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Developing PMRI-based E-worksheets integrating mandi kasai cultural context to enhance students' understanding of relations and functions

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Abstract

Background: Relations and functions are fundamental mathematics topics that require students to connect abstract concepts with real-life situations. However, students' conceptual understanding remains limited due to the abstract nature of the material and the lack of contextual digital learning resources integrating local culture.
Aims: This study aimed to develop a PMRI-based e-worksheet integrating the Mandi Kasai cultural context and to evaluate its validity, practicality, and effectiveness in learning relations and functions.
Method: This Research and Development (R&D) study adopted the ADDIE model, including analysis, design, development, implementation, and evaluation stages. The participants were eighth-grade students at SMP Negeri 4 Lubuk Linggau City. Data were collected through expert validation sheets, teacher and student response questionnaires, and learning achievement tests, and analyzed using descriptive quantitative techniques.
Results: The e-worksheet obtained validity scores of 91% from material experts, 93% from media experts, and 96% from language experts. Practicality reached 89.33% based on teacher responses and 93.34% based on student responses. The learning effectiveness analysis produced an N-gain score of 0.67, indicating a moderate improvement in students' understanding.
Conclusion: The PMRI-based e-worksheet integrating the Mandi Kasai cultural context is valid, practical, and effective for supporting students' understanding of relations and functions.

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INTRODUCTION

Mathematics learning still faces challenges in helping students understand abstract concepts meaningfully. Therefore, educators need to integrate digital technology appropriately to design interactive, student-centered learning. This integration becomes crucial as digital technology advances in mathematics education (Amaludin et al., 2025). This can encourage student participation and activeness that is tailored to students' learning characteristics (Rohmah et al., 2023). The integration of digital technology into mathematics learning not only expands students' access to information and materials but also enables teachers to develop responsive learning resources. Furthermore, it can help students learn the material more independently according to their learning needs. Through interactive visual presentations, students can explore concepts more clearly and dynamically (Drijvers & Sinclair, 2024; Engelbrecht & Borba, 2024). In addition, digital technology allows teachers to provide real-time feedback and systematically monitor students' learning

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processes, so that interventions can be tailored to students' needs (Tefa & Liang, 2026). One way is by providing digital teaching materials. Using structured digital teaching materials makes it easier for students to review material, access additional exercises, or conduct interactive simulations that support concept reinforcement and problem-solving skills (Hershkovitz et al., 2024). Digital teaching materials also support the development of critical and creative thinking skills when learning activities are designed to encourage reasoning, exploration, and reflection.(Nuryami et al., 2025; Zhao & Abdullah, 2025).

Empirical studies show that mathematics learning at the junior high school level is still often dominated by teacher-centered learning (Fahjri et al., 2025; Wanabuliandari et al., 2023). Not a few teachers only rely on textbooks in learning activities without exploring more interesting and varied learning alternatives (Siregar, 2021). Teachers rely heavily on textbooks as the primary teaching reference, often accepting their content uncritically (Nasrullah et al., 2025). This condition is of particular concern in material that demands the interconnectedness of concepts and representations, such as relations and functions. The material on relations and functions requires students to be able to connect concepts to real-world situations to make learning more meaningful. A relation between two sets is an ordered pair containing one object from each set (Joseph, 2020). Each element x in A is assigned a uniquely determined element $f(x)$ in B by a correspondence rule f, which is a function from A to B (Jannah et al., 2019). However, most students have difficulty understanding the material on relations and functions because the material is presented in an abstract manner (Faizah & Ramlah, 2025; Uswati, 2022; Yuliani et al., 2024). Several studies have shown that students often encounter difficulties in understanding formal definitions, interpreting meaning, using algebraic notation and expressions, connecting various function representations, and understanding the characteristics and management of functions (Parhizgar et al., 2022; Walde, 2017). The inability to grasp this idea thoroughly causes three problems: first, difficulties with understanding later concepts such as limits, derivatives, or integrals; second, doubts about the function's relevance to other areas of study or future careers; and third, a lack of interest and motivation to learn the concept because of the wasted potential it seems to have (Trujillo et al., 2023).

One of the efforts that can be made to overcome this problem is through the use of digital teaching materials that are appropriate, relevant, and in accordance with the needs of mathematics learning (Hidayat et al., 2022). Types of digital teaching materials to prepare for mathematics learning such as electronic student worksheets (Hidayat et al., 2025). Within this framework, digital learning aids such as electronic student worksheets are feasible (Hidayat et al., 2025). To get students more involved in what they are studying, teachers are using electronic student worksheets (Esen et al., 2023; Hidayat & Aripin, 2023; Ramlah et al., 2023) and facilitate interactive and independent learning (Susanti & Wulandari, 2022; Widjajanti et al., 2023). The use of electronic student worksheets also helps teachers in managing learning, facilitating concept discovery, developing process skills and scientific attitudes, and monitoring the achievement of student learning objectives (Kurniansyah et al., 2022; Pertiwi et al., 2020; Purnomo et al., 2024; Rohaeti et al., 2023). Several things that need to be considered in compiling teaching materials include the material and problems presented that are related to the environment or context of activities around students (Hendriana et al., 2019). Relevant to this is the use of the RME approach or *Pendidikan Matematika Realistik Indonesia*. RME or the Indonesian adaptation of PMRI which emphasizes the relevance of mathematics to everyday life by using real problems (Van den Heuvel-Panhuizen & Drijvers, 2020; Wijaya et al., 2018), included in the local cultural context in Indonesia (Prahmana et al., 2020). In PMRI, principles and characteristics are explicitly integrated through contextual activities that guide

students from informal reasoning to formal mathematical representations (Putri et al., 2022). In this way, learning becomes more meaningful, focused, and easier for students to understand.

Besides that, Siligar et al (2025) It is claimed that by incorporating local cultural context into the RME learning method, students can find mathematics more relevant and meaningful, and it can also help them understand the material better when they reach a formal level of understanding. Adha et al (Adha et al., 2024) also stated that RME is an effective pedagogical strategy that facilitates students' development from concrete to abstract mathematical concepts. Context problems in RME function to support the reinvention process, namely helping students build formal mathematics from situations that are meaningful and experienced by students (Gravemeijer & Doorman, 1999). One of the contexts used is the local cultural context of the city of Lubuklinggau, namely *Mandi Kasai*, where this context is the starting point for students to move towards formal understanding. (Juandi et al., 2022; Purwasi et al., 2025). Local cultural context is a cultural identity, creating a more meaningful learning environment (Dhema et al., 2025). Apart from that, facts on the ground show that the integration of local culture in mathematics learning in the Lubuklinggau region is still not optimal (Luthfiana & Fitriyana, 2025). Therefore, the *Mandi Kasai* is explored as a context to relate to the topic of relationships and functions. Therefore, the *Mandi Kasai* ritual was chosen as a local cultural context in learning about relationships and functions because it has a conceptual fit with the characteristics of the material. *Mandi Kasai* contains elements of activities, stages, actors, equipment, and relationships between objects that can be represented in the form of ordered pairs, correspondences, relations, and functions. These connections make *Mandi Kasai* more operational in helping students connect abstract mathematical concepts with cultural experiences close to their lives. The *Mandi Kasai* ritual is a sacred and unique tradition native to Lubuklinggau City, South Sumatra, involving the ritual of bathing newlyweds in a river. This cultural practice, which has been passed down through generations since the time of the Palembang Sultanate, symbolizes self-purification, the release of singlehood, and mental preparation before embarking on the journey of marriage (Friansah et al., 2023; Isbandiyah & Supriyanto, 2023). So this context will be the starting point in understanding the concrete situation in the content of relations and functions.

Previous research shows that RME-based electronic worksheets use various contexts of activities around students in mathematics learning, Johar et al. (2025) Electronic worksheets using the context of Islamic values can support students' mathematical knowledge and communication; E-Worksheet Based on RME with the Context of *Kawai Kanduk Ogan Komering Ulu* (OKU) Selatan (Erwansyah et al., 2025). Putri et al. (2025) electronic worksheet based on the Ethno RME approach by incorporating the context of the Mayang Rontek Dance. Next, Sari et al. (2023) related to electronic worksheets based on RME in supporting students' mathematical literacy electronic worksheets based on ethno RME using the context of the *Kudus* tower (Sari et al., 2024). These studies demonstrate that RME-based e-worksheets can integrate religious, cultural, and ethnomathematics contexts into mathematics learning. However, the primary focus of these studies is still limited to the use of context as a learning setting, while the specific fit between cultural activities and the conceptual structure of specific mathematical materials has not been adequately studied. A critical comparison of previous research shows that each context contributes differently. The context of Islamic values strengthens the affective and communication dimensions of mathematics, local traditions such as *Kawai Kanduk* and the *Mayang Rontek* Dance support cultural recognition, while the context of *Kudus* tower contributes to ethnomathematics exploration. However, these studies have not explicitly demonstrated how living local cultural practices can be transformed into learning activities that represent ordered pairs, correspondences, relations, and functions.

However, most of this research has yet to explore the local cultural context that is still preserved from generation to generation, such as the *Mandi Kasai* tradition in Lubuklinggau City.

This context has high cultural value and real activities that can be observed by students, thus potentially increasing the meaningfulness of mathematics learning. Therefore, an intervention is needed in the form of designing RME based electronic worksheets with the *Mandi Kasai* context, while also exploring how this context can improve students' mathematical thinking skills and adapt to their needs and characteristics. This study aims to develop a PMRI-based e-worksheet by integrating the cultural context of *Mandi Kasai* into the topic of relations and functions. The developed product is intended as a digital teaching material evaluated in terms of validity, practicality, and effectiveness in supporting students' understanding of relations and functions. The contribution of this study lies not merely in introducing *Mandi Kasai* as a cultural context, but also in linking the structure of this cultural practice to the characteristics of relations and functions through PMRI principles. Thus, this study extends previous research on PMRI-based e-worksheets by demonstrating how a local cultural context can be systematically transformed into contextual, visual, and meaningful mathematics learning activities. The scope of this study is limited to the development and quality testing of the e-worksheet, particularly its validity, practicality, and effectiveness in supporting students' understanding of relations and functions.

LITERATURE REVIEW

RME or PMRI teaches students that mathematics is essentially an interpersonal skill (Van den Heuvel-Panhuizen & Drijvers, 2014). PMRI developed as an adaptation of RME in the Indonesian educational context, so the selection of learning contexts needs to consider proximity to students' experiences and the characteristics of the mathematical concepts being studied (Zulkardi et al., 2020a). Learning mathematical ideas becomes more relevant and easier to understand when students are able to connect them to real-life events through the use of context in RME (Van den Heuvel-Panhuizen & Drijvers, 2014). The five characteristics of RME are as follows: contextualization, model-based teaching, student-initiated construction and production, interaction, and interconnectedness (Treffers, 1987). Furthermore, the PMRI Principles refer to the basic foundations that guide how learning is designed. There are three main principles in PMRI: first, guided reinvention and progressive mathematization; didactical phenomenology and self-developed models (Gravemeijer, 1994)

In practice, the characteristics and principles of PMRI can be integrated into teaching materials. Sembiring, Hadi, and Dolk also emphasized that developing PMRI-based teaching materials is a crucial component in supporting the success of realistic mathematics learning in the classroom (Sembiring et al., 2008). Zulkardi and Putri (2010) demonstrated that developing PMRI-based teaching materials can help students develop a more meaningful understanding of concepts because the material is structured through contexts and activities close to students' lives. Several studies have shown that RME-based learning can support students' cognitive achievement, problem-solving skills, critical thinking, and mathematical abilities when implemented through systematically designed activities and teaching materials (Laurens et al., 2018; Lestari et al., 2023; Sutarni et al., 2024).

The development of learning technology then opens up opportunities to develop PMRI teaching materials in electronic form, one of which is through e-worksheets. E-worksheets allow PMRI principles and characteristics to be presented more interactively through context exploration, activities, visual representations, guided questions, and learning feedback. Several studies also support the relevance of developing e-worksheets and RME/PMRI-based worksheets. Lestari et al. (2023) showed that RME-based worksheets can be developed in a valid, practical, and effective manner to support students' critical thinking skills. Sutarni et al. (2024) also showed that the RME-based worksheets they developed met the aspects of validity, feasibility, and effectiveness in improving students' mathematical abilities. Meanwhile, Sari et al. (N. Sari et al., 2023) developed

RME-based e-worksheets to support junior high school students' mathematical literacy, and Widyawati et al. (2024) emphasized the importance of multi-representation e-worksheets in helping students understand mathematical concepts through visual, symbolic, and verbal representations. These findings reinforce the need to design PMRI-based e-worksheets as digital teaching materials that incorporate meaningful context, exploratory activities, visual representations, guided inquiry, interaction, and learning evaluation.

The use of local cultural context in PMRI-based e-worksheets is theoretically grounded in ethnomathematics studies. D'Ambrosio (1985) explains that ethnomathematics connects mathematics with the practices, history, and culture of a community. Similarly, Bishop (1988) asserts that cultural activities incorporate universal mathematical practices, such as counting, measuring, placing, designing, playing, and explaining. In the context of PMRI, local culture is not simply positioned as an illustration but must have didactic potential to guide students in the mathematical concepts being learned. Prahmana et al. (Prahmana et al., 2020)demonstrated that the development of RME/PMRI in Indonesia emphasizes the connection between mathematics, reality, and students' experiences. This is reinforced by Lidinillah et al. (2022) , who found that the integration of ethnomathematics in mathematics learning can be achieved through various approaches, including RME. Meanwhile, Leton et al. (2025)demonstrated that local wisdom-based teaching materials can make mathematics learning more relevant and support students' mathematical literacy. Based on this foundation, the *Mandi Kasai* cultural context was chosen in this study not only for its cultural values, but also because it contains activities, stages, participants, equipment, and relationships between objects that can be represented mathematically. These elements can be linked to the material on relationships and functions through observation activities, object grouping, sequential pairing, relationship mapping, and conceptual generalization. Thus, the local cultural context serves as a didactic tool that connects concrete experiences.

METHOD

Research Design

This research is a research and development (R&D) study using the ADDIE model. R&D research was chosen because it aims to produce and test the quality of a learning product in the form of a PMRI-based e-worksheet within the *Mandi Kasai* cultural context. The ADDIE model consists of five stages: analyze, design, develop, implement, and evaluate. This model is used because it provides a systematic, flexible, and appropriate development procedure for designing, developing, implementing, and evaluating learning tools (Branch, 2009). In the analyze stage, researchers analyzed learning needs, student characteristics, material relationships and functions, and the relevance of the *Mandi Kasai* cultural context. In the design stage, researchers designed the e-worksheet structure, learning activities, assessment instruments, and product appearance. In the develop stage, the product design was developed and validated by material experts, media experts, and linguists. In the implement stage, the e-worksheet was applied in learning to assess its implementation and user response. In the evaluate stage, researchers assessed the product quality based on validity, practicality, and effectiveness.

Participant

Participants in this study were eighth-grade students of SMP Negeri 4 Lubuk Linggau City. A small-group trial involving six students with heterogeneous abilities and one mathematics teacher was conducted to obtain initial data on the product's practicality. A large group trial involving 30 students was conducted to assess the use of e-worksheets in learning. Product validation was conducted by three validators: a language, a media expert, and a content expert.

Instrument

The research instruments consisted of an expert validation sheet, a practicality questionnaire, and a learning outcome test. The expert validation sheet covered material, media, and language aspects to assess the feasibility of the developed e-worksheet. The practicality questionnaire was administered to teachers and students to determine the e-worksheet's ease of use, readability, and implementation in learning. Meanwhile, pretest and posttest instruments were used to measure the e-worksheet's effectiveness in facilitating students' understanding of relations and functions.

Procedure

This research procedure uses the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. In the analysis stage, researchers identified learning needs, curriculum suitability, and student characteristics, such as initial abilities, learning styles, interests, levels of understanding, and learning difficulties. The analysis results were used as the basis for designing an e-worksheet that met student needs and learning objectives. In the design stage, researchers drafted the e-worksheet, including content structure, activity flow, product display, and research instruments. The instruments developed included validation sheets from subject matter experts, language experts, and media experts. Next, in the development stage, the product design was developed into an initial e-worksheet, which was then validated by experts. The validators' suggestions and input were used to revise the product until it was deemed feasible. Afterward, practicality testing was conducted through teacher feedback and small group trials. In the implementation stage, the e-worksheet was implemented in learning through a field trial in one class. This stage aimed to determine the feasibility of the product's use and obtain data on student learning outcomes. In the evaluation stage, researchers conducted formative evaluations at each stage of development and summative evaluations at the end of the study. This evaluation aims to ensure that the developed e-worksheets meet the criteria of being valid, practical, and effective for use in learning. Thus, this research procedure ensures that each stage of product development and evaluation is carried out systematically, in a directed and comprehensive manner, as can be seen in Figure 1.

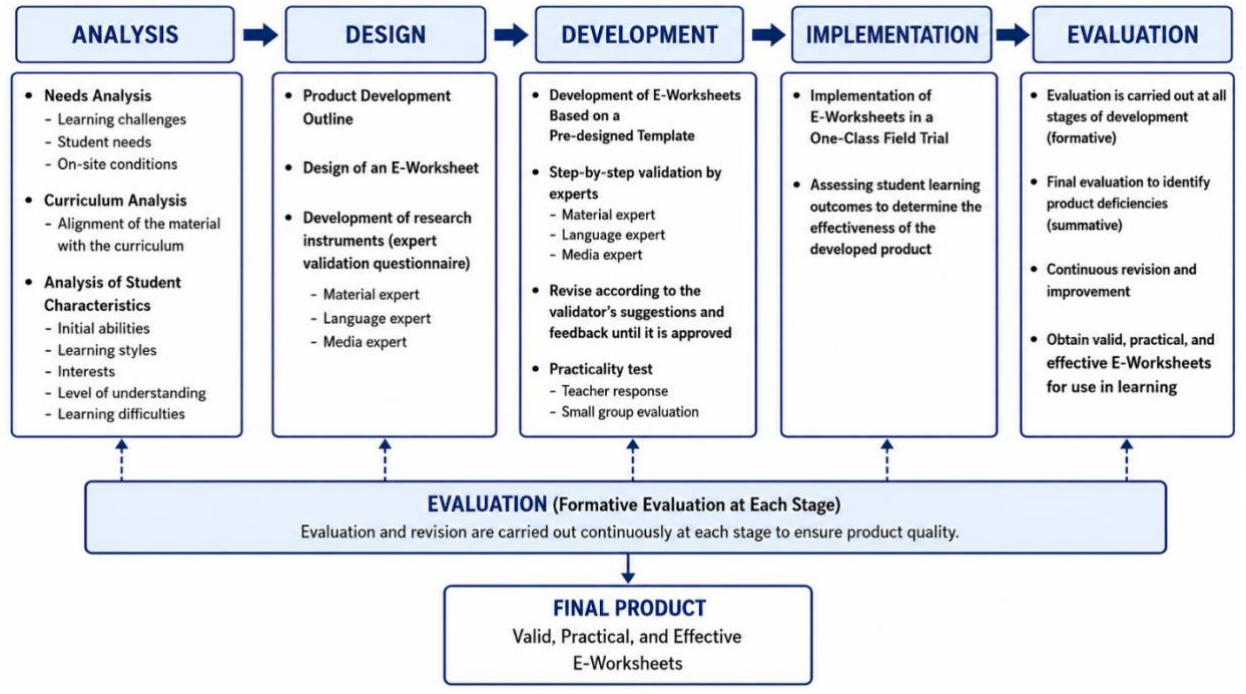


Figure 1. Research Procedure Flow

Data Analysis

Data analysis in this study used a descriptive quantitative approach. Validation data were obtained through a validation and practicality questionnaire using a Likert scale with a score range of 1 to 5, ranging from poor to very good for the validation sheet and strongly disagree to strongly agree. The validation and practicality data were then analyzed descriptively. The formulas used to calculate the validity and practicality values are as follows.

$$Value = \frac{\text{Total scores obtained}}{Total\ score} x\ 100\%$$

The results of the analysis were then interpreted based on the product validity categories presented in Table 1.

Table 1. Validity Category

Validity Value (%)	Category
80 < V ≤ 100	Very Valid
60 < V ≤ 80	Valid
40 < V ≤ 60	Quite Valid
20 < V ≤ 40	Invalid
0 < V ≤ 20	Very Invalid

Source: (Hidayat & Linda, 2023)

Thus, a PMRI-based e-worksheet with the *Mandi Kasai* cultural context is declared valid if it obtains a validity value of more than 60%.

Table 2. Practicality Category

Practical Value (%)	Category
80 < P ≤ 100	Very Practical
60 < P ≤ 80	Practical
40 < P ≤ 60	Quite Practical
20 < P ≤ 40	Impractical
0 < P ≤ 20	Very Impractical

Source: (Hidayat & Linda, 2023)

Thus, the PMRI-based electronic worksheet with the *Mandi Kasai* cultural context is declared practical if it obtains a practicality value of more than 60%. Effectiveness data analysis was obtained from student pretest and posttest results. The pretest was administered before using the e-worksheet, while the posttest was administered after students participated in learning using the developed e-worksheets. A comparison of the two test results was used to determine improvements in student learning outcomes after using the product. The effectiveness of the e-worksheet was analyzed using the N-Gain formula as follows.

$$Normalized\ Gain\ (g) = \frac{SPost - SPre}{Sm\ ideal - Spre}$$

The effectiveness category of the e-worksheets developed can be seen in Table 3.

Table 3. Effectiveness Categories

N-gain Value	Criteria
g > 0.7	High
0.3 < g ≤ 0.7	Medium
g ≤ 0.3	Low

Source: (Nissen et al., 2018)

The N-Gain table shows how much improvement in learning outcomes students achieve compared to the maximum possible improvement. A product is considered effective when the N-Gain is $0.3 < g \leq 0.7$ or $g > 0.7$.

RESULTS AND DISCUSSION

Results

In terms of effectiveness, e-worksheets have been proven to improve student learning outcomes. Evaluation results showed that the total pretest score obtained by 30 students was 491, while the total posttest score increased to 2,175. Analysis using the N-Gain index resulted in a value of 0.67, which is included in the moderate category, indicating a 67% increase in learning outcomes after using e-worksheets in the learning process. The components contained in the PMRI-based e-worksheet developed in the context of *Mandi Kasai* consist of 1. Title that shows the identity and topic of the material discussed, 2. Learning instructions, 3. Learning objectives, 4. Supporting information in the form of a short summary of the material, 5. Tasks and work steps that contain activity instructions or sequences of activities, 6. Tasks as an assessment that functions to measure the extent of student understanding after completing the entire series of activities in the e-worksheet. Several components make into the electronic student worksheet's original design, including.

1.1 Cover

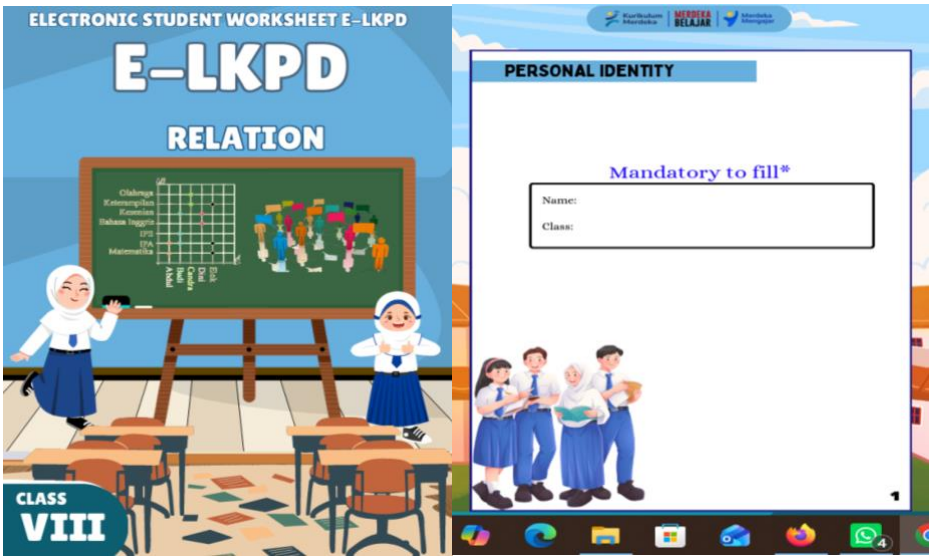
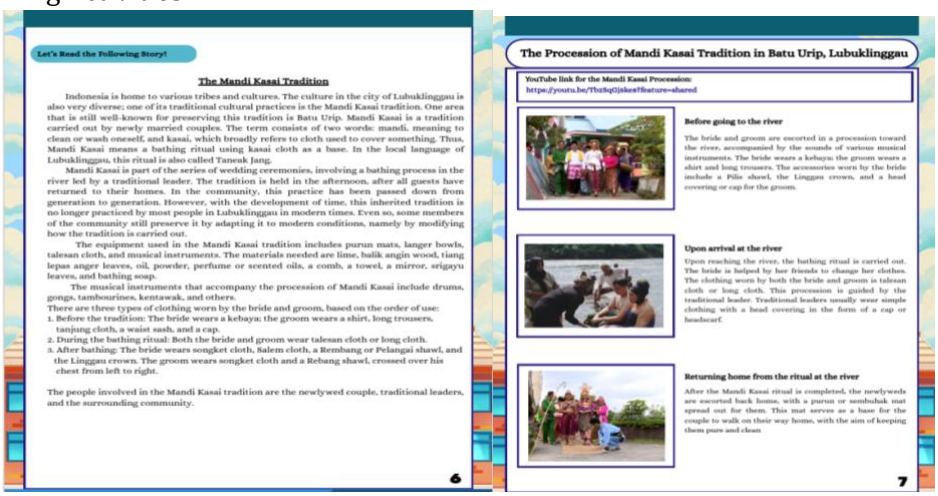


Figure 2. Cover page and student identity

1.2 Learning Activities



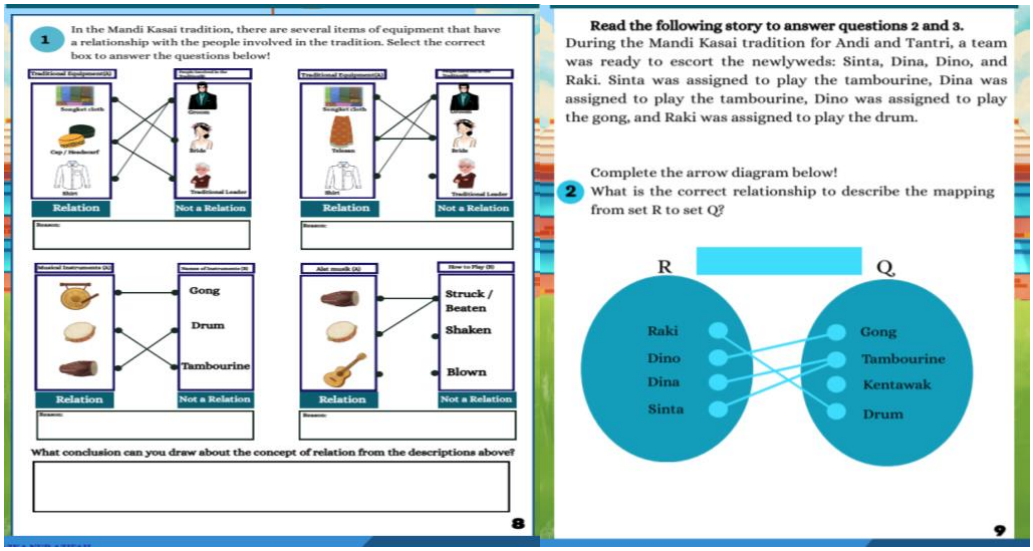


Figure 3. Learning Activities

Each validation process was followed by revisions based on the validators' suggestions and input until the developed electronic worksheets were declared valid. Table 5 displays the findings of the expert validation.

Table 4. Language Feasibility Aspects

Number	Assessment Indicators	Score Obtained
1	The developed e-worksheet has straightforward language.	15
2	The developed e-worksheet is communicative.	5
3	The language used in the dialogic and interactive e-worksheet is appropriate.	5
4	The developed e-worksheet is suitable for student development.	13
5	The developed e-worksheet complies with language rules.	20

Table 4 shows that the total score obtained was 58 out of a maximum score of 60. So the percentage of validity value was 96%, indicating that the aspects assessed were in the very valid category.

Table 5. Feasibility of Graphics by Media Experts

Number	Assessment Indicators	Score Obtained
1	Size of the developed e-worksheet	9
2	Developed e-worksheet cover design	33
3	Developed e-worksheet design	79

Table 5 shows that the total score obtained was 121 out of a maximum score of 130. So the percentage of validity value was 93%, indicating that the aspects assessed were in the very valid category.

Table 6. Results of Validation by Material Experts

Number	Assessment Indicators	Score Obtained
1	The e-worksheet material aligns with the learning outcomes.	13
2	The e-worksheet material is accurate.	18
3	The e-worksheet material is up-to-date.	10
4	The developed e-worksheet encourages curiosity.	9
5	The presentation techniques in the e-worksheet are easy to understand.	5
6	The components contained in the e-worksheet support the presentation.	14
7	The presentation of learning contained in the e-worksheets is easy to understand.	4
8	Assessment of the material contained in the e-worksheet.	32

Table 6 shows that the total score obtained was 105 out of a maximum score of 115. So the percentage of validity value was 91%, indicating that the aspects assessed were in the very valid category. The recapitulation of the practicality test results at the implementation stage can be seen in Table 7.

Table 7. Summary of Results and Practicality Categories

Subject	Practicality (%)	Category
Lecturer	89.33%	Very Practical
Students (6 People)	93.34%	Very Practical

Based on the interpretation of the results in the table above, it can be seen that the developed e-worksheets were categorized as very practical, according to both lecturers and students. This indicates that the e-worksheets are easy to use, have clear instructions, and are tailored to user needs, allowing them to be implemented in learning without significant obstacles. Therefore, the developed e-worksheets meet the criteria for practicality and are suitable for use as a learning medium. Branch (2009) conducted a practicality test in the evaluation phase through a limited-scale formative evaluation involving six students. Although this number is relatively small, this phase aimed to obtain initial input as a basis for refining the e-worksheets before wider implementation. The limited number of respondents was part of the initial trial design and not intended to generalize the final results. Recapitulation of Student Learning Outcomes at the implementation stage can be seen in table 8.

Table 8. Summary of Student Learning Outcomes

Number	Component	Value
1	Pretest Score	491
2	Posttest Score	2175
3	N-Gain	0.67
4	Percentage Increase	67%

Based on the results of the N-Gain calculation, the pre-test score of 30 students was 491 and the post-test score was 2175. The analysis results showed an N-Gain value of 0.67, which is in the moderate category. This finding indicates that the use of the developed e-worksheets is quite effective in improving student learning outcomes. The improvement that occurred shows that students experienced a development in understanding after participating in the learning process using the developed e-worksheets.

Discussion

The main problem underlying this research is the lack of teaching materials that integrate local wisdom, even though education and culture are inseparable, complementing each other and revitalizing each other (Manapa, 2021). One form of local culture of the Lubuklinggau community is the *Mandi Kasai* tradition, a self-purification procession that embodies religious values, cooperation, mutual assistance, responsibility, respect for cultural traditions, courtesy, social awareness, honesty, peace-loving, and self-confidence. These values align with the dimensions of the Pancasila Student Profile in the Independent Curriculum, making *Mandi Kasai* not merely an object of cultural introduction, but a source of relevant character values integrated into learning through a contextual approach.

In the *Mandi Kasai* procession, several main elements are systematically interrelated: the participants, the traditional equipment, the stages of implementation, and the symbolic meaning of each item used. The set of traditional equipment (flower water, plain flour, setawar leaves, seding leaves, and water containers) can be paired with their corresponding symbolic meanings; the set of procession participants (bride and groom, parents, traditional elders, and emcee) can be paired with their respective duties; and the set of procession stages (preparation, sprinkling, prayer recitation, closing) can be paired with the activities that occur at each stage. These three forms of pairing

mathematically represent the concept of relationships, namely the relationship between members of one set and members of another set. This can be presented in the form of arrow diagrams, ordered pairs, or Cartesian diagrams. Furthermore, the context of *Mandi Kasai* is also relevant for introducing the concept of function. Each actor in the procession has one main task attached to it, the traditional elder leads the prayer, the parents do the watering of the flowers, the master of ceremonies guides the procession, and the bride and groom follow the entire series of ceremonies, so that each member of the domain (actor) is paired with exactly one member of the codomain (task). This condition fulfills the formal definition of function, namely a special relationship that maps each member of the domain to exactly one member of the codomain. Through this concrete experience, students not only know the definition of relations and functions in the abstract, but also can distinguish between the two based on real situations that they observe directly.

This finding confirms that local wisdom, such as the *Mandi Kasai* tradition, can function as an effective contextual bridge for learning abstract mathematical concepts, as well as being an alternative model for developing teaching materials that combine academic achievement with the preservation of cultural values. This finding supports Nieveen's (1999) opinion, validity, practicality, and effectiveness are the three pillars that form the basis for developing high-quality products. The validity of the teaching materials obtained in this study cannot be separated from the application of PMRI which places the real context as the starting point for learning so that students can build their own mathematical understanding through the mathematization process (D. O. P. Putra & Purnomo, 2023; Zakaria & Dewantara, 2024; Zulkardi et al., 2020b). This principle is also in line with the characteristics of PMRI which emphasizes the use of context, models, student contributions, interactivity, and the relationship between mathematical concepts (Treffers, 1987; Van den Heuvel-Panhuizen & Drijvers, 2014). Thus, the cultural context of Mandi Kasai functions as a medium that facilitates students in constructing concepts of relations and functions gradually from concrete situations to formal representations. The findings of this study are in line with research Johar et al. (2025) This demonstrates that students' mathematical abilities can be enhanced through the integration of ethnomathematics and the Realistic Mathematics Education approach. This is achieved through the implementation of learning activities that are deeply rooted in the local cultural context, thus making mathematical concepts more accessible and meaningful. Besides that, Nursyahidah et al (2025) found that the integration of ethnomathematics, digital technology, and RME helped students build connections between cultural experiences and mathematical reasoning while improving numeracy skills through contextualized learning activities. These findings reinforce the view that mathematics learning will be more effective when students are given the opportunity to connect formal concepts with their real-life experiences. (Asyari et al., 2025; Gravemeijer & Doorman, 1999; R. W. Y. Putra et al., 2024)

The findings of this study are also supported by Nur Atikasari et al (2024) who found that the use of ethnomathematics-based E-Worksheets was able to improve students' creative thinking skills through contextual and relevant learning experiences. T. A. Putri et al (2025) reported that the development of an Ethno-PMRI-based e-worksheet met the criteria for validity and effectiveness in improving students' understanding of mathematical concepts. Furthermore, (Maanana et al., 2023) explained that implementing the PMRI model can improve students' mathematical connection skills and interest in learning mathematics. Although similar research has been conducted frequently, the main difference in this study lies in the innovation of the context, media, and learning materials. Previous studies generally used everyday life contexts or general situations that did not specifically highlight local culture as a learning resource. In contrast, this study integrates *mandi kasai* culture as a learning context so that students can understand the concepts of relationships and functions through cultural experiences close to their lives. Furthermore, this study developed digital and interactive e-worksheets, whereas previous studies often used printed e-worksheets. From a

pedagogical perspective, this study emphasizes student-centered learning through exploration, discussion, and independent discovery of concepts in accordance with the characteristics of PMRI, while previous studies have not fully maximized the use of digital technology and local wisdom simultaneously. This shows that the integration of local culture into digital teaching materials is an effective strategy for creating contextual, meaningful, and student centered mathematics learning. Therefore, the integration of the RME approach, digital technology, and *Mandi Kasai* local wisdom with e-worksheets can be seen as an effective innovative strategy for realizing contextual, meaningful, student-centered mathematics learning, and in line with the demands of 21st century learning.

Implications

Based on the findings of this study, PMRI-based e-worksheets that incorporate the *Mandi Kasai* cultural background of PMRI can serve as a complement to digital based learning in mathematics education, allowing for more engaging, relevant, and student driven instruction. Teachers can apply the research findings through three concrete steps. First, teachers can identify local traditions or wisdom in their respective regions that have sequential or paired structures, such as traditional ceremonies, traditional games, or kinship systems, to be mapped into relevant mathematical concepts, as exemplified by the mapping of task actors and equipment, and the meaning of the *Mandi Kasai* tradition in this study. Second, teachers can follow the stages of developing PMRI-based teaching materials used in this study, namely starting learning from real contexts or cultural phenomena, guiding students to discover relationship patterns inductively, and then directing students to formal mathematical representations in the form of arrow diagrams, ordered pairs, or Cartesian diagrams. Third, teachers can replicate the e-worksheet format developed in this study, which includes cultural illustrations, step-by-step guiding questions, and concept mapping exercises, as a template for designing similar digital teaching materials for other mathematics materials in their own classes.

Limitations and Suggestions for Future Research

This study has several limitations. First, the product trial was conducted in only one school with a limited number of subjects, so generalizing the research results to a wider population still requires further study. Second, The developed e-worksheet only focuses on relation and function material, so it cannot be ascertained whether the integration of *Mandi Kasai* local wisdom is also effective when applied to other mathematical topics that have different conceptual characteristics. because the success of this approach rests on the suitability between the structure of cultural elements such as actors, equipment, stages of the procession with the structure of mathematical concepts that are relational and functional, while other topics such as algebra, geometry have different concepts. Therefore, generalizing this approach to other mathematical topics requires readjustment to the mapped cultural elements, and its effectiveness cannot be assumed to be the same without further testing. Based on the research results, the PMRI e-worksheet with the *Mandi Kasai* cultural context shows potential as an alternative digital teaching material that can support more contextual and meaningful mathematics learning. However, considering that this research is still limited to a specific cultural context and location, it is recommended that teachers do not immediately implement it widely, but rather consider further testing and validation based on different student characteristics, cultural contexts, and school environments. Thus, teachers and researchers can make the necessary adjustments to make these e-worksheets more adaptive and applicable before being implemented more widely in learning practices. Future researchers can conduct trials on a wider range of schools and diverse student characteristics to obtain a better level of generalizability. Further research is needed to examine the long-term impact of e-worksheets on critical thinking, problem-solving, creativity, and student retention, using longitudinal designs, such

as delayed testing after a certain period of time, to determine the durability of the effects. Furthermore, comparative research comparing *Mandi Kasai based* e-worksheets with other teaching materials, both culturally diverse and conventional, is needed to ensure that the improvement in learning outcomes is truly due to the contextual-cultural approach.

CONCLUSION

This study produced PMRI-based e-worksheets using the *Mandi Kasai* cultural context on the relationship and function material developed through the ADDIE model. The results of the study indicate that the developed e-worksheets meet the criteria of validity, practicality, and effectiveness. The validity aspect is demonstrated by the results of expert assessments stating that the developed e-worksheets are in accordance with the characteristics of the material, learning objectives, PMRI principles, and the rules for compiling digital teaching materials. The practicality aspect is demonstrated by the positive response of students to the use of e-worksheets in the learning process. Meanwhile, the effectiveness aspect is seen from the increase in student learning outcomes after using the developed e-worksheets. Although this increase is still descriptive based on a comparison of scores before and after use, further study with inferential statistical testing is needed to strengthen the conclusion regarding the significance of the increase. Overall, the results of this study indicate that PMRI e-worksheets with *Mandi Kasai* culture are suitable for use as an alternative digital teaching material in mathematics learning, especially on the relationship and function material, because they are able to integrate local wisdom values with a contextual and meaningful learning approach.

AUTHOR CONTRIBUTIONS STATEMENT

Idul Adha contributed to the conceptualization of the study, research design, development of the PMRI-based e-worksheet, data collection, data analysis, interpretation of the findings, and preparation of the original manuscript. Anna Fauziah contributed to the research methodology, validation process, data interpretation, and critical revision of the manuscript. Azka Nur Azifah contributed to the development of the research instruments, implementation of the learning activities, data collection, and manuscript editing. Rani Refianti contributed to the validation of the instructional content, review of the PMRI framework and the integration of the Mandi Kasai cultural context, and critical review of the manuscript. Lucy Asri Purwasi supervised the overall research process, provided methodological and academic guidance, contributed to the interpretation of the findings, and critically reviewed and approved the final version of the manuscript. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

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