields. RME offers students the opportunity to think critically and creatively when analyzing mathematical concepts within real-world contexts. Therefore, the development of Higher-Order Thinking Skills (HOTS) in students is highly relevant to RME, as this approach provides students with the space to explore mathematical concepts comprehensively and utilize their thinking skills to solve contextual problems (Nurmudi, 2020).

The deficiency in students' mathematical thinking skills can also stem from the absence of interactive learning tools and media that can stimulate their learning motivation, thereby hindering the development of their thinking skills (Milovanović et al., 2013). Research conducted by Milovanović et al. demonstrates that multimedia can facilitate students' comprehension of learning

materials and their ability to apply knowledge to mathematical problems and exercises (Chen et al., 2023). Another study conducted by Nusir et al. focused on the impact of using multimedia in mathematics education (Nusir et al., 2013). Their findings indicate that interactive multimedia, incorporating images and animations within educational games, proves highly effective in motivating young children to engage in learning and enhancing their mathematical skills.

In the era of educational disruption, where learning increasingly occurs online or in hybrid formats and heavily relies on technology, it is imperative that learning materials are rooted in interactive technology and harness the potential of the internet and cyberspace (Coman et al., 2020). One such technology that can be effectively employed in education is virtual exhibitions. A virtual exhibition is a digital collection encompassing images, sounds, manuscripts, documents, and other content related to history, science, and culture, accessible electronically (Astita et al., 2015). For instance, research conducted by Li (2023) highlights that virtual exhibitions can serve as interactive learning tools, offering students an enjoyable learning experience. Through virtual exhibitions, students can gain an immersive learning experience akin to navigating a virtual gallery brimming with knowledge. These virtual exhibitions facilitate interactive and meaningful learning, ultimately enhancing students' comprehension and higher-order thinking skills (Darwis & Hardiansyah, 2023). Moreover, the design of virtual exhibition-based learning is relatively straightforward, and platforms such as ArtSteps provide comprehensive services for creating virtual exhibitions.

The potential offered by utilizing virtual exhibitions in the context of realistic mathematics learning is exceptionally promising. This research bridges a crucial gap by presenting an alternative, flexible, and easily accessible learning medium, addressing the limitations of interactive technology-based mathematics learning resources. The design employed incorporates the principles of Realistic Mathematics Education (RME), with an emphasis on activities that foster connections between mathematical concepts and real-world applications, as well as the process of uncovering these concepts and solving contextual problems. This fusion of technology and realistic learning approaches presents students with a captivating and enjoyable means of learning mathematics while optimizing their high-level thinking abilities in every learning activity. Consequently, this research is dedicated to the development of virtual exhibition-based RME learning resources, with the overarching goal of enhancing students' Higher-Order Thinking Skills (HOTS). The study aims to create and assess the quality of virtual exhibition-based RME learning materials to elevate students' cognitive abilities.

## LITERATURE REVIEW

### Learning Media

Reiser and Dempsey define learning media as physical equipment used to present learning to students (Reiser & Dempsey, 2012). This definition highlights that any physical equipment, whether it's textbooks, visual aids, audio materials, computers, or other resources, falls under the category of learning media. Learning media encompasses all physical tools and materials utilized

by instructors, lecturers, teachers, tutors, or other educators to facilitate learning and achieve learning objectives.

The learning media in question spans traditional formats like chalk, handouts, diagrams, slides, overheads, real objects, video recordings, and films, as well as advanced media such as computers, DVDs, CD-ROMs, the Internet, and interactive video conferencing (Romadoni & Rudhito, 2016). Learning media's development is of paramount importance because it can enhance the quality of education, align with the evolving paradigms of education, meet market demands, and align with the global vision of inclusive education. Learning media is an integral part of the learning process, serving as an indispensable tool that accelerates comprehension, enhances quality, and lays a solid foundation for learning.

### **Realistic Mathematics Education (RME)**

In realistic mathematics learning, the educational process commences with something real or closely related to students' real-life experiences. "Realistic" in this context doesn't necessarily mean it must be tangible or exist in reality; it can also pertain to concepts that can be imagined by students and are relevant to the topics under study (Febrian, & Perdana, 2017). Such imaginings can be harnessed within the learning process, fostering meaningful engagement for students.

Soedjadi (2014) proposed that Realistic Mathematics Education (RME) represents an innovative approach to mathematics education that aligns with constructivist theory. Within RME, there is a heightened focus on tapping into the potential inherent in each child or student. A teacher's belief in this potential significantly influences how they manage mathematics instruction and shapes students' comfort in engaging in activities commensurate with their abilities. These dynamics have a profound impact on the teaching culture and the learning culture. This innovation in mathematics learning not only transforms the conceptual landscape of mathematical materials and their interrelationships but also, and no less importantly, shifts the educational culture toward a more dynamic approach, all while staying within the boundaries of social ethics. Under this innovative framework, students are encouraged to express their opinions, accept differing viewpoints, and appreciate the importance of negotiation in life. Meanwhile, the role of the teacher must evolve from one of traditional "teaching" to that of a facilitator.

### **Virtual Exhibitions**

A virtual exhibition is a collection of digital replicas of real events or objects developed using multimedia and virtual reality tools to create a simulated environment on a computer, delivered via the web (Khoon Ramaiah, 2008). This technology aims to provide users with the same satisfaction as if they were physically present at the event or interacting with the objects. Typically, virtual exhibitions involve simulating real environments using virtual reality tools, which can be more complex, expensive, and time-consuming to develop compared to simple online exhibits.

Exhibitions can be categorized based on several factors, including: 1) type (aesthetic and reconstructive); 2) goals (fundraising, appreciation, and festivals); 3) the number of participants (single, joint, and group); 4) space (formal, informal, real, and illusory); 5) interests (economic, educational, political, and cultural); and 6) tempo (permanent, incidental, and periodic) (Khairunnisa et al., 2021). Therefore, when classifying a virtual exhibition, it falls into the category of an illusory space due to its existence in the virtual realm, represented as a computer-generated simulation.

### **High Order Thinking Skills (HOTS)**

High-order thinking skills, often referred to as higher-order thinking skills, encompass problem-solving, creative thinking, critical thinking, argumentation, and decision-making abilities. According to Newman and Wehlage, the cultivation of high-order thinking skills empowers students to discern ideas clearly, engage in effective argumentation, tackle problems adeptly, construct coherent explanations, formulate hypotheses, and gain a deeper understanding of complex concepts (Widodo & Kadarwati, 2013).

Vui further explains that high-order thinking skills manifest when an individual links new information to existing knowledge stored in their memory, thereby connecting, reorganizing, and expanding upon this information to accomplish a goal or find solutions to challenging problems (Kurniati et al., 2016). The primary aim of high-order thinking skills is to enhance students' cognitive abilities, especially in critical thinking when processing various types of information, employing creative problem-solving using their acquired knowledge, and making decisions in complex situations (Saputra, 2016).

## **METHODS**

### **Place and Time of Research**

The location of this research is at Widiatmika in the the 2022/2023 academic year. The subject of this research is students in 8<sup>th</sup> grade of 8A and 8B.

### **Research Design and Procedure**

This research is a type of research and development or Research and Development (R&D) that aims to produce certain products, and test the effectiveness of these products (Sugiyono, 2015). The method used by the authors in developing learning media is the R&D method modified from Borg and Gall which includes (Borg & Gall, 1983):

#### 1) Potentials and Problems

Before developing learning media, a needs analysis was carried out in the form of a preliminary study at Widiatmika Middle School which was carried out in the form of interviews conducted by researchers with one of the mathematics teachers at Widiatmika Middle School on August 1, 2022. Researchers found problems with students' HOTS

abilities and the unavailability of media. technology-based interactive learning suitable for RME learning.

2) Collecting Data

The next step is to collect references for the development of media-based learning media obtained from relevant sources, namely various articles and other references obtained from the internet. Researchers also collect sources from valid websites and YouTube to learn tutorials for preparing virtual exhibition-based media.

3) Product Design

Planning to make the initial product is to collect materials that will be done by searching through the internet. Simultaneously, the preparation of material taken from the main material, such as books, journals, theses, and others is also carried out. In designing RME media based on virtual exhibitions, the things to do are: determine the template, fill in the template with the exhibition design, determine the material, determine the placement of the material, as well as fill in the virtual exhibition with prepared materials, re-check.

4) Design Validation

Design validation is an assessment process to measure the effectiveness of a product design rationally not based on field facts. Professional experts are presented in the assessment of new products created. At this stage, material and media experts validate the initial design of learning media which will later obtain appropriate learning media for use. Design validation is carried out in two parts. First, the material expert test aims to examine aspects of the feasibility of the content presented in the form of the suitability of the material with the curriculum (content standards), language feasibility, and presentation. Two material experts consisting of lecturers and mathematics teachers who are experts in the material given. second, the media expert test aims to determine the accuracy of the minimum standards that examine aspects of visual communication, language feasibility, and software engineering contained in learning media. Two experts in the field of educational technology were presented to assess the products that have been made.

5) Design Revisions

After the product design has been validated by material and media experts, criticism and suggestions will be obtained so that developers know the drawbacks of the learning media that have been made.

6) Product Trial

The finished product is then tested in learning activities. The product trial was carried out using a small group evaluation involving 10 students of class 8A. An of Widiatmika Middle School, and a field test involving 42 students of class 8B of Widiatmika Middle School.

7) Product Revisions

From the results that have been tested on the product, if the product is not perfect, then revisions and improvements are made to the learning media made so that it can produce a final product that is ready to be used in schools.

## Population and Sample

The population of this study is grade 8th Widiatmika Middle School. This study had 2 trials, namely a limited trial using a sample of 10 students from class 8A, and a field trial using 42 students of class 8B. The sample selection used a purposive random sampling technique where the sample was determined with certain considerations. In this case, the consideration is to select students and classes that are representative and consist of students with various levels of ability.

## Data Collection Techniques

This research uses several data collection instruments, namely:

### 1) Interviews

Interviews were conducted to find out the responses, comments, and suggestions of eighth-grade mathematicians. The interview method was chosen because the researcher could be closer to the informant so that the information obtained was more in-depth. The interviews were conducted before the manufacture of learning media to obtain information about problems in learning mathematics and knowing the responses of the media for learning mathematics.

### 2) Observations

This observation was carried out by researchers regarding the learning process carried out and knowing the teaching materials used, seeing the characteristics of students or student behavior patterns during the learning process. In this study, the type of non-participant researcher observation was used, that is, the only came to the place where the activity of the person being observed, but the researcher was not involved as a researcher and as an independent observer in the activity.

### 3) Questionnaires

Questionnaires are used to collect data about the accuracy of the components of learning media, the accuracy of the design or design of learning media, and the accuracy of the content of learning media. In this development research, the questionnaire was presented by researchers using google forms (Google Forms) to obtain data from all students regarding the accuracy and attractiveness of e-mail.

### 4) Validation Sheet

The validation sheet for learning media devices is used to obtain information about the quality of learning media based on the assessment of the expert validator. The information obtained through this instrument is used as a consideration in revising the learning media that has been developed to produce a valid final product.

### 5) Test

This test is carried out on students before and after using the media that has been developed. The test results are used to determine the effectiveness of the media. The test used in this

study is a description test consisting of HOTS questions on circle material. This test consists of 5 questions that are given to students at the end of the lesson.

### **Product Trial Techniques**

Product trials are considered necessary because the products produced are really of high quality, effective, and on target. In addition, product trials are a condition that must be met by a researcher who conducts a development research model. Product trials are carried out after the resulting product is declared valid by validators. Product trials conducted should pay attention to the following: 1) trial design and 2) test subjects.

#### **1. Trial Design**

In this study, three types of trials were carried out, namely validity, effectiveness, and practicality. For the data obtained to be more accurate for further improvement and development research. The three types of tests can be described as follows:

##### **a. Validity Test**

The validity test is a trial carried out to obtain data in the form of validity assessments and suggestions on the level of validity of the product being developed, which in this case is a learning medium. The validators referred to in this development research are media experts as well as material experts.

##### **b. Effectiveness test**

Effectiveness testing is carried out by piloting the product-to-product users. Product trials were carried out in small groups of students who had never studied the material used. The purpose of this test is to assess the effectiveness of the product in the learning process for the improvement of HOTS students.

##### **c. Practicality test**

A practicality test is a trial carried out to obtain data at the level of ease of a product being developed. To find out the level of practicality of the product in this development research can be obtained using a student response questionnaire.

#### **2. Test Subjects**

The test subjects used in this development research are expert groups and target users of the product. In this case, the expert group in question is a validator consisting of expert lecturers at the Mathematics Education Study Program at the FKIP Universitas Mahasaraswati Denpasar and mathematics teachers at Widiatmika Middle School. The target product users in this study are class VIII students of Widiatmika Middle School.

### Data Analysis Techniques

Data analysis is carried out to find out an overview of the quality of the results of the learning media products developed, through quantitative data that has been obtained so that it will be known whether the products developed, namely virtual exhibition-based RME learning media, have met the criteria for validity, effectiveness, and practicality. The data analysis techniques obtained from each instrument are described as follows.

#### a. Quality Criteria

Research data in the form of qualitative data is converted into quantitative data by determining the average value. After that, the value is converted into a qualitative value that reflects the quality of the media according to the category of ideal assessment criteria as follows.

No	Quantitative Score Range	Qualitative Category
1	$\bar{X}_i + 1,5 SB_1 < \bar{X}$	Very good
2	$\bar{X}_i + 0,5 SB_1 < \bar{X} \leq \bar{X}_i + 1,5 SB_i$	Well
3	$\bar{X}_i - 0,5 SB_1 < \bar{X} \leq \bar{X}_i + 0,5 SB_i$	Enough
4	$\bar{X}_i - 1,5 SB_1 < \bar{X} \leq \bar{X}_i - 0,5 SB_i$	Not enough
5	$\bar{X} < \bar{X}_i - 1,5 SB_1$	Very less

Table 1. Ideal Assessment Criteria

Information:

$\bar{X}_i$  : ideal average that can be found using the formula

$$\bar{X}_i = \frac{1}{2} \times (\text{ideal maximum score} + \text{ideal minimum score})$$

$SB_i$  : The ideal standard deviation that can be found by the formula

$$SB_i = \frac{1}{6} \times (\text{ideal maximum score} + \text{ideal minimum score})$$

Ideal maximum score =  $\sum$  item criteria  $\times$  the highest score

$$\text{Ideal minimum score} = \sum \text{item criteria} \times \text{lowest score}$$

The ideal percentage of Student Activity Sheets (P), namely:

$$\bar{P} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

### b. Media Assessment by Experts

As for the results of the assessment regarding the quality of the media in the form of qualitative data, the data is then converted into quantitative data with the following conversion guidelines:

Information	Score
Very Less (SK)	1
Less (K)	2
Enough (C)	3
Good (B)	4
Very Good (SB)	5

Table 2. Guidelines for Converting Qualitative Data by Experts

After obtaining data regarding the quality of medias in quantitative form, then the data is processed to determine the quality of medias per aspect and as follows:

#### 1) Material Expert

After obtaining data regarding the quality of medias in quantitative form, then the data is processed to determine the quality of medias per aspect. Calculations of material experts on the Aspects of Concept Truth, Aspects of Concept Depth, Aspects of Breadth of Concepts, Aspects of Implementability, and Aspects of Linguistics are as follows:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\begin{aligned} \text{Ideal maximum score} &= \frac{\sum \text{item criteria} \times \text{the highest score}}{\text{number of indicators for each aspect}} \\ &= \frac{\text{Total score of each aspect}}{\text{number of indicators for each aspect}} \end{aligned}$$

For material expert assessment as a whole use the following formula:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\begin{aligned} \text{Ideal maximum score} &= \sum \text{item criteria} \times \text{the highest score} \\ \text{Assessment result score} &= \frac{\text{Jumlah skor keseluruhan aspek}}{\text{number of indicators for all aspects}} \end{aligned}$$

## 2) Media Expert

After obtaining data regarding the quality of medias in quantitative form, then the data is processed to determine the quality of medias for the Media Anatomy Aspect, Image Quality Aspect, and Full View Aspect, as follows:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\text{Ideal maximum score} = \sum \text{item criteria} \times \text{the highest score}$$

$$\text{Assessment result score} = \frac{\text{Total score of media anatomy aspect}}{\text{number of indicators for each aspect}}$$

For aspects of media experts as a whole use the following formula:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\text{Ideal maximum score} = \sum \text{item criteria} \times \text{the highest score}$$

$$\text{Assessment result score} = \frac{\text{Overall view aspect score sum}}{\text{number of indicators for all aspects}}$$

The assessment of material experts and media experts is as follows:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\text{Ideal maximum score} = \sum \text{item criteria} \times \text{the highest score}$$

$$\text{Assessment result score} = \frac{\text{Total scores of material experts and media experts}}{\text{total number of indicators of experts}}$$

## Calculation of Student Opinions Regarding the Quality of RME Media Based on Virtual Exhibition

As for the results of the assessment regarding the quality of the media in the form of qualitative data, the data is then converted into quantitative data with the following conversion guidelines:

Information	Score
Very Less (SK)	1
Less (K)	2
Enough (C)	3
OK ( B )	4
Very Good (SB)	5

Table 3. Guidelines for Converting Student Opinion Qualitative Data

After obtaining data regarding the quality of medias in quantitative form, then the data is processed to determine the quality of medias per aspect and as follows:

$$\bar{p} = \frac{\text{Assessment result score}}{\text{Ideal maximum score}} \times 100\%$$

Information:

$$\text{Ideal maximum score} = \sum \text{item criteria} \times \text{the highest score}$$

$$\text{Assessment result score} = \frac{\text{The total score of the quality of the student's opinion on media of indicators for all aspects}}{\text{Ideal maximum score}}$$

The results Percentage of ideal assessment criteria can be seen in the following table:

No	Quantitative score range	Qualitative Category
1	$\bar{P} > 80\%$	Very good
2	$66,67\% < \bar{P} \leq 80\%$	Well
3	$53,33\% < \bar{P} \leq 66,67\%$	Enough
4	$40\% < \bar{P} \leq 53,33\%$	Not enough
5	$\bar{P} \leq 40\%$	Very less

Table 4. Percentage of Ideal Rating Criteria Results

#### d. Student HOTS Assessment

The student HOTS assessment is carried out through the average student score and the percentage of students who pass. The calculations are as follows:

$$\text{Average student grades} = \frac{\text{the total value of the students}}{\text{the total number of students}} \times 100\%$$

$$\text{Completed student presentation} = \frac{\text{number of students who completed}}{\text{the total number of students}} \times 100\%$$

## RESULTS

In the development of our learning media based on Realistic Mathematics Education (RME), a pivotal element was the construction of the mathematizing process, centered around the captivating concept of the area of a circle, as showcased within our virtual exhibition. Our approach sought to immerse students in a dynamic mathematical environment where they could actively grapple with this fundamental geometric concept. The selection and presentation of materials within the virtual exhibition were thoughtfully crafted to provoke profound mathematical thinking and inquiry, with the area of a circle serving as a central theme. The data on the results of each stage of the research and development procedure carried out is as follows:

### 1) Potentials and Problems

At this stage, researchers are looking for information about the media that is being developed in the world of education. One of the technologies that continue to develop and are often used in smartphones. Young people, especially school students, are now familiar with the digital world, so researchers decided to provide opportunities for students to learn interactively using virtual exhibitions.

Researchers conduct research at Widiatmika Middle School which is a target school of the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Mahasaraswati Denpasar where researchers teach. Researchers found a fundamental problem in grade 8<sup>th</sup> students, namely that students consider mathematics boring, difficulty understanding mathematical concepts, and the absence of mathematics learning media that is interesting, entertaining, and that teenagers currently like. The existing problems provide ideas for researchers to develop virtual exhibition-based RME learning media to improve the students' HOTS.

From Table 5 above, it is evident that media focused on circle materials had not been previously employed in mathematics learning. This pioneering research has opened up new avenues for the development of Realistic Mathematics Education (RME) media products using virtual exhibitions, particularly within the context of Widiatmika Middle School. The data presented in Table 5 underscores the unique and innovative nature of this approach, suggesting that it has the potential to introduce fresh and effective instructional strategies to enhance students' mathematical understanding and engagement. Researchers can leverage these findings to further explore and refine RME-based virtual exhibition media, thereby enriching the learning experience for students at Widiatmika Middle School and potentially in broader educational settings as well. This pioneering effort highlights the importance of continuously pushing the boundaries of educational technology to enhance mathematics education.

No	Question Topic	Conclusion Answers	Teacher	Conclusion Answers	Student
1	The learning method used	Teachers adapt to situations and conditions, most often using problem-based learning		Lectures and practice questions	
2	The difficulties faced by students	In studying circle material, namely the application of circle formulas in solving real problems and solving problems related to central angles, arc lengths, and areas of circular arcs and their relationships.		Apply the formula to the problem	
3	How to overcome student difficulties	Give lots of practice questions		Ask friends, read notebooks, or search via Google	
4.	The media used during learning	<i>Powerpoint</i>		<i>Powerpoint</i>	
5.	Utilizing smartphones for teaching	Never		Never	
6.	Applying e-learning to learning	Ever been		Ever been	
7.	Using virtual exhibition media in learning mathematics	Never		Never	
8.	Interest in and use of virtual media exhibitions	Interested		Interested	

Table 5. Results of Interviews with Teachers and Students

## 2) Data collection

Data collection is the process of finding problems and potential of an object of research so that the data obtained can be considered in the manufacture, and research, so that the data obtained can be considered in the design of a product.

Before carrying out the development of learning media, a needs analysis is carried out. A needs analysis in the form of a preliminary study was carried out on 1 August 2022 at Widiatmika Middle School. Preliminary studies were carried out when the mathematics

learning process took place, namely interviews with teachers in the field of mathematics studies.

### 3) Product Design

The design of media products includes RME learning based on virtual exhibitions. The media is adapted to the needs of students and directions from the mathematics teacher. The virtual exhibition-based RME media is divided into 4 parts: the first part contains elements related to circles, the second part contains the use of area and circumference formulas, and the third part contains the relationship between the central angle and the length of the arc, and the relationship between the angles the center with the area of the sector, and the fourth part is about solving problems related to the elements of circles, circumference, and area of circles, as well as arc length and area of circles.

Media virtual exhibition in the form of digital images of material in words which is then inserted into the digital space. The following are the general stages in making virtual exhibition-based RME media, namely:

- a. Making material containing the mathematical concept of a circle adapted to competency standards and basic competencies and syllabus based on the 2013 curriculum
- b. Preparation of dialogue between characters, images, animations, and backgrounds that will be used in making virtual exhibition-based RME media
- c. Making RME media based on virtual exhibitions made by researchers as follows:

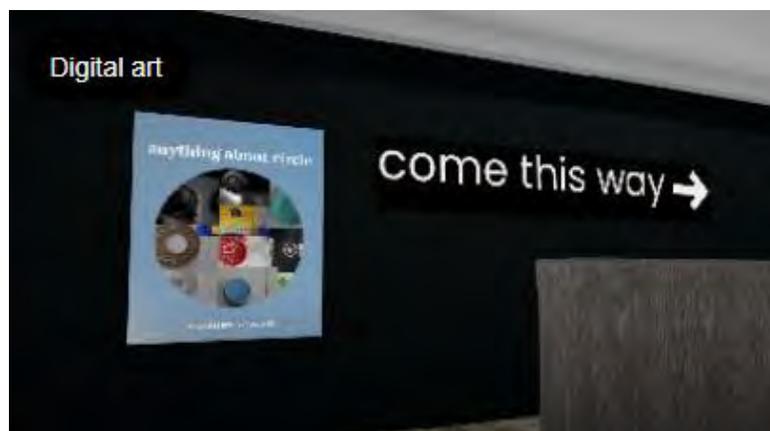


Figure 1. Virtual Exhibition on Circle Material

### 4) Design Validation

This stage is a stage related to the assessment of the product that has been designed. Two experienced experts or experts were presented at the product validation stage to assess the

learning media that had been made by the researcher. The assessment consisted of 2 media experts, namely validation by a mathematics education lecturer, namely Mrs. Kadek Rahayu Puspawati, S.Pd., M.Pd., and validation by a grade VIII math teacher at Widiatmika Middle School, namely Mrs. Putu Yulia Prawestri, S.Pd., M.Pd. Apart from the 2 media experts, there were also 2 material experts, namely Mrs. Kadek Rahayu Puspawati, S.Pd., M.Pd. and Mrs. Putu Yulia Prawestri, S.Pd., M.Pd. The following is a presentation of the results of the validation of material and media experts.

#### a) Media Validation Results by Material Experts

We carefully curated a collection of real-world scenarios and objects that brought the concept of the area of a circle to life. Virtual exhibits included visually engaging interactive simulations, where students could experiment with changing the radius or diameter of circles, and instantly observe how these modifications affected the circle's area. We also provided historical context and real-life applications of circle area calculations, such as designing circular gardens or estimating the amount of material required for circular-shaped objects in various industries. Moreover, guided questions within the exhibition encouraged students to analyze, infer, and generalize mathematical principles from their interactions with the presented materials. This meticulous approach ensured that the mathematizing process naturally emerged as students explored the area of a circle within authentic real-world contexts, fostering a deeper understanding of mathematics grounded in practicality and relevance, while simultaneously nurturing their higher-order thinking skills, including critical analysis, problem-solving, and creative mathematical reasoning. The results of this development research are in the form of (1) a virtual exhibition-based RME learning media for students in the Circle material, and (2) student HOTS achievement using virtual exhibition-based RME learning media.

The aspects assessed by material experts are aspects of concept correctness, concept depth, concept breadth, implementability, and language.

No	Aspect	Ideal Percentage	Category
1	Concept Truth	86.66 %	Very good
2	Concept Depth	90%	Very good
3	Breadth of Concept	95%	Very good
4	Execution	93.33 %	Very good
5	language	90%	Very good
Percentage of Overall Aspects		91 %	Very good

Table 6. The Ideal Percentage of Validation Results by 2 Material Expert Validators

Based on Table 6 regarding the results of validation by material experts, it can be seen that the total average ideal percentage in material expert validation is 91%, which can conclude

that the RME media based on virtual exhibitions that have been developed are included in very good criteria for use in learning mathematics so that it does not revision is needed.

### b) Media Validation Results by Media Experts

The aspects assessed by material experts are aspects of media anatomy, image quality, and overall appearance.

No	Aspect	Ideal Percentage	Category
1	Media Anatomy	93.33 %	Very good
2	Image Quality	80%	Well
3	Full View	88%	Very good
Percentage of Overall Aspects		87.27 %	Very good

Table 7. The Ideal Percentage of Validation Results by 2 Media Expert Validators

Based on Table 7 regarding the results of validation by media experts, it can be seen that the acquisition of an ideal total average percentage in the validation of media experts, which is equal to 87.27%, can conclude that the RME media based on virtual exhibitions that have been developed are included in the very good criteria for use in learning mathematics so that no revision is needed.

### Design Revision

From the results of the validation, several comments and suggestions were obtained regarding RME media based on virtual exhibitions that had been made by researchers. From the validation results obtained, namely from material experts, among others, there were several typing errors in the media, in one of the dialogues there was a sentence that still confused students, it is necessary to be consistent in writing the multiplication symbol (x) on the media, and in the circle image, there are letters that are not clear. Comments and suggestions from media experts included changing the font color in the fourth part (part 4) of the virtual exhibition-based RME media, and improving the font size in several speech balloons. Researchers use these comments and suggestions as a reference in revising the virtual exhibition-based RME media that will be developed.

### 5) Product Trials

Products that have gone through the validation stages by material experts and media experts and have been repaired are then tested by researchers with limited field trials whose implementation aims to test the effectiveness of the product. The product trial results are as follows:

### a) Limited Trial

The limited try-out was carried out in small groups involving 10 class VIII. Widiatmika Middle School students were selected heterogeneously based on ability in class and gender using a purposive sampling technique. The limited trial was conducted in two meetings, the first meeting was used to fill out a motivational questionnaire before using the media, and carried out the pre-test, the second meeting was used to use virtual exhibition-based RME media, the post-test, and finally the virtual exhibition-based RME media assessment.

### b) Field Trials

After conducting a limited trial, the product was then tested again with a field trial involving 42 Widiatmika Middle School students from class VIII.C. This field trial was carried out to ensure the data that had been obtained by giving questionnaires and tests. The limited trial was conducted in two meetings, the first meeting was used to fill out a motivational questionnaire before using medias, and to do a pre-test, the second meeting was used to use virtual exhibition-based RME media, post-test, and finally, an RME media assessment based on virtual exhibitions.

## Classroom Activity

During limited trials and field trials, students carried out several class activities guided by the teacher. The trial steps are as follows:

### Limited Trials:

1. Introduction to RME Media: In the limited trials, the first step involved introducing the Realistic Mathematics Education (RME) media to a smaller group of students. This introduction aimed to familiarize them with the new learning tool.
2. Guided Classroom Activities: After the introduction, students engaged in various classroom activities guided by their mathematics teacher. These activities were designed to use the RME media effectively as a learning resource.
3. Teacher Support: Throughout the limited trials, the mathematics teacher played an active role in supporting and guiding students during their interactions with the RME media. This support ensured that students could effectively navigate and understand the learning content.
4. Assessment: After using the RME media, students' performance was assessed. This assessment helped researchers understand how well the media supported their learning and whether any improvements were needed.

### Field Test:

1. Expanding the Scope: In the field test, the researchers expanded the scope by involving a larger group of students. This step aimed to assess the effectiveness of the RME media on a broader scale.
2. Continued Classroom Activities: Similar to the limited trials, students in the field test also engaged in classroom activities guided by their mathematics teacher. These activities were designed to explore the full potential of the RME media in a real classroom setting.
3. Teacher's Integral Role: Just like in the limited trials, the mathematics teacher remained a crucial part of the process. The teacher provided support, answered questions, and facilitated discussions related to the RME media content.
4. Performance Evaluation: After the field test, students' performance was evaluated once more. This evaluation helped researchers gauge the media's effectiveness in enhancing students' understanding of mathematical concepts.

In summary, the limited trials and field test involved introducing the RME media, conducting classroom activities, receiving guidance from the mathematics teacher, and assessing students' performance to determine how well the media supported their learning. These steps allowed researchers to refine the media and assess its impact on a smaller and larger scale, respectively.

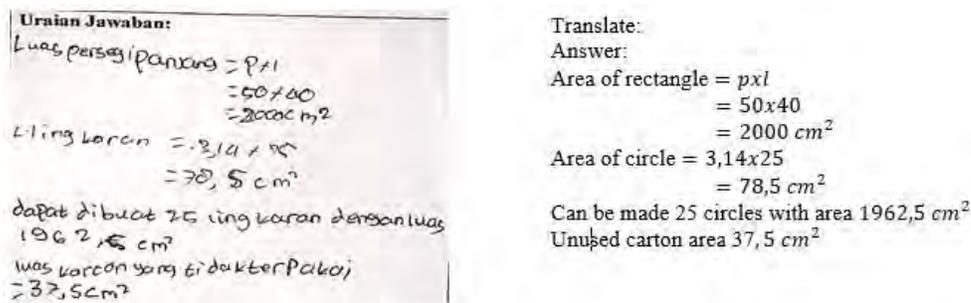


Figure 2. Students Accessing Virtual Exhibition

At the time of implementing virtual exhibition-based RME media, students carried out learning in the classroom accompanied by a mathematics teacher. Students provide laptop facilities to be able to access the internet. In the first activity, students are then asked to form groups of 3-5 people. Each group distributed worksheets containing projects that they had to complete related to the area of the circle material. In the second activity, in groups then work on the worksheets given. The material that students work on is to understand the area of a circle. Students open a virtual exhibition through the link provided. Students then go to the section on understanding the concept of the area of a circle. Students see and study the media and illustrations of the area of the circle

area concept provided in the virtual exhibition. Through these explanations and media, students then work on projects on worksheets related to the concept material for the area of a circle.

In the third activity, students were asked to find the formula for the area of a circle. This activity is also available in the student worksheet. Students then open a virtual exhibition through the link provided, and then explore material for finding the area of a circle. After that, the students together in their groups worked on the project on the worksheet. In the fourth activity, students are asked to solve several realistic problems related to the area of a circle. These problems are presented in student worksheets. Students are asked to work together with their group mates in working on these problems, helping each other, and exchanging ideas. The problems presented are problems at the higher-order thinking skills (HOTS) level. The following is an example of a problem solved by students related to the area of a circle.



Uraian Jawaban:  
 Luas persegi panjang =  $p \times l$   
 $= 50 \times 40$   
 $= 2000 \text{ cm}^2$   
 Liling karan =  $2,14 \times 15$   
 $= 32,1 \text{ cm}$   
 dapat dibuat 25 liling karan dengan luas  
 $1962,5 \text{ cm}^2$   
 luas karan yang tidak terpakai  
 $= 37,5 \text{ cm}^2$

Translate:  
 Answer:  
 Area of rectangle =  $p \times l$   
 $= 50 \times 40$   
 $= 2000 \text{ cm}^2$   
 Area of circle =  $2,14 \times 15$   
 $= 32,1 \text{ cm}$   
 Can be made 25 circles with area  $1962,5 \text{ cm}^2$   
 Unused carton area  $37,5 \text{ cm}^2$

Figure 3. Example of Student's Answer

The answers from students show that students are able to understand realistic problems and find appropriate ways to solve these problems, but students are not yet able to do proper reasoning. In the last activity, students jointly convey the results obtained. In this activity the teacher confirms the concepts students have learned and concludes material from the area of the circle. Students are then given a questionnaire to provide responses to the use of virtual exhibition-based RME media.

After conducting limited trials and field trials to know the effectiveness of virtual exhibition-based RME media on achieving students' conceptual understanding of circle material, it was discovered that the product being developed was effective so no further trials were carried out. Furthermore, virtual exhibition-based RME media can be utilized as a learning resource for students and teachers at Widiatmika Middle School for class VIII. A summary of student HOTS data in a limited test is presented in Table 4.6 and the field test is presented in Table 8 below.

The research results presented in the Limited Test and the Field Test unmistakably demonstrate the effectiveness of the media designed to enhance students' Higher-Order Thinking Skills (HOTS) in the context of circle materials. The analysis of the data reveals that this innovative learning tool aligns closely with HOTS indicators, as evidenced by substantial improvements in both average scores and completion percentages between the pre-test and post-test assessments.

Assessment Aspects	Limited Test		Field Test	
	Pre-Test	Post-test	Pre-Test	Post-test
Average	47,33	82.50	35,22	79,89
Completeness	1	6	3	33
The highest score	75,86	99.14	84.05	100
Lowest Value	40,52	71.98	11,21	58,62
Percentage of Completed Students	10 %	60 %	7 %	79 %

Table 8. HOTS Data in Limited Tests and Field Tests

In the Limited Test, the students initially displayed an average pre-test achievement of 47.33, with a modest completion rate of only 10%. However, after engaging with the learning media, their post-test average soared to 82.50, accompanied by a commendable completion percentage of 60%. This remarkable progress signifies that the media effectively addressed the HOTS indicators, as it prompted students to think critically, solve complex problems, and analyze mathematical concepts with depth and precision. These outcomes are consistent with established HOTS indicator references, such as Bloom's Taxonomy, which emphasizes cognitive skills such as: analyzing, evaluating, creating.

Similarly, the Field Test results mirrored the success observed in the Limited Test. Students commenced with an average pre-test achievement of 35.22 and a completion rate of just 7%. However, the post-test outcomes revealed a noteworthy transformation, with an average score of 79.59 and an impressive completion percentage of 79%. This substantial enhancement aligns with HOTS indicators, reinforcing the media's ability to stimulate higher-order thinking. It is important to note that the improvements observed encompass various HOTS domains, encompassing analysis, synthesis, and evaluation.

In conclusion, the research results underscore the media's capacity to meet and exceed HOTS indicators as defined by recognized references in educational psychology and assessment methodologies. This not only validates the educational value of the designed media but also emphasizes its potential to elevate students' cognitive abilities, ultimately fostering a deeper and more meaningful grasp of mathematical concepts, particularly in the context of circle materials.

## 7) Results and Analysis of Student Opinions Regarding the Quality of Virtual Exhibition-Based RME Media

Data on student opinions regarding the quality of virtual exhibition-based RME media for each research trial are limited and the field can be seen in the appendix. A brief description of student opinion data regarding the quality of virtual exhibition-based RME media in the limited and field tests is presented in Table 9 and the field, tests are presented in Table 9 below:

Assessment Aspects	Limited Score	Test	Field Test Score
Total Score Total	862		3489
Average	86,2		83.07
Ideal Presentation	86%		83%

Table 9. Summary of Student Opinion Data Regarding the Quality of Mathematical Media E-books in Limited Tests and Field Tests

Based on the data that has been obtained from the limited test and field test, the average score of students' opinions on the quality of RME media based on virtual exhibitions in the limited test is 86.2 with an ideal presentation of 86%, which is the ideal assessment criteria belongs to the criteria "very good" while the results of students' opinions on the quality of virtual exhibition-based RME media in the field test obtained was 83.07 with an ideal presentation of 83%, where the ideal assessment criteria belonged to the "very good" criteria-Based on the averages and ideal presentations from limited trials and field trials, it can be concluded that the assessment of students' opinions on the quality of RME media based on virtual exhibitions from limited trials and field trials is categorized as "very good" and can be used as a medium of learning on the material circle.

## DISCUSSION

In this study, we designed and developed a virtual exhibition aimed at enhancing students' high-order thinking skills (HOTS) by integrating the three principles and five characteristics of Realistic Mathematics Education (RME) (Palupi & Khabibah, 2018). We ensured that our virtual exhibition adhered to three fundamental RME principles: 'Rediscover,' 'Didactic Phenomena,' and 'Self-Developed Models.' To illustrate the 'Rediscover' principle, our virtual exhibition incorporated interactive elements, allowing students to independently explore mathematical concepts through virtual tools and simulations. Additionally, the 'Didactic Phenomena' principle was embraced by embedding real-world scenarios and phenomena throughout the exhibition, providing students with tangible contexts for mathematical exploration. Furthermore, the 'Self-Developed Models' principle was enacted through activities that prompted students to construct their mathematical models to tackle real-world problems, fostering a sense of ownership over their learning.

Our virtual exhibition also encompassed the five key characteristics of RME (Julie et al., 2014), beginning with 'Real-World Use.' We integrated practical applications of mathematics, showcasing how the mathematical concepts presented in the exhibition are employed in various real-life scenarios such as make a circular lid from cardboard, sprinkler, etc. 'Modelling' was another crucial component, as we encouraged students to create mathematical models to elucidate phenomena showcased within the exhibition. The 'Use of Production and Construction' characteristic was evident in the interactive activities provided, where students actively built their understanding of mathematics by constructing geometric shapes, creating data visualizations, and programming mathematical simulations. 'Use of Interaction' was promoted through interactive exercises and discussions that allowed students to engage directly with mathematical content and

receive timely feedback. Lastly, 'Intertwining' was a central theme, highlighting the interconnectedness of various mathematical concepts and encouraging students to explore these relationships for a deeper comprehension.

Our findings demonstrate a significant positive impact on students' HOTS through the integration of RME principles and characteristics within the virtual exhibition. Student performance and engagement data consistently indicated that the principles of 'Rediscover,' 'Didactic Phenomena,' and 'Self-Developed Models,' along with the characteristics of 'Real-World Use,' 'Modelling,' 'Use of Production and Construction,' 'Use of Interaction,' and 'Intertwining,' collectively contributed to an enriched learning experience. These results have noteworthy implications for mathematics education, emphasizing the effectiveness of aligning instructional media with RME principles and characteristics to foster deeper understanding and higher-order thinking skills among students." Based on the findings from the previously described research, it has been established that the virtual exhibition-based Realistic Mathematics Education (RME) media effectively serves as a learning tool for enhancing Higher-Order Thinking Skills (HOTS) in the context of circle materials. The following presents the results of the HOTS post-test. This learning medium, which has successfully passed the rigorous validation processes by material and media experts, connects mathematical concepts with the circle subject matter through realistic experiences and familiar knowledge accessible to students.

The research discussed above can unequivocally be considered a resounding success, driven by the development of innovative media tailored specifically for 8th-grade students at Widiatmika Middle School. This media has demonstrated substantial improvements in students' HOTS abilities, resulting in a significant number of students meeting or surpassing the predetermined completion criteria set by Widiatmika Middle School. These achievements underscore the remarkable quality of the developed media, a fact validated by recent evaluations and assessments conducted by educational experts and the students themselves. Notably, contemporary educational research by Marzano and Kendall (2017) reinforces the importance of technology-integrated instructional media in enhancing student outcomes. Their findings emphasize the role of multimedia resources, such as virtual exhibitions, in promoting active learning, critical thinking, and engagement in mathematics education, aligning seamlessly with the outcomes observed in this study.

Furthermore, the application of the Realistic Mathematics Education (RME) approach, as endorsed by recent research by Van den Heuvel-Panhuizen and Drijvers (2014), has proven instrumental in catalyzing the positive transformation observed in students' higher-order thinking skills. The RME approach, rooted in constructivist principles and problem-solving strategies, has gained renewed attention in the context of modern mathematics education. It aligns perfectly with contemporary educational philosophies that emphasize fostering conceptual understanding, analytical thinking, and the development of 21st-century skills. In conclusion, this research stands as a testament to the potential of cutting-edge instructional media and pedagogical approaches to revolutionize

mathematics education. The incorporation of multimedia resources and the strategic application of the RME approach represent powerful tools for educators seeking to empower students with the advanced cognitive skills necessary for success in our ever-evolving educational landscape (Kilpatrick et al., 2001). The application of the RME approach has a significant positive effect on improving students' higher-order thinking skills (Anderson & Krathwohl, (2001).

The integration of Realistic Mathematics Education (RME) with technology has a profoundly positive impact on enhancing students' Higher-Order Thinking Skills (HOTS). The support from technology, such as the developed virtual exhibition media, offers students an engaging and realistic learning experience. It enables students to explore various mathematical concepts through enjoyable activities. As suggested by Papadakis et al., digital technologies can indeed play a constructive role in enhancing early mathematics skills (Sasmi et al., 2020). The utilization of mobile technologies in mathematics education further encourages meaningful student engagement by embedding the subject in real-world contexts. Ideally, mobile technologies should be seamlessly integrated into mathematics teaching and learning to create a new, more dynamic learning environment (Papadakis et al., 2021).

Moreover, RME learning complemented by virtual exhibition media presents modern, effective, and enjoyable opportunities for students to study mathematics. "Modern" signifies that students can leverage the latest virtual reality technology in their math education. "Effective" implies that virtual exhibition media can be accessed at any time and from anywhere, making learning more convenient for students. Lastly, "fun" indicates that learning activities using virtual exhibition media boost students' enthusiasm and motivation for learning mathematics. This is corroborated by the significant improvement in students' HOTS abilities and the positive feedback they provide regarding the use of RME media based on virtual exhibitions. In line with Padmasari et al., mixed-reality-based virtual exhibitions can indeed be seen as innovative solutions and positive trends in the realm of digital technology advancement (Padmasari et al., 2022).

## CONCLUSIONS

Data analysis is conducted to provide an overview of the quality of the developed learning media products. This analysis relies on quantitative data, helping to determine whether the products meet criteria for validity, effectiveness, and practicality. The validation results indicate an ideal average percentage of 87.27% from media experts and 91% from material experts, demonstrating that the RME media based on virtual exhibitions developed are of very high quality for use in mathematics education. In the Limited Test, students' Higher-Order Thinking Skills (HOTS) test completion rate was 60%, which increased to 79% in the Field Test. Furthermore, the average score from students' feedback on the quality of RME media based on virtual exhibitions is 83. These findings highlight the positive influence of combining RME learning with technology in enhancing students' HOTS.

This research makes a significant contribution by offering RME learning using virtual exhibition media, creating a modern, effective, and enjoyable approach to studying mathematics. There remains room for improvement and expansion, potentially exploring other mathematical topics to broaden the scope and innovate the design of these educational materials.

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