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DEVELOPMENT OF REALISTIC MATHEMATICS EDUCATION-BASED WORKSHEETS TO FACILITATE MATHEMATICAL CONNECTION ABILITIES ON PYTHAGOREAN THEOREM MATERIAL

Devi Irawaty Nadeak[1], *Atma Murni[2], Susda Heleni[3]
[1,2,3] Universitas Riau, Indonesia
atma.murni@lecturer.unri.ac.id

ABSTRACT This study aimed to develop a student worksheet on the Pythagorean Theorem utilizing the Realistic Mathematics Education (RME) approach, designed to meet validity and practicality standards to enhance the mathematical connection abilities of 8th-grade students. The research adopted the 4D development model, which includes the stages of Define, Design, Develop, and Disseminate. To ensure the validity of the student worksheet, three experts conducted a comprehensive validation process. Feasibility data were collected through trials involving 8th-grade students. The validation results indicated a score of 90.77%, categorized as "very valid." Small group trials yielded a practicality score of 89.98%, categorized as "very practical." Furthermore, large-scale trials demonstrated an average score of 89.29%, also categorized as "very practical." These findings highlight the effectiveness of the RME approach in facilitating students' mathematical connection abilities through the Pythagorean Theorem material. The developed student worksheet was proven to be valid, practical, and highly beneficial for supporting the development of mathematical connections among 8th-grade students.

Keywords: realistic mathematics education, pythagorean theorem, student worksheet, mathematical connection skills

ABSTRAK Penelitian ini bertujuan untuk mengembangkan lembar kerja peserta didik (LKPD) pada materi Teorema Pythagoras dengan pendekatan Realistic Mathematics Education (RME), yang dirancang agar memenuhi standar validitas dan kepraktisan untuk meningkatkan kemampuan koneksi matematis siswa kelas 8. Penelitian ini menggunakan model pengembangan 4D yang mencakup tahap Define, Design, Develop, dan Disseminate. Untuk memastikan validitas LKPD, dilakukan proses validasi yang melibatkan tiga ahli. Data kelayakan diperoleh melalui uji coba yang melibatkan siswa kelas 8. Hasil validasi menunjukkan skor sebesar 90,77%, yang dikategorikan sebagai "sangat valid." Uji coba

kelompok kecil menghasilkan skor kepraktisan sebesar 89,98%, yang juga dikategorikan sebagai "sangat praktis." Selain itu, uji coba skala besar menunjukkan rata-rata skor 89,29%, yang juga masuk kategori "sangat praktis." Temuan ini menyoroti efektivitas pendekatan RME dalam memfasilitasi kemampuan koneksi matematis siswa melalui materi Teorema Pythagoras. LKPD yang dikembangkan terbukti valid, praktis, dan sangat bermanfaat untuk mendukung pengembangan koneksi matematis siswa kelas 8.

Keywords: pendidikan matematika realistik, teorema pythagoras, lembar kerja peserta didik, kemampuan koneksi matematis

INTRODUCTION

One of the essential components in learning mathematics is mathematical connection ability (Hasbi et al., 2021). If students do not apply concepts to their experiences while studying mathematics, they may face difficulties because they have to memorize separate concepts (Hidayat et al., 2018). Mathematical connection ability refers to students' capacity to use the relationships between mathematical topics or concepts being discussed and other mathematical concepts, other subjects, and everyday life to solve mathematical problems (Siagian, 2016). Salim & Pitriani (2021) define mathematical connection ability as students' skill in making connections between concepts within and outside of mathematics. Thus, mathematical connection ability is crucial for students to link procedures or mathematical topics, even connecting them to other disciplines and real-life situations.

Low mathematical connection ability becomes evident when students struggle to implement mathematical concepts despite being able to mention existing concepts. Anwar et al. (2021) emphasize the importance of nurturing mathematical connection ability in students. When students can connect mathematical concepts, their knowledge will endure and deepen because they understand the relationships between mathematical topics, both within and beyond the context of mathematics, including connections to everyday life (Nurafni & Pujiastuti, 2019).

In this study, a pre-research test was conducted at SMPN 3 Mandau targeting eighth-grade students (totaling 15 students) to assess their mathematical connection ability. During the pre-research, students were given a test containing indicators related to mathematical connection ability, focusing on the Pythagorean Theorem. The pre-research test questions are provided in Figure 1.

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Kemal dan gilang pulang les dengan sepeda masing-masing dalam waktu yang bersamaan. Keduanya berpisah di simpang empat Gatot Subroto dan Sultan Syarif Qasim. Kemal melaju ke Jalan Gatot Subroto sedangkan Gilang melaju ke Jalan Sultan Syarif Qasim. Jika Kemal melaju dengan kecepatan 9 km/jam. Kemal dan Gilang terpisah sejauh 1,5 km setelah 6 menit. Hitunglah jarak Gilang dari simpang empat!

Figure 1 Pre-research Test Questions

When working on the pre-research test, students needed to connect the topic of speed with the Pythagorean Theorem, relate it to physics, and link it to their daily lives by determining the distance traveled. One student's incorrect approach is shown in Figure 2.

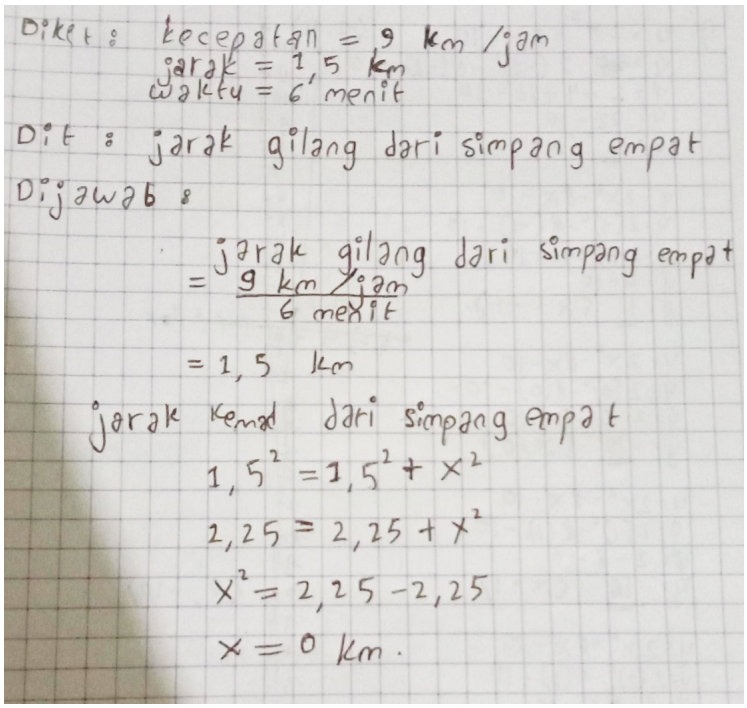

Figure 2 Student's Incorrect Calculation

Based on Figure 2, it is evident that the student incorrectly applied the speed formula to calculate the distance traveled. This demonstrates that the student did not fully understand the problem, and thus, the indicator related to connecting with everyday life was not met. Additionally, the student lacked knowledge of the mathematical concepts involved in question, specifically related to speed and the Pythagorean Theorem. As observed from the pre-research results, students have not yet mastered drawing connections between different concepts, linking them to other fields of knowledge, or even relating them to real-world situations. This aligns

with Qobtiyah's (2018) findings that students' mathematical connection ability remains suboptimal or low, as they have not yet applied one concept to another.

One approach that can establish a connection between learning and real life situations is Realistic Mathematics Education (RME). RME is a mathematics teaching approach based on mathematizing everyday experiences and applying them to daily life (Dhoruri, 2010). Yuniawatika et al. (2016)argue that RME is a theory of mathematics learning that starts with what students experience in real life, emphasizing process skills, discussion, collaboration, and argumentation with classmates so that they can discover mathematical ideas on their own in their daily lives. RME provides students with opportunities to rediscover mathematical concepts and ideas. It positions real-world problems known and experienced by students as the starting point for learning (Melinda & Ariawan, 2021). This aligns with the characteristics of RME, including (1) using contextual problems, (2) employing models, (3) utilizing student constructions, (4) being interactive, and (5) integrating with other topics (Rosmala, 2021).

In the learning process, students should have ample opportunities to express their thoughts individually and collaboratively. Therefore, supportive tools are essential to focus on students' learning and ensure that all students have access to these tools. This enhances students' chances of expressing their ideas during learning. To address learning difficulties and meet students' needs, it is necessary to develop instructional support tools that can be fully absorbed and centered on students, such as Student Worksheets (Nurdiyanto et al., 2020). Siregar (2021) states that there is a significant improvement in students' mathematical connection ability when learning with Student Worksheets. The choice of Student Worksheets is because teachers can personally design Student Worksheets according to the students' situation (Adha & Refianti, 2019). Thus, the use of Student Worksheets is considered effective in enhancing mathematical connection ability.

The Pythagorean Theorem and mathematical connection ability are closely related. They involve connecting concepts and procedures related to the Pythagorean Theorem, linking it to other fields of knowledge, and relating it to students' real-life experiences (Nurdiyanto et al., 2020). Leveraging the characteristics of RME, Student Worksheets development aligns with various aspects of students' daily lives, addressing common problems and allowing students to articulate their ideas (Rosmala, 2021). Through student contributions, interactions occur, enabling them to actively construct knowledge and solve problems by intertwining different topics. Therefore, this developmental research aims to create RME-based Student Worksheets for the Pythagorean Theorem that is both valid and practical.

METHODS

This research follows Research and Development (R&D) approach, specifically utilizing the 4D model. The 4D model consists of four main phases: Define, Design,

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Develop, and Disseminate (Thiagarajan et al., 1974). In the Define phase, a comprehensive need's analysis is conducted to identify the challenges faced in teaching and learning. Various analytical methodologies, including initial-final analysis, student analysis, concept analysis, task analysis, and formulation of learning objectives, can be used for comprehensive testing. The design process involves collecting and organizing relevant references for instructional material design. During this stage, a basic framework for the Student Worksheets is created, followed by detailed design of the Student Worksheets. Additionally, the initial development of instructional material occurs, along with the creation of validation sheets for Student Worksheets and questionnaires to assess practicality.

At the develop stage, the Student Worksheets drafts are validated by experts. After addressing the experts's feedback and ensuring Student Worksheets' validity, individual testing is conducted with three students to assess readability. If LKPD is deemed valid, field trials are conducted, involving a small group of six students initially and later a larger group of 31 students as research subjects. During the Disseminate phase, the developed product is published or distributed to a broader scope, including other classes or schools.

Data collection methods include interviews, documentation analysis, and the distribution of validation and practicality questionnaires. Interviews serve as a means to gather information through exchanges between teachers and students. Documentation analysis examines instructional resources used during teaching. To assess credibility, completeness, and implementation of instructional resources, validation sheets, readability questionnaires, and practicality questionnaires are employed. Validity data are collected by distributing validity questionnaires to three validators. Table 1 below are details of the validator assessment aspects.

Table 1 Validation Sheet Grids

Aspect Assessed	Number of Statements
Components of the Student Worksheets	3
Suitability of learning material	4
Suitability of Student Worksheets steps with the Realistic Mathematics Education (RME) approach	5
Suitability of activities in the Student Worksheets with mathematical connection ability indicators	3
Suitability of the Student Worksheets with didactic requirements	2
Suitability of the Student Worksheets with construction requirements	5
Suitability of the Student Worksheets with technical requirements	4

The validity level of Student Worksheets is determined using an adapted formula (Akbar, 2013):

$$V = \frac{TS_p}{TS_h} \times 100\%$$

Where:

V : percentage score from the questionnaire

TS_p : empirical total score from respondents

TS_h : maximum expected total score

The interpretation of validity analysis results is as follows (Akbar, 2013):

Table 2 Validity Categories

Score Interval	Category
$85{,}01\% \leq V \leq 100\%$	Highly Valid
$70{,}01\% \leq V \leq 85\%$	Valid
$50{,}01\% \leq V \leq 70\%$	Less Valid
$1\% \leq V \leq 50\%$	Not Valid

A response questionnaire contains statements about students' experiences after working with Student Worksheets. The assessment aspects and questionnaire indicators are presented in Table 3.

Table 3 Questionnaire Response Grid for Students

Aspect Assessed	Indicators	Number of Statements
Layout	Text clarity	1
	Image clarity	1
	Image alignment with content	1
	Use of white space	1
	Appealing Student Worksheets layout	1
Content presentation	Problem presentation	1
	Sentence clarity	2
	Alignment of problem with the Pythagorean Theorem material	1
Benefits	Ease of learning	3
	Interest in using Student Worksheets	1
	Improvement in learning motivation	2

Student response sheets are designed using a Likert scale and in checklist format. To assess practicality, the formula for calculating the percentage of practicality is as follows (Akbar, 2013):

$$V_p = \frac{TS_p}{TS_h} \times 100\%$$

Where:

V_p : percentage score from the questionnaire

TS_p : empirical total score from respondents

TS_h : maximum expected total score

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The interpretation of practicality analysis results is as follows (Akbar, 2013):

Table 4. Practicality Categories

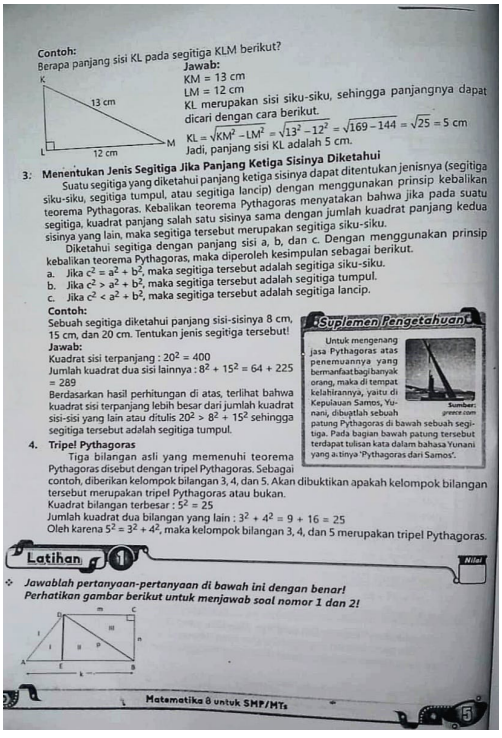
Score Interval	Category
$85{,}01\% \leq V_p \leq 100\%$	Highly Practical
$70{,}01\% \leq V_p \leq 85\%$	Practical
$50{,}01\% \leq V_p \leq 70\%$	Less Practical
$1\% \leq V_p \leq 50\%$	Not Practical

FINDING AND DISCUSSION

The results of this study are an Student Worksheet based on the Realistic Mathematics Education (RME) approach, focusing on the Pythagorean theorem topic. This Student Worksheets aims to facilitate mathematical connection abilities for eighth-grade junior high school students. The development process followed the 4D model, with the following stages:

Define Stage

This stage involves identifying the fundamental issues and finding solutions. Initial analysis was conducted through interviews. The findings revealed that the existing Student Worksheets did not include solution steps that could enhance students' mathematical connections. The current Student Worksheets only consisted of material summaries and exercise questions, as shown in Figure 3.


Contoh:
Berapa panjang sisi KL pada segitiga KLM berikut?

Jawab:
KM = 13 cm
LM = 12 cm
KL merupakan sisi siku-siku, sehingga panjangnya dapat dicari dengan cara berikut.
$KL = \sqrt{KM^2 - LM^2} = \sqrt{13^2 - 12^2} = \sqrt{169 - 144} = \sqrt{25} = 5$ cm
Jadi, panjang sisi KL adalah 5 cm.

3: **Menentukan Jenis Segitiga Jika Panjang Ketiga Sisinya Diketahui**
Suatu segitiga yang diketahui panjang ketiga sisinya dapat ditentukan jenisnya (segitiga siku-siku, segitiga tumpul, atau segitiga lancip) dengan menggunakan prinsip kebalikan teorema Pythagoras. Kebalikan teorema Pythagoras menyatakan bahwa jika pada suatu segitiga, kuadrat panjang salah satu sisinya sama dengan jumlah kuadrat panjang kedua sisinya yang lain, maka segitiga tersebut merupakan segitiga siku-siku.
Diketahui segitiga dengan panjang sisi a, b, dan c. Dengan menggunakan prinsip kebalikan teorema Pythagoras, maka diperoleh kesimpulan sebagai berikut.
a. Jika $c^2 = a^2 + b^2$, maka segitiga tersebut adalah segitiga siku-siku.
b. Jika $c^2 > a^2 + b^2$, maka segitiga tersebut adalah segitiga tumpul.
c. Jika $c^2 < a^2 + b^2$, maka segitiga tersebut adalah segitiga lancip.

Contoh:
Sebuah segitiga diketahui panjang sisi-sisinya 8 cm, 15 cm, dan 20 cm. Tentukan jenis segitiga tersebut!
Jawab:
Kuadrat sisi terpanjang : $20^2 = 400$
Jumlah kuadrat dua sisi lainnya : $8^2 + 15^2 = 64 + 225 = 289$
Berdasarkan hasil perhitungan di atas, terlihat bahwa kuadrat sisi terpanjang lebih besar dari jumlah kuadrat sisi-sisi yang lain atau ditulis $20^2 > 8^2 + 15^2$ sehingga segitiga tersebut adalah segitiga tumpul.

4. **Tripel Pythagoras**
Tiga bilangan asli yang memenuhi teorema Pythagoras disebut dengan tripel Pythagoras. Sebagai contoh, diberikan kelompok bilangan 3, 4, dan 5. Akan dibuktikan apakah kelompok bilangan tersebut merupakan tripel Pythagoras atau bukan.
Kuadrat bilangan terbesar : $5^2 = 25$
Jumlah kuadrat dua bilangan yang lain : $3^2 + 4^2 = 9 + 16 = 25$
Oleh karena $5^2 = 3^2 + 4^2$, maka kelompok bilangan 3, 4, dan 5 merupakan tripel Pythagoras.

Suplemen Pengetahuan
Untuk mengenang jasa Pythagoras atas penemuannya yang bermanfaat bagi banyak orang, maka di tempat kelahirannya, yaitu di Kepulauan Samos, Yunani, dibuatlah sebuah patung Pythagoras di bawah sebuah segitiga. Pada bagian bawah patung tersebut terdapat tulisan kata dalam bahasa Yunani yang artinya 'Pythagoras dari Samos'.
Sumber: greece.com

Latihan 1
Nilai
Jawablah pertanyaan-pertanyaan di bawah ini dengan benar!
Perhatikan gambar berikut untuk menjawab soal nomor 1 dan 2!

Matematika 8 untuk SMP/MTs

Figure 3 Student Worksheets That Student Use

In addition, an analysis of student characteristics was conducted by observing eighth-grade classes with an average age of 14 years. Acccording to Ramadhina (2024) the basic characteristics of development that occur is that children are already able to reason logically and think abstract. The observation results indicated that the learning process was not student-centered, and students were not actively engaged. Teachers explained the material without involving students in constructing their own knowledge to enhance mathematical connections.

Design Stage

In this stage, we designed the basic framework according to the characteristics of Realistic Mathematics Education (RME) approach. Additionally, we created the initial draft of the LKPD. We also developed validation sheets and student response questionnaires.

Develop Stage

Two main activities were carried out during the development stage, including (1) expert assessment, and (2) trials. The result of the develop stage are as follows:

Table 5 Validity Result

Assessed Aspect	Average (%)	Category
Components of the Student Worksheets	95,56	Highly Valid
Suitability of learning material	88,75	Highly Valid
Suitability of Student Worksheets steps with the Realistic Mathematics Education (RME) approach	82,00	Valid
Suitability of activities in the Student Worksheets with mathematical connection ability indicators	89,44	Highly Valid
Suitability of the Student Worksheets with didactic requirements	97,50	Highly Valid
Suitability of the Student Worksheets with construction requirements	88,00	Highly Valid
Suitability of the Student Worksheets with technical requirements	94,17	Highly Valid
Total Average	90,77	Highly Valid

The average validity score obtained was 90,77%, indicating that the Student Worksheets was highly valid. These results indicate that the Student Worksheets is feasible to be tested after improving several parts according to the expert's criticism.

After improving the Student Worksheets based on expert critiques, a pilot test was conducted with eighth-grade students. Small group trials involved six students to assess the practicality of the Student Worksheets. The results are summarized in Table 6.

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Table 6. Student Response Questionnaire Results from Small Group Test

Assessed Aspect	Average (%)	Category
Layout	90,50	Highly Practical
Content presentation	89,58	Highly Practical
Benefits	89,86	Highly Practical
Total Average	89,98	Highly Practical

Table 6 shows that the average practicality percentage of the Student Worksheets is 89,98%. This value implies that the Student Worksheets is highly practical for use and can proceed to the next stage.

Next is the large-group trial, which serves as a benchmark for assessing the practicality of the LKPD on a larger scale. Table 7 presents the results of the large-scale trial.

Table 7. Student Response Questionnaire Results from Large Group Test

Assessed Aspect	Average (%)	Category
Layout	88,26	Highly Practical
Content presentation	87,18	Highly Practical
Benefits	89,44	Highly Practical
Total Average	89,29	Highly Practical

Through Table 7, it is evident that the average practicality level of the large-group trial is 89,29%. This value categorizes the Student Worksheets as highly practical and suitable for use.

Disseminate Stage

After confirming the validity and practicality of the Student Worksheets, the next steps involve packaging it into a book format, conducting a research seminar presentation, and publishing the research results in a scientific journal.

Relevant to this study, Maimunah et al. (2019) developed an Student Worksheets based on realistic mathematics education with a maritime context for eleventh-grade high school students. Their study replaced the ADDIE model with the 4D development model. While their research focused on eleventh-grade students, our study targets eighth-grade students in the Pythagorean theorem topic. Notably, their study did not explore students' mathematical connection abilities, a crucial component in mathematics. By developing Student Worksheets based on realistic mathematics education can support students' connection skills to develop.

CONCLUSIONS AND RECOMMENDATIONS

The findings of this research conclude that the Student Worksheet developed using the Realistic Mathematics Education (RME) approach is valid and practical, making it an effective tool to support teaching and learning activities. The worksheet facilitates students' mathematical connection skills by linking abstract concepts to real-world contexts, enhancing their understanding and engagement. Future research is recommended to evaluate the effectiveness of this worksheet in improving student learning outcomes through experimental studies. Additionally, teachers are encouraged to integrate this worksheet into various mathematical topics to promote meaningful learning experiences, while further exploration of its application in diverse educational settings could provide valuable insights for broader implementation.

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