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Development of Didactical Teaching Materials on Circle Concepts Based on Realistic Mathematics Education

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Abstrak

Penelitian ini bertujuan untuk mengembangkan bahan ajar desain didaktis materi lingkaran berbasis Pendidikan Matematika Realistik (RME) untuk peserta didik SMP kelas VIII. Permasalahan yang diangkat dalam penelitian ini adalah kurangnya bahan ajar yang mengintegrasikan pendekatan kontekstual seperti RME, yang dapat membantu siswa memahami konsep matematika dengan cara yang lebih relevan dan aplikatif dalam kehidupan sehari-hari. Penelitian ini menggunakan metode pengembangan dengan model 4D yang terdiri dari empat tahapan: define, design, develop, dan disseminate. Teknik pengumpulan data dilakukan melalui validasi ahli, uji coba kelompok kecil dan kelompok besar. Data yang diperoleh dari validasi ahli dan uji coba tersebut kemudian dianalisis secara deskriptif kuantitatif untuk menilai kelayakan bahan ajar yang dikembangkan. Hasil penelitian menunjukkan bahwa bahan ajar desain didaktis materi lingkaran berbasis RME memperoleh penilaian yang sangat layak, dengan rata-rata penilaian sebesar 91,4% dari seluruh tahapan uji coba. Oleh karena itu, bahan ajar ini dinyatakan valid dan layak untuk digunakan dalam proses pembelajaran matematika di sekolah menengah pertama. Implikasi dari penelitian ini adalah bahwa pengembangan bahan ajar berbasis RME dapat meningkatkan kualitas pembelajaran matematika yang lebih kontekstual dan efektif dalam membantu siswa memahami konsep-konsep matematika.
Kata Kunci: Bahan ajar; desain didaktis; lingkaran; realistic mathematics education

Abstract

This study aims to develop a didactical design of teaching materials on the topic of circles based on Realistic Mathematics Education (RME) for eighth-grade junior high school students. The problem addressed in this research is the lack of teaching materials that integrate contextual approaches such as RME, which can help students understand mathematical concepts in a more relevant and applicable way in everyday life. This research employs a development method using the 4D model, which consists of four stages: define, design, develop, and disseminate. Data collection techniques were conducted through expert validation and small and large group trials. The data obtained from these validations and trials were then analyzed descriptively and quantitatively to assess the feasibility of the developed teaching materials. The results of the study indicate that the didactical design of teaching materials on the topic of circles based on RME received a very feasible rating, with an average score of 91.4% from all trial stages. Therefore, these teaching materials are considered valid and feasible for use in mathematics learning at the junior high school level. The implications of this research suggest that the development of RME-based teaching materials can enhance the quality of mathematics learning, making it more contextual and effective in helping students understand mathematical concepts.
Keywords: Teaching materials; didactical design; circle; realistic mathematics education

I. INTRODUCTION

Mathematics is a field of knowledge built from a variety of structured topics, consisting of several interrelated areas such as geometry, algebra, statistics, and trigonometry (NCTM, 2000; Pradiarti && Subanji, 2022). Geometry is an important branch of mathematics for students to master because its applications are beneficial in daily life (Arwadi, Sidjara, & Suarlin, 2023). Additionally, geometry plays a crucial role in studying other branches of mathematics and provides tools that can simplify problem-solving through the use of images, diagrams, and coordinate systems (Abdussakir & Achadiyah, 2009; Aini Suryowati, 2022).

One of the concepts within the domain of geometry is the circle. A circle is a flat geometric shape that is commonly encountered and utilized by students (Elyana, Astutiningtyas, & Susanto, 2023). The topic of circles is studied in Grade VIII, Semester 2 of Junior High School (SMP). Essentially, the topic of circles has a significant chance of being understood by junior high school students because its applications are frequently encountered in everyday life, and they have already acquired its basic concepts since Elementary School.

However, several research findings indicate that students' performance in learning about circles remains relatively low (Arofah & Noordyana, 2021; Atiyah & Nuraeni, 2022). Students often make mistakes and struggle with problems related to circles (Abdussakir & Achadiyah, 2009; Budiyanti, 2010; Hendra, 2011; Khoirudin, 2014; Leviana, 2012). This occurs because students' problem-solving contexts are limited to formulas provided by the teacher. One of the weaknesses of this condition is that if students forget the formulas, they cannot solve the problems accurately.

Observations by Abdussakir and Achadiyah (2009) revealed that many Grade VIII students still have difficulty understanding the formulas for the circumference and area of a circle. When asked to find the circumference or area of a circle given its radius or diameter, students do not answer immediately. Some say they have forgotten the formula, and others use the formula incorrectly.

These difficulties are suspected to be caused by the way teachers teach. Teachers tend to rely solely on lecturing by writing formulas, providing examples, and assigning tasks (Agterberg, Oostdam, & Janssen, 2022). Students merely receive and memorize the formulas for the circumference and area of a circle (Lehmann, 2024). As a result, the knowledge gained by students only lasts temporarily because it is not constructed independently by the students.

Research by Budiyanti (2010) shows that students still struggle with word problems and problems involving diagrams related to the circumference and area of a circle. This is due to students' low understanding of the concepts of circumference and area, both conceptually and procedurally. Errors in solving circle problems, particularly those related to the concepts of central angles, arc length, and sector area (Freiman & Folkov, 2022), were also found by Leviana (2011) in her research. The findings identified students' difficulties in distinguishing circle elements and other

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issues related to their ability to connect, generalize, and solve problems. These difficulties indicate that students still face challenges in learning about circles, especially regarding central angles, arc length, and sector area.

The errors and difficulties students face in solving these problems suggest that their ability to tackle issues related to circles is still limited to specific problem contexts (Brijlal & Abakah, 2022). This triggers learning obstacles. Therefore, students need learning experiences that help them understand circle concepts well and address and anticipate learning obstacles.

In addition to the teaching methods and students' limited problem-solving abilities, the presentation of materials in educational resources can also cause learning obstacles (Kusnadi & Mardiani, 2022; Lisnani & Inharjanto, 2023; Rahmawati & Afriansyah, 2023). Students' difficulties in learning about circles need to be addressed through teachers' efforts in planning, implementing, and evaluating the learning process. This role is performed by teachers before, during, and after the learning process.

The Minister of Education and Culture Regulation No. 65 of 2013 (Department of Education and Culture, 2013) on Process Standards states that every educator in an educational unit is required to prepare a complete and systematic Lesson Plan (RPP) so that learning takes place interactively, inspiringly, enjoyably, challengingly, efficiently, motivates students to participate actively, and provides sufficient space for initiative, creativity, and independence according to students' talents, interests, and physical and psychological development. This requires educators to design mathematics lessons that meet students' needs. Therefore, an analysis of students' learning difficulties needs to be conducted before designing or planning lessons.

The success of learning is closely related to the design of teaching materials (didactic design) developed by the teacher. Teaching materials designed with an appropriate learning approach and oriented towards research on students' learning obstacles are expected to address and anticipate these obstacles, thereby achieving the goals of mathematics education effectively.

This research is important because it addresses a gap in existing teaching materials by developing didactical materials based on Realistic Mathematics Education (RME), which is more contextual and applicable to real-life problems. The novelty of this study lies in its focus on designing teaching materials for learning circles that integrate the RME approach. RME emphasizes understanding mathematical concepts through real-world contexts, helping students relate abstract mathematical ideas to their everyday experiences. By developing these materials, this study aims to improve students' understanding of geometry, especially on the topic of circles, and to bridge the gap between theoretical concepts and practical applications.

The development of didactic design teaching materials plays a significant role in mathematics education. This role greatly affects how students engage in the learning

process in the classroom. The development of didactic design teaching materials is expected to meet the challenges of mathematics education, particularly regarding the obstacles and difficulties that students encounter.

II. METHOD

The research method used in this study is the development research method, or research and development (R&D), utilizing the 4D development model. The 4D model consists of four steps: define (analysis), design (design), development (development), and dissemination (dissemination). The research was conducted on January – July 2024. The stages of development in this study are as shown by Figure 1 (Maydiantoro, 2019; Salsabella et al., 2023).

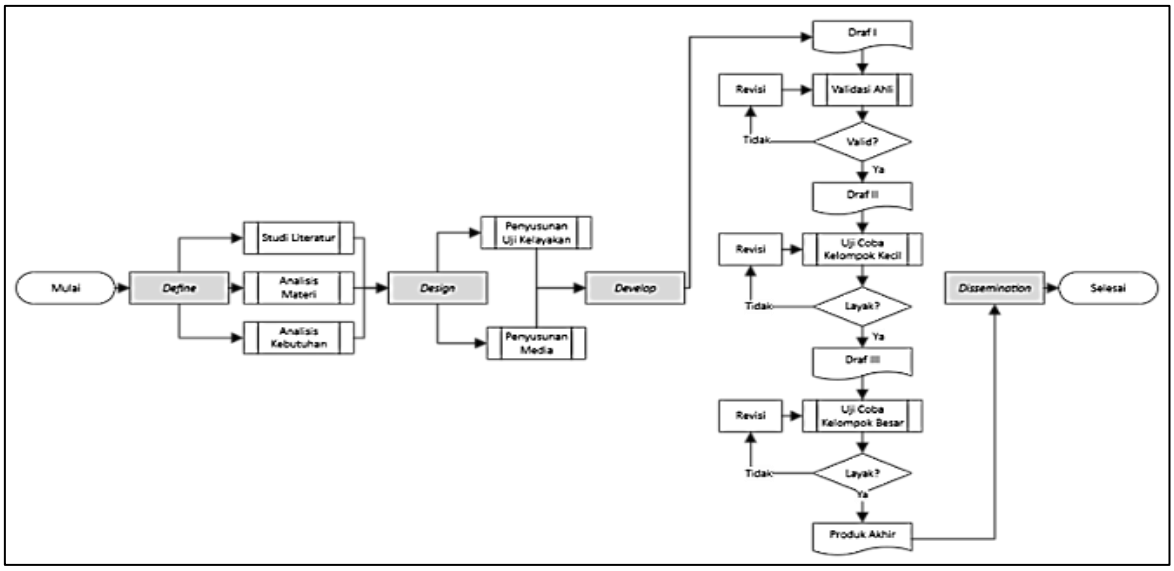

Figure 1. Steps of 4D Model

The validation process includes validation by subject matter and language experts, as well as media experts. The product testing phase involves both small group testing and large group testing. Small group testing is conducted with 10 Grade IX junior high school students and one mathematics teacher. Large group testing is conducted with 30 Grade IX junior high school students and three mathematics teachers. During each validation process, the experts, small group, and large group tests use validation instruments or assessments that include feedback and input on the validated and tested product.

In this study, the calculation process will use a Likert scale (see Table 1).

Table 1.
Likert scale

Score of Response	Category	Code
5	Strongly Agree	S S
4	Agree	S
3	Neutral	R
2	Disagree	TS
1	Strongly Disagree	STS

After the scores from each questionnaire are calculated, the next step will be to compute the percentage of the

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product's feasibility value in this study. The following is the formula for calculating the percentage of the feasibility value of the educational media product.

$$Percentage = \frac{total\ score\ obtained}{maximum\ score} \times 100\%$$

After obtaining the percentage of the product's feasibility value, the next step is to interpret the scores based on the following Table 2:

Table 2.
Criteria for the Feasibility

Average validator score	Category
80% ≤ P ≤ 100%	Very Valid
60% ≤ P < 80%	Valid
40% ≤ P < 60%	Valid Enough
20% ≤ P < 40%	Less Valid
0% ≤ P < 20%	Invalid

III. RESULT AND DISCUSSION

A. Result

The research and development of circle teaching materials based on RME for Grade VIII junior high school students was carried out through several stages or steps referring to the 4D development model. The first stage is define, which involves needs analysis activities.

The next stage is design, aimed at creating feasibility testing instruments and designing media to match the results of the needs analysis. This stage includes the development of blueprints and validation questionnaires, as well as product feasibility testing. The blueprints and validation questionnaires for experts, as well as the blueprints and questionnaires for trial tests, were validated by one validator lecturer each. The media design phase involves creating the layout design of teaching materials, producing instructional videos, and developing the initial draft of the media (Draft I). The design process for teaching materials uses Canva as the primary supporting tool. Subsequently, all teaching material designs, text, images, and animations were compiled and arranged into a flipbook module using Heyzine on a web browser.

The RME-based teaching module that has been developed was then validated by experts, including subject matter and language experts, as well as media experts. The following data presents the results of the validation by subject matter and language experts, conducted by two expert lecturers (see Table 3).

Table 3.
Results of Validation by Materials Experts

No	Aspect	Achievement
1	Content Accuracy	88,75%
2	Material Coverage	90%
3	RME	85,67%
4	Feasibility of Presentation	83,3%
5	Language	87,5%
Total	87%	

Based on the data in the table above regarding the results of expert validation for content and language of the developed product, it received an overall percentage of 87%, which can be interpreted as very feasible. Next, data from the media expert validation conducted by two validators is presented as follows (see Table 4).

Table 4.
Results of Validation by Media Experts

No	Aspect	Achievement
1	Content Accuracy	90%
2	Design	87%
Total	88.5%	

Based on the data in the table above regarding the results of media expert validation for the developed product, it received an overall percentage of 88.5%, which can be interpreted as very feasible.

After undergoing validation by the experts and being revised according to their suggestions and feedback from both content and language experts and media experts, the next step is to test the product's feasibility with students and teachers. This feasibility testing is divided into two stages: small group trials and large group trials. The following presents the results of the small group trials (see Table 5).

Table 5.
Results of Testing to Small Group to Student

No	Aspect	Achievement
1	Appearance	100%
2	Content	100%
3	Benefit	100%
Total	100%	

Table 6.
Results of Testing to Small Group to Teacher

No	Aspect	Achievement
1	Content	80%
2	Structure	80%
3	RME	80%
4	Appearance	100%
5	Language	100%
Total	88%	

Based on the data in the Table 6 regarding the results of the small group trials with students, the product received an overall percentage of 100%, which can be interpreted as very feasible. In contrast, the results of the small group trials with teachers showed an overall percentage of 88%, which is also interpreted as very feasible.

Subsequently, the product, revised based on feedback or suggestions from students and teachers during the small group trials, was tested with students and teachers in the large group trials. The following presents the data from the large group trials (see Table 7).

Table 7.
Results of Testing to Large Group to Student

No	Aspect	Achievement
1	Appearance	94%
2	Content	93%
3	Benefit	93,3%
Total	93.4%	

Table 8.
Results of Testing to Large Group to Teacher

No	Aspect	Achievement
1	Content	90%
2	Structure	92%
3	RME	85%
4	Appearance	98%
5	Language	94%
Total	91.8%	

Based on the data in the Table 8 regarding the results of the large group trials with students, the product received an overall percentage of 93.4%, which can be interpreted as very feasible. Meanwhile, the large group trials with teachers showed an overall percentage of 91.8%, which is also interpreted as very feasible.

Following this, a product evaluation process was conducted to determine the feasibility of the developed product. The feasibility of the product is assessed based on the evaluations from content and language experts, media experts, as well as the results from small and large group trials conducted with students and teachers. The results are as follows (see Table 9).

Table 9.
Product Evaluation Results at Each Stage

Stage	Percentage	Interpretation

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Stage	Percentage	Interpretation
Results of Validation by Materials Experts	87%	Very Feasible
Results of Validation by Media Experts	88,5%	Very Feasible
Results of Testing to Small Group to Student	100%	Very Feasible
Results of Testing to Small Group to Teacher	88%	Very Feasible
Results of Testing to Large Group to Student	93,4%	Very Feasible
Results of Testing to Large Group to Teacher	91,8%	Very Feasible
Average	91.45%	Very Feasible

Based on the assessment results in the table above, the overall average for each stage is 91.45%, which is interpreted as very feasible.

B. Discussion

Based on the research findings, it can be concluded that the didactic teaching materials on circle concepts based on Realistic Mathematics Education (RME) developed in this study are valid and highly suitable for use. This conclusion is supported by data obtained from expert validation, small group trials, and large group trials with students and teachers. The expert validation for content and language received an average percentage of 87%, while the media expert validation received an average percentage of 88.5%. The small group trial with students achieved a percentage of 100%, and the small group trial with teachers received a percentage of 88%. The large group trial with students obtained a percentage of 93.4%, and the large group trial with teachers received a percentage of 91.7%.

The results of this study align with previous research indicating that Realistic Mathematics Education (RME)-based teaching materials can significantly improve students' understanding and engagement with mathematical concepts. Research by Van den Heuvel-Panhuizen (2003) highlights the effectiveness of RME in enhancing students' conceptual understanding by connecting mathematical problems to real-world contexts. This approach has been shown to help students better grasp abstract mathematical ideas, such as those involved in understanding the properties of circles. Additionally, research by Gravemeijer (1994) underscores the importance of context-based learning in fostering a deeper understanding of mathematics, a key feature of the materials developed in this study.

Further support for the effectiveness of RME-based teaching materials can be found in the study by Wijaya and Wijayanti (2017), which explored the development of RME-based learning materials in geometry. Their findings show that students who were taught using RME-based materials demonstrated significantly improved problem-solving skills and higher retention of mathematical concepts. This aligns with the findings in this study, where students showed a high level of engagement and understanding during the trials, particularly when learning about circles.

According to Sunarto (2014), a learning media is considered feasible if it receives a score interpretation of >60%. This aligns with the criteria for score interpretation adapted from Riduwan (2016), which states that media with an overall percentage of 61%-80% is categorized as feasible, and

81%-100% is categorized as very feasible. Thus, it can be interpreted that the developed learning media is categorized as very feasible and can be utilized as a teaching resource for circle concepts in eighth-grade junior high school classes.

These findings are consistent with the notion that well-designed teaching materials, particularly those based on RME, can address the learning challenges faced by students and improve their understanding of complex mathematical concepts such as the circle. By focusing on real-life applications and fostering students' ability to connect mathematical ideas to their everyday experiences, RME-based materials hold promise for enhancing the quality of mathematics education in junior high schools.

IV. CONCLUSION

Based on the research results and discussion, it can be concluded that the development of didactic teaching materials on circle concepts based on Realistic Mathematics Education (RME) for eighth-grade junior high school students has resulted in a product that has gone through the stages of needs analysis, design, development, and limited dissemination. Validation results from content and language experts, media experts, as well as trials with students and teachers show that this teaching material is considered highly feasible, with an average feasibility score of 91.45%. Therefore, it can be concluded that the didactic teaching materials on circle concepts based on Realistic Mathematics Education (RME) for eighth-grade junior high school students are suitable for use in the mathematics learning process.

Based on the findings of this study, it is recommended that these RME-based teaching materials be applied more widely in various schools to help students better understand mathematical concepts, especially the topic of circles, in a more contextual and engaging way. Additionally, further development could focus on creating digital or interactive multimedia teaching materials to support both distance learning and blended learning methods. Educators are also encouraged to receive training on the use of these materials to enhance teaching effectiveness.

This study recommends that further research be conducted to develop RME-based teaching materials for other mathematical topics, such as geometry and algebra, to verify whether the same approach can help address students' learning difficulties in those areas. Furthermore, more extensive testing of these materials should be carried out across various educational levels and learning contexts to expand their applicability and effectiveness.

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