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Indonesian Realistic Mathematics Education-Based Interactive Digital Worksheets: Enhancing Fractions and Numeracy in Primary Education

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Abstract

Primary school pupils' difficulties in understanding the concept of fractions through conventional textbooks highlight the need for interactive and contextual teaching materials to strengthen numeracy. This study aims to develop and test the validity, practicality, and effectiveness of interactive digital worksheets (E-LKPD) based on Indonesian Realistic Mathematics Education (PMRI) for the topic of fractions. The research employed a research and development method using the ADDIE model, comprising the analysis, design, development, implementation, and evaluation stages. The research instruments consisted of a needs analysis questionnaire, an expert validation sheet, a practicality questionnaire, and a learning outcome test. The research results indicate that the E-LKPD falls into the 'valid' category, with content expert ratings of 78%, media expert ratings of 94.2%, and language expert ratings of 95.8%. Usability also falls into the 'very high' category, with a percentage of 89.25% in the one-to-one test and 87.25% in the small-group test. The effectiveness of the E-LKPD is demonstrated by an N-Gain value of 0.66, which falls into the moderate category. These findings indicate that the PMRI-based interactive E-LKPD is suitable for use as digital teaching material to strengthen primary school pupils' understanding of fractions and numeracy skills.

INTRODUCTION

Background of the Study

Numeracy is an essential competence that primary school pupils must master to support logical thinking, problem-solving, and decision-making in daily life (Hikamudin et al., 2023; Iswara et al., 2022). However, mathematics learning in primary schools, particularly regarding fractions, still faces various challenges due to the abstract and context-poor presentation of the material in conventional textbooks (Diputra et al., 2023; Fauzi & Suryadi, 2020; Unaenah et al., 2023). This situation causes pupils to struggle to relate the concept of fractions to real-life experiences, thereby leading to poor conceptual understanding and numeracy skills (Bal İncebacak & Ersoy, 2022; Poluakan et al., 2024). In fact, the concept of fractions is a crucial foundation for advanced mathematics learning (Amo-Asante & Bonyah, 2023; Karika & Csíkos, 2022; Pedersen & Bjerre, 2021; Ubah, 2021). Advances in educational technology have enabled the development of interactive, student-centred digital teaching materials (Sakinah et al., 2023). Consequently, the innovation of technology-based teaching materials that are contextual and meaningful has become crucial in mathematics learning in primary schools.

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The Indonesian Realistic Mathematics Education approach is important to apply in the teaching of fractions as it emphasises the use of real-life contexts that are relevant to pupils' lives. Through this approach, pupils do not merely memorise procedures, but are able to understand the concept of fractions in a meaningful way through direct experience. PMRI helps to make abstract material more concrete, thereby enhancing students' conceptual understanding and numeracy skills. Furthermore, E-LKPD is considered suitable for strengthening numeracy in fraction-related material as it offers interactive, visual, and contextual learning. With technological support, E-LKPD can help students understand fraction concepts through clearer representations, whilst also boosting motivation and independent learning.

Problem of the Study

The main problem in this study is the low level of conceptual understanding and numeracy skills among primary school pupils regarding fractions, due to a lack of interactive and contextual teaching materials. Initial findings from the analysis stage indicate that the teaching materials used in schools are still dominated by conventional textbooks and printed worksheets, which emphasise calculation procedures without linking the concept of fractions to everyday contexts. Interviews with teachers revealed that pupils tend to memorise the steps to solve problems without understanding the conceptual meaning of fractions. Furthermore, an analysis of the curriculum and learning resources highlighted the limited integration of contextual numeracy activities within the teaching materials used. This situation leads to low levels of active student engagement in learning and difficulties in applying fraction concepts to real-life situations. Therefore, there is a need to develop innovative digital teaching materials capable of supporting meaningful and contextual learning of fractions.

Furthermore, the results of journal article analysis indicate that students' low numeracy skills are also influenced by the lack of integration of contextual activities in teaching materials and the minimal use of learning technology. Research by Hidayati et al. (2023) and Sakinah et al. (2023) shows that interactive digital teaching materials can significantly enhance student engagement and understanding of mathematical concepts. Meanwhile, Ihwan & Rusnilawati (2025) and Iswara et al. (2022) emphasise that strengthening numeracy requires learning that links mathematical concepts to real-life situations to make them more meaningful. However, in reality, the teaching materials used in schools do not yet fully support this. Therefore, there is a need to develop innovative digital teaching materials capable of integrating contextual approaches and technology to optimally improve students' understanding of fraction concepts and numeracy skills.

Research's State of the Art

Previous research indicates that interactive digital teaching materials have the potential to improve motivation, engagement, and learning outcomes among primary school pupils (Desyandri et al., 2021; Muthanga et al., 2023; Susanti et al., 2022). The Indonesian Realistic Mathematics Education (PMRI) approach, rooted in Realistic Mathematics Education (RME), emphasises the use of real-life contexts as a starting point for mathematics learning, thereby helping pupils build conceptual understanding (Edwar et al., 2023; Meidiana et al., 2021; Syutaridho et al., 2023). A number of studies report that the use of PMRI can improve primary school pupils' understanding of mathematical concepts and problem-solving skills (Astriani et al., 2023; Purwanti, 2020). Furthermore, the development of digital-based worksheets is considered effective in promoting independent and interactive learning (Anggereni et al., 2022; Khoiri, 2023). However, most research still focuses on printed worksheets or simple digital media without fully integrating the PMRI principles. Consequently, the development of interactive E-LKPDs systematically designed based on the PMRI principles still requires further study.

The Indonesian Realistic Mathematics Education (PMRI) approach, which is rooted in Realistic Mathematics Education (RME), emphasises the use of real-life contexts as the starting point for learning mathematics (Meidiana et al., 2021; Putri et al., 2025). PMRI has key characteristics, namely the use of contextual problems, models as thinking bridges, active student participation, interactivity, and the interconnection between concepts. The PMRI process involves understanding contextual problems, solving problems using one's own strategies, discussing results, and drawing conclusions. Indicators of PMRI implementation are evident in students' ability to relate mathematical concepts to

real life and in improved conceptual understanding. The strength of PMRI lies in its ability to make learning more meaningful and to encourage students to actively construct their own knowledge (Purwanti, 2020).

Fractions are one of the fundamental concepts in mathematics, encompassing an understanding of parts of a whole, comparisons, and arithmetic operations involving fractions. The nature of this subject matter is abstract, thus requiring visual representations and real-world contexts to facilitate student understanding. Indicators of mastery of fractions include the ability to recognise fraction forms, compare, simplify, and perform arithmetic operations with fractions. In relation to numeracy, numeracy skills are defined as the ability to use number concepts and mathematical operations to solve problems in everyday life (Iswara et al., 2022). The characteristics of numeracy include the ability to think logically, analytically, and practically. Indicators include the ability to understand numerical information, interpret data, and make decisions based on calculations. The advantage of strengthening numeracy is that it helps students become better prepared to tackle real-world problems rationally. However, most research still focuses on printed worksheets or simple digital media without fully integrating PMRI principles. Consequently, the development of interactive PMRI-based e-worksheets on fractions to improve numeracy skills still requires further study.

Gap Study and Objective

Based on a literature review, various studies have examined the development of digital teaching materials and the application of contextual approaches in mathematics learning. Research by Desyandri et al. (2021), Sari et al. (2023), and Susanti et al. (2022) indicates that interactive digital teaching materials can improve student motivation and learning outcomes. Furthermore, Anggereni et al. (2022) reveal that the development of interactive E-LKPDs is effective in promoting independent learning and student engagement. However, these studies generally have not deeply integrated a contextual approach, particularly in linking mathematical concepts to students' real-life experiences. On the other hand, the implementation of Indonesian Realistic Mathematics Education has been extensively researched and proven to enhance students' conceptual understanding and mathematical problem-solving skills (Edwar et al., 2023). Nevertheless, the majority of these studies still focus on classroom implementation without being supported by the development of structured interactive digital teaching materials. Meanwhile, research on numeracy, as highlighted by Poluakan et al. (2024) and Sakinah et al. (2023) emphasises the importance of integrating real-world contexts in improving students' numeracy skills. However, studies that specifically combine numeracy, PMRI, and digital teaching materials remain very limited.

Consequently, there is a research gap: there remains a scarcity of studies that comprehensively develop PMRI-based interactive E-LKPDs and test their validity, practicality, and effectiveness in strengthening primary school pupils' numeracy, particularly regarding fractions. Furthermore, research explicitly linking contextual numeracy activities within PMRI-based E-LKPDs is also rarely found. Therefore, this study aims to develop PMRI-based interactive E-LKPDs using the ADDIE model and to test the quality of the resulting product. Specifically, this study is designed to answer the following research questions: (1) What is the level of validity of PMRI-based interactive E-LKPDs on the topic of fractions? (2) What is the level of practicality of PMRI-based interactive E-LKPDs based on user responses? and (3) How effective are PMRI-based interactive E-LKPDs in strengthening primary school pupils' understanding of fractions and numeracy skills? With the formulation of these research questions, it is hoped that this study will have a clear focus and make a significant contribution to the development of innovative digital teaching materials in primary schools.

METHOD

Type and Design

This study employs a research and development (R&D) methodology based on the ADDIE model, which comprises the stages of Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because of its systematic and iterative nature, making it suitable for the development and evaluation of interactive digital teaching materials. The analysis stage involves analysing learning needs, the characteristics of primary school pupils, and the curriculum relating to

fractions. The design stage covers the design of the structure of interactive E-LKPDs based on Indonesian Realistic Mathematics Education (PMRI), the compilation of fraction material, and the design of contextual numeracy activities. The development stage involves the creation of the interactive E-LKPD and validation by subject matter experts, media experts, and language experts. The implementation stage is carried out through a pilot study with primary school pupils, whilst the evaluation stage aims to assess the validity, practicality, and effectiveness of the developed product. This research involves human subjects, namely primary school pupils, and has obtained ethical approval from the relevant authorities under number 1492/UN9.FKIP/TU.SB5/2025. Informed consent was obtained before the data collection process.

Data and Data Sources

Data collection in this study was carried out in stages in accordance with the ADDIE model development process, so that the types and sources of data were tailored to the objectives of each stage of developing the interactive E-LKPD based on Indonesian Realistic Mathematics Education (PMRI). In the Analysis phase, data were obtained through a learning needs analysis by distributing questionnaires to 25 Year 3 pupils at a primary school in Air Balui, Sanga Desa Sub-district, as well as four Year 3 teachers from four different primary schools in Air Balui, Musi Banyuasin Regency. The data collected included quantitative data in the form of percentages from the student and teacher needs questionnaires, as well as qualitative data in the form of feedback regarding content, media, learning activities, and assessment. The results of this needs analysis were used as the basis for designing the content and layout of the E-LKPD.

During the Development phase, data was collected through expert validation to assess the suitability of the E-LKPD product. Validation was carried out by three experts—a subject matter expert, a media expert, and a language expert—using a 1–5 Likert scale validation sheet. In addition, a limited one-to-one trial was conducted with 3 students and a small-group trial with 8 students to obtain data on the clarity of the interface, ease of use, and comprehensibility of the E-LKPD instructions. Feedback from this stage was used as the basis for revising and refining the product prior to the implementation stage. During the Implementation phase, data was collected through the application of the E-LKPD in pilot classes. Learning outcomes were measured using pre-tests and post-tests. Furthermore, data on practicality was obtained through user feedback questionnaires and observations of student activities during lessons. In the Evaluation stage, data is analysed to assess the effectiveness of the PMRI-based interactive E-LKPD. The analysis focuses on improvements in student learning outcomes, calculated using N-Gain. The results of this analysis are used to determine the success of the E-LKPD in improving students' understanding of fraction concepts and numeracy skills. A summary of the types of data, data sources, and their intended uses is presented in Table 1.

Table 1. Types of Data, Data Sources, and Purpose of Use

Data Type	Data Format	Data Source	Purpose of Use
Quantitative data	Survey scores on the analysis of students' and teachers' needs	Students and class teachers	Identifying Learning Needs and the Basis for E-LKPD Design
Quantitative data	Expert validation scores (content, media, and language)	Expert validators	Determining the level of validity and suitability of the E-LKPD
Qualitative data	Suggestions and feedback from the expert validation	Expert validators	Basis for product revision and improvement
Quantitative data	Scores from one-to-one and small group trial questionnaires	Students	Measuring the clarity of instructions, understanding of the material, and practicality of using the E-LKPD
Quantitative data	Pre-test and post-test scores	Students in the pilot class	Measuring the effectiveness of E-LKPD through improvements in learning outcomes (N-Gain)

Data Type	Data Format	Data Source	Purpose of Use
Supporting data	Curriculum documents, syllabuses, and teaching materials	School	Supporting the analysis of learning needs and the suitability of learning materials

Table 1 illustrates the types of data, data sources, and their intended uses in the E-LKPD development research. Quantitative data were used to identify learning needs, assess product validity, and measure the effectiveness of the E-LKPD through pre-test and post-test scores. Qualitative data, comprising expert recommendations and the results of one-to-one and small-group trials, were utilised as the basis for revising and refining the product. In addition, supporting data from curriculum documents and learning resources were used to ensure the material's alignment with learning needs. Aside from the table, the data collection process in this study can be broadly illustrated as shown in Figure 1.

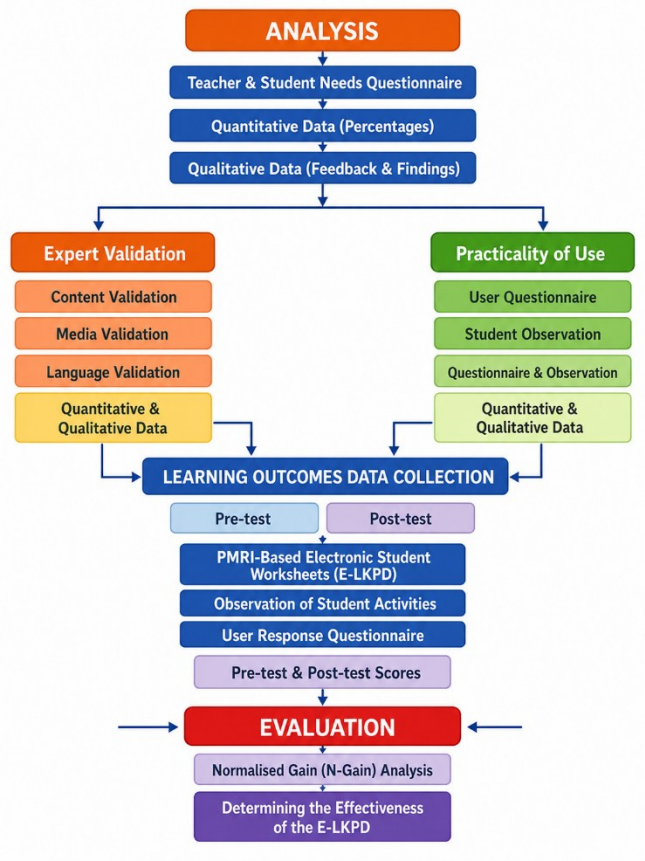

Figure 1. Research Data Collection Flowchart

Figure 1 outlines the research data collection procedure, which follows the stages of the ADDIE model. The process began with a needs analysis, using questionnaires distributed to both teachers and students to gather quantitative and qualitative information as a foundation for developing the E-LKPD. Expert validation and a practicality test were then conducted to assess the product's feasibility and ease of use. The final stage measured learning outcomes through pre-tests and post-tests, and these were subsequently analysed with N-gain calculations to determine the effectiveness of the PMRI-based E-LKPD.The data are facts or information used to discuss or determine the answer to a research question. The subjects from whom data can be collected for research are the study's data sources. The library's collection of books, audio, documents, and other printed materials can serve as a data source for the researcher.

Data Collection Technique

Data were gathered through several distinct procedures. Product validation data were obtained via expert validation sheets administered to three types of validators: subject matter experts, media

experts, and language experts. These validators were lecturers or education practitioners with academic backgrounds and experience in mathematics education, learning media, and linguistics. Each validator evaluated the E-LKPD on the dimensions of content suitability, media design, interactivity, and linguistic clarity, using a five-point Likert scale: excellent (5), good (4), adequate (3), poor (2), and very poor (1). Practicality data were collected through student response questionnaires during one-to-one and small-group trials, together with observation sheets that recorded student engagement while using the E-LKPD. Effectiveness data were obtained from learning outcome tests in the form of pre-tests and post-tests, administered before and after instruction with the PMRI-based interactive E-LKPD.

Data Analysis

The study examined the validity, practicality, and effectiveness of the interactive E-LKPD, which is rooted in PMRI. Validity data were analysed based on assessment scores supplied by three validators: a subject matter expert, a media expert, and a language expert. All of the validators possessed competence and experience in mathematics education, learning media, and linguistics. The assessment used a five-point Likert scale, with categories ranging from 'very good' (5) to 'very poor' (1). The evaluation considered how well the material met curriculum and learner needs, its design, interactivity, and the clarity of the language used. Validation scores were then analysed by calculating the percentage of validity using the formula.

$$Percentage = \frac{Score\ Obtained}{Total\ Maximum\ Score} \times 100\%$$

The resulting percentages were categorised according to the product suitability criteria presented in Table 2.

Table 2. Expert Validation Criteria

Achievement Score (%)	Validity Category
85,5% – 100%	Highly Valid
62,5% – 85,5%	Valid
43,5% – 62,5%	Less Valid
25% – 43,5%	Invalid

Table 2 displays the expert validation criteria used to determine the suitability of the E-LKPD based on the percentage of the score obtained. The range is divided into four categories, from invalid to highly valid, and serves as a reference for interpreting the validators' assessments of content, media, and language. By applying these criteria, decisions about revisions and the overall suitability of the product can be made in an objective and measurable manner. Practicality data were collected through student response questionnaires during one-to-one and small-group trials, and through observation sheets that recorded student engagement while using the E-LKPD. These instruments were designed to assess the clarity of the interface, ease of use, comprehensibility of instructions, and the level of student engagement throughout the learning process. Effectiveness data were gathered through learning outcome tests in the form of pre-tests and post-tests, administered before and after instruction with the PMRI-based interactive E-LKPD. Pre-test and post-test scores were analysed to measure improvements in student learning outcomes by means of N-gain calculations, using the formula:

$$N\text{-}gain = \frac{S_{posttest} - S_{pretest}}{S_{maksimum} - S_{pretest}}$$

The interpretation of the N-gain values followed the criteria shown in Table 3.

Table 3. N-gain Calculation Criteria

N-gain	category
N-gain > 0,70	High
0,30 ≤ N-gain≤0,70	Moderate
N-gain < 0,30	Low

Table 3 provides a framework for interpreting N-gain values when evaluating improvements in student learning outcomes after using E-LKPD. Values are categorised as high, moderate or low to denote the extent to which conceptual understanding and numeracy skills have been enhanced. Clearly, an elevated N-gain value indicates a more significant improvement in learning outcomes.

RESULTS

Results of the Needs Analysis

During the analysis phase, a learning needs assessment was conducted by means of administering a questionnaire to 25 third-grade pupils and four third-grade teachers in Air Balui, Musi Banyuasin Regency. The objective of the exercise was to ascertain the requirements of pupils and teachers with regard to teaching materials. For a comprehensive overview of the findings, please refer to Table 4.

Table 4. Results of the Student and Teacher Needs Analysis for the E-LKPD

Aspect of Needs Analysis	Percentage of Need (%)	Category
Conceptual Relevance	100%	Highly Needed
Need for Learning Media	97%	Highly Needed
Clarity and Ease of Presentation	100%	Highly Needed
Media Appearance and Design	98%	Highly Needed
Learning Motivation	100%	Highly Needed
Evaluation and Measurement of Understanding	100%	Highly Needed
Average	**99%**	**Highly Needed**

As demonstrated in Table 4, every aspect of the E-LKPD needs analysis was rated as highly necessary. Conceptual relevance, clarity and ease of presentation, learning motivation and evaluation and measurement of understanding each received 100%, signalling unanimous agreement on the importance of these elements in developing the E-LKPD. Learning media and their appearance and design likewise recorded very high percentages (97% and 98%, respectively), thus remaining firmly within the 'highly needed' category. With an overall average of 99%, the findings suggest that an interactive E-LKPD is urgently needed as a teaching resource to optimise learning.

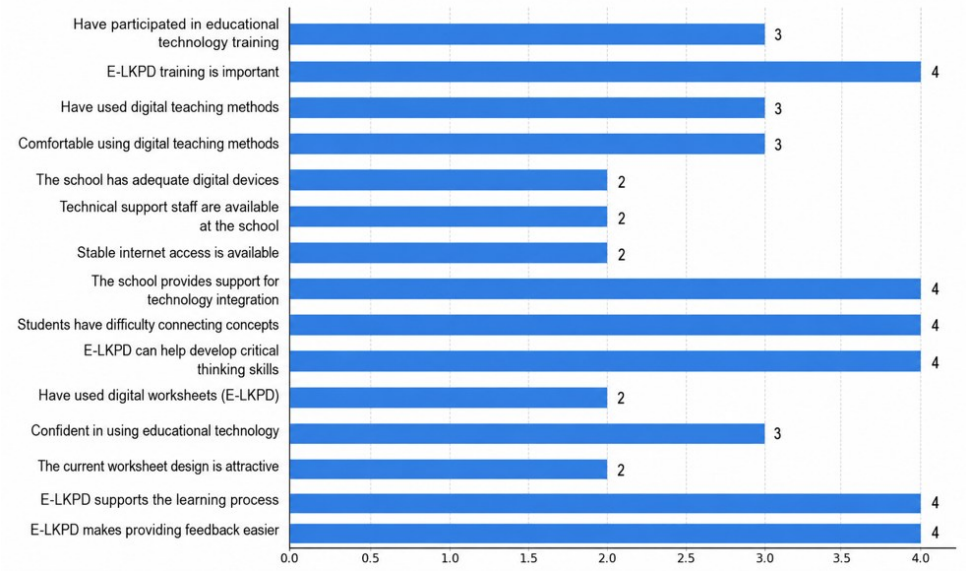

Figure 2. Summary of the Teacher Needs Questionnaire Results for the PMRI-Based Fraction E-LKPD

Alongside the student needs analysis, a teacher needs analysis was conducted to gain a comprehensive understanding of educators' preparedness and requirements for using the interactive PMRI-based E-LKPD. This step was critical because teachers act as the main facilitators in the classroom, in both the learning process and the deployment of teaching materials. The analysis of teacher needs was based on the expectation that the E-LKPD under development would align with student characteristics and provide teachers with the capacity to design, implement and evaluate effective fraction instruction. The results of the teacher needs analysis are shown in Figure 2. Figure 2 shows that all teachers from the four primary schools responded 'Yes' to every aspect of the need for the PMRI-based fraction E-LKPD, as indicated by the questionnaire results. This signals that teachers require interactive, contextual digital teaching materials to support fraction instruction. The unanimous agreement among teachers confirms that the E-LKPD is considered relevant to the learning needs and characteristics of primary school pupils, highlighting the significant demand from educators for the development of a PMRI-based E-LKPD.

Design Phase of the E-LKPD

The design phase commenced with the construction of a flowchart and continued with the creation of a storyboard layout. At this stage, each page of the E-LKPD was planned in detail according to the sequence mapped out in the flowchart. The storyboard layout is made up of several elements. This includes initial sketches or page mock-ups; the placement of visual elements, such as images, icons and illustrations; the arrangement of text, from titles to content and instructions; and the incorporation of interactive components, such as navigation buttons, multiple-choice questions, and project-based activities. Figure 3 shows an example of a storyboard layout page for the E-LKPD.

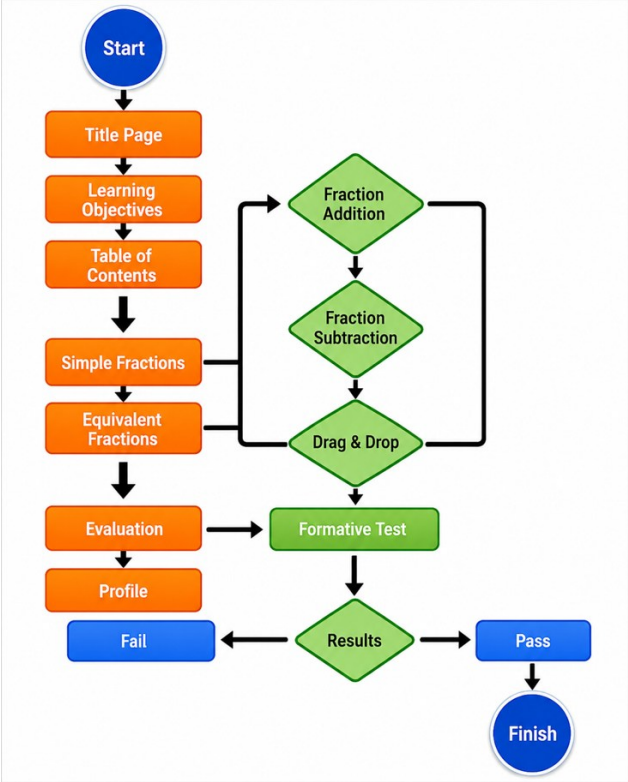

Figure 3. Flowchart of the PMRI-Based Interactive E-LKPD

Development Phase of the E-LKPD

Upon completion of the design phase, the development phase began with the creation of a storyboard layout. Each page of the e-learning course was carefully designed to reflect the sequence set out in the flowchart. This layout comprises initial sketches or page mock-ups, placement of visual elements such as images, icons, and illustrations, arrangement of text ranging from titles and content to instructions, and integration of interactive components including navigation buttons, multiple-choice questions, and project-based activities. This storyboard served as an early prototype of the E-

LKPD, illustrating the layout and interaction design before the development of full interactive media. Figure 4 and Figure 5. The complete set of storyboard results is available via the following link: https://www.liveworksheets.com/c?a=s&t=zgZa3cH7iH&sr=n&l=vz&i=ouxtfcu&r=pt&f=dzdfudun&ms=uz&cd=pgb-d0k-3o-lygjxmzekxhzngnexnxlxg&mw=hs

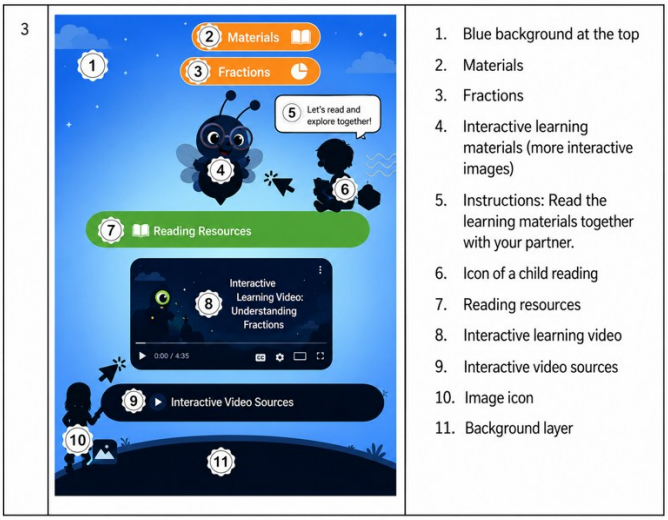

Figure 4. Storyboard Layout of the Interactive PMRI-Based E-LKPD

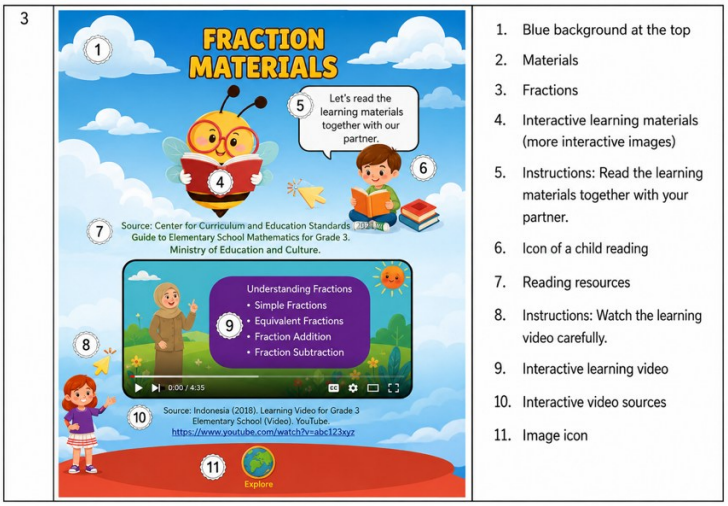

Figure 5. Storyboard Prototype of the PMRI-Based E-LKPD

Results of the E-LKPD Validation

During the development phase, product validation was undertaken by three experts: a subject matter expert, a media expert, and a language expert. This process aimed to evaluate the quality of the interactive PMRI-based E-LKPD's content, language and visual presentation, and ensure its suitability for primary school pupils' characteristics and needs. A summary of the validation results is presented in Table 5.

Table 5. Summary of Expert Validation Results for the Interactive PMRI-Based E-LKPD

Type of Validation	Score Obtained	Maximum Score	Percentage (%)	Category
Content Expert Validation	58	75	78%	Valid
Language Expert Validation	72	75	95,8%	Highly Valid
Media Expert Validation	71	75	94,2%	Highly Valid

Table 5 summarises the validation of the interactive PMRI-based E-LKPD, as carried out by subject matter, language, and media experts. Subject matter expert validation yielded a percentage of

78%, placing it in the valid category. Meanwhile, the language and media expert validations reached 95.8% and 94.2%, respectively, both of which fall within the 'highly valid' category. These results suggest that the interactive PMRI-based E-LKPD could be used as a teaching resource. However, the score of 78% also reveals that certain aspects were not yet optimal. A number of areas for improvement were identified, as follows: The presentation of certain concepts was found to be inadequate in terms of its level of detail. Furthermore, the sequence of the material was not yet entirely systematic. The range of context-based example questions was also found to be limited, and the interconnections between concepts had not been explained with sufficient clarity.

To address these shortcomings, the researcher undertook several revisions. The following four changes are recommended to enhance the quality of pupils' experience and facilitate more effective learning: 1) The explanations should be revised and expanded to make them more thorough and accessible to pupils; 2) The material should be organised more systematically and coherently; 3) A wider variety of contextual questions should be added that are aligned with the characteristics of PMRI; 4) The relationships between concepts should be clarified through additional illustrations and explanatory notes. These enhancements were implemented to elevate the quality of the E-LKPD content to an optimal level. As noted, the language and media expert validations reached 95.8% and 94.2% respectively, both of which are in the highly valid category. These figures demonstrate that the E-LKPD already meets very good standards in terms of language use and visual design. Overall, the validation results confirm that the interactive, PMRI-based E-LKPD is fit for purpose as a teaching resource, requiring only minor revisions to the content for further refinement.

Suggestions and Feedback from the Expert Validators

In addition to providing quantitative assessments of the interactive PMRI-based E-LKPD's validity, the expert validators offered qualitative suggestions and feedback to guide product improvement. A series of revisions to the E-LKPD were necessitated by a review of the recommendations. The objective of these revisions was to enhance the quality of the content, language and visual presentation. These included the refinement of the subject matter to align more closely with the pupils' characteristics, the simplification of the language and the enhancement of its communicative nature (including the integration of numbers and symbols), and the improvement of the visuals to make them more engaging and user-friendly. Figure 6, Figure 7, and Figure 8 illustrate the revised product following consultation with subject matter experts, media specialists and language experts.

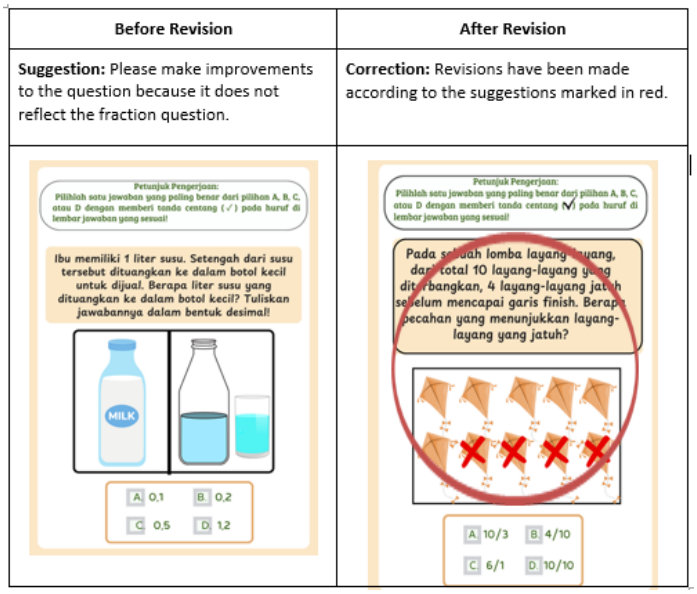

Figure 6. Revisions Based on Subject Matter Expert Suggestions

As illustrated in Figure 6, an E-LKPD question was revised in accordance with feedback from the subject matter expert. The original question asked for the quantity of milk in a bottle to be expressed as a decimal, which was considered an unsuitable way of explaining the concept of fractions. Following refinement, the question was replaced with one set in the context of a kite-flying competition, in which

pupils were tasked with determining the fraction of kites that fell out of the total flown. This revision has been shown to make the question more effective for learning about fractions, thereby helping pupils to understand the relationship between parts and wholes. Figure 7 shows the revisions made in response to recommendations from media experts.

Before Revision	After Revision
Suggestion: The writing of E-LKPD is marked with dashes, and the cover color is improved to make it more attractive.	**Correction:** Revisions have been made according to the suggestions marked in red.
	

Figure 7. Revisions Based on Media Expert Suggestions

Figure 7 illustrates a comparison of the E-LKPD cover design before and after revision. The earlier version featured a dark background with light blue text and simple visual elements. Following a thorough revision process, the colour scheme was modified to incorporate brighter tones and the title 'E-LKPD' was added to the top of the cover. These changes were made to enhance the cover's visual appeal and facilitate pupils' reading experience. The following section provides an illustration of the revisions made in accordance with the language expert's recommendations, as depicted in Figure 8.

Before Revision	After Revision
Suggestion: Please pay attention to consistency of letters, no number symbols next to images.	**Correction:** Corrections have been made according to the suggestions marked by the red circle.
	

Figure 8. Revisions Based on Language Expert Suggestions

As illustrated in Figure 8, the E-LKPD has been revised in line with feedback from the language expert. In the 'Before revision' column, numerical values were used to represent the answers, which was not in line with the established language guidelines. Following a thorough revision process, it was found that the numbers were inconsistent, so they were removed. This adjustment has been shown to result in a more organised and consistent layout of questions, which facilitates comprehension for pupils.

Results of the Practicality Test

The practicality of the E-LKPD was assessed through two trials: a one-to-one trial involving three pupils, and a small-group trial involving eight pupils. The aim of these trials was to evaluate how easy it was for pupils to use the E-LKPD. The results are presented in Table 6.

Table 6. Summary of the Practicality Test Results for the Interactive PMRI-Based E-LKPD

Type of Trial	Number of Subjects	Score Obtained	Ideal Score	Practicality Percentage (%)	Category
One-to-one	3 students	66,3	75	89,25%	Very Practical
Small group	8 students	65,3	75	87,25%	Very Practical
Average				**88,25%**	**Very Practical**

As shown in Table 6, the results of the practicality test for the interactive, PMRI-based E-LKPD are summarised. The one-to-one trial involving three pupils yielded a practicality percentage of 89.25%, placing it in the 'very practical' category. The small-group trial involving eight pupils yielded a practicality percentage of 87.25%, also categorised as 'very practical'. A mean practicality percentage of 88.25% was found, suggesting that the interactive PMRI-based E-LKPD is straightforward to use and provides effective support for the learning process.

Effectiveness Results of the E-LKPD

The effectiveness of the E-LKPD was measured by comparing students' pre-test and post-test scores during the Implementation phase. The N-gain metric was utilised to analyse improvements in learning outcomes, thereby quantifying the extent to which students' understanding improved after using the E-LKPD. The N-gain calculation results are displayed in Table 7.

Table 7. N-Gain Calculation Results

Number of Students	Mean Pre-test	Mean Post-test	N-Gain Value	Category
25	53	84	0,66	Moderate

As shown in Table 7, the N-gain calculation indicates an improvement in pupils' learning outcomes following the introduction of the interactive PMRI-based E-LKPD. The mean pre-test score of 53 increased to 84 in the post-test among the 25 pupils who participated. With a value of 0.66, the N-gain falls within the moderate category, suggesting that the E-LKPD was reasonably effective in enhancing pupils' conceptual understanding, though there is scope for further improvement. The findings of this study suggest that implementing the E-LKPD has a favourable influence on learning outcomes.

Results of Students' Numeracy Strengthening

The findings suggest that using the interactive, PMRI-based E-LKPD to teach fractions significantly improved the numeracy skills of Year 4 primary school pupils. Activities within the E-LKPD, such as representing fractions using pictures, solving contextualised problems and completing interactive exercises, enabled pupils to apply fraction concepts to real-world situations. This improvement is reflected in the pre- and post-test results: the mean score rose from 53 to 84, indicating a moderate increase in mastery of fraction concepts and problem-solving ability, with an N-gain of 0.66. Furthermore, an analysis of supporting documents, including the Kurikulum Merdeka, the ATP, teaching modules, and the LKPD, confirmed that the E-LKPD activities are aligned with the expected numeracy standards and support pupils' mathematical thinking skills.

Interacting with the interactive elements of the E-LKPD, such as multiple-choice questions and navigation buttons, enhanced students' abilities in representation, communication and mathematical reasoning. This is consistent with the principles of PMRI, which emphasise using real-world contexts to improve numeracy. The E-LKPD helped pupils comprehend fraction concepts and reinforced their numeracy skills, including their ability to analyse, compare and apply fractions in everyday life. These findings confirm that the PMRI-based E-LKPD innovation can effectively develop primary school pupils' numeracy skills in a contextual and interactive way.

DISCUSSIONS

This study focuses on three key aspects of the development of the interactive PMRI-based E-LKPD: validity, practicality, and effectiveness. These aspects are significant indicators of the quality of teaching materials, particularly in the context of primary school mathematics instruction. Firstly, the results of the needs analysis demonstrate that all aspects assessed by pupils and teachers were categorised as 'highly needed', with an average percentage of 99%. This suggests a discrepancy between the current teaching materials and the learning requirements of the classroom. The high demand for an interactive PMRI-based E-LKPD highlights the need for teaching resources that are informative, contextualised and interactive, and that can establish connections between mathematical concepts and everyday life. This finding aligns with the work of Chang et al. (2021), Ratnasari et al. (2025) and Wati et al. (2025), which confirms that providing pupils with contextual digital teaching materials can boost their motivation and engagement. Furthermore, Valdivieso and Cid (2025) assert that integrating technology into learning is more effective when it is based on authentic user requirements. The teachers' support for developing the E-LKPD in this study also shows that educators are ready to adopt digital learning innovations. This is consistent with the findings of Boholano et al. (2024), Haezer et al. (2024), and Triyani et al. (2024), who state that teacher acceptance is essential for successfully implementing digital media in the classroom.

Secondly, with regard to validity, the validation results indicate that the interactive, PMRI-based E-LKPD is valid to highly valid. Subject matter expert validation yielded a score of 78% (valid category), while language and media experts achieved scores of 95.8% and 94.2% respectively (highly valid category). Overall, these results demonstrate that the product meets the feasibility criteria in terms of content, language, and presentation. The validity scores show that the material presented is aligned with the basic competencies, learning indicators and principles of PMRI, particularly the connection of mathematical concepts to real-world contexts. However, as the subject matter expert validation score has not yet reached the 'highly valid' category, several aspects still require improvement, including the depth of the content, the systematic organisation of the material and the variety of contextual questions. The researcher's revisions were strategic measures to enhance the product's quality. These comprised the addition of more detailed explanations, the reorganisation of the learning sequence, and the strengthening of the contextual framing of the questions.

This finding is consistent with the research of Mahenge (2023), Karakose et al. (2021), and Tongco (2025), who argue that digital teaching materials developed based on a robust theoretical framework tend to be highly valid. Furthermore, studies by Arya and Rahmadina (2024) and Hafsah et al. (2024) demonstrate that E-LKPDs based on learning models such as problem-based learning or augmented reality technology also attain high levels of validity. The work of Shofiyah Qonitah et al. (2022) and Subandi and Hidayah (2023) corroborates this assertion, highlighting the pivotal role of high validity in content, language, and design in determining the suitability of digital teaching materials. Therefore, the validity results of the present study corroborate earlier findings that integrating the PMRI approach into an E-LKPD can yield a fit-for-purpose teaching resource.

Thirdly, with respect to practicality, the trial results indicate that the interactive PMRI-based E-LKPD falls within the "very practical" category, with an average percentage of 88.25%. This signifies that the product is straightforward for pupils to use, features clear instructions, and offers an attractive, interactive interface. The efficacy of this practical approach is further evidenced by the favourable responses from pupils during the learning process. This finding is consistent with the research of Syafrudin et al. (2025), who state that digital interactive learning media tend to elicit positive responses from learners owing to their ease of use. As Rahayu et al. (2025) found, digital

student worksheets are highly practical, with the potential to enhance pupil engagement in mathematics learning. As demonstrated in the studies conducted by de Araujo et al. (2023) and Li et al. (2023), digital teaching materials have been shown to function as effective independent learning resources, a consequence of their flexible access and clear instructions. Compared with previous studies, the practical results of the present research are relatively consistent and even somewhat higher. This may be due to the integration of PMRI principles, which make learning more contextual and easier for pupils to understand. It is suggested that combining digital technology with an appropriate pedagogical approach has the potential to improve the quality of teaching materials used in the classroom.

Fourthly, in terms of effectiveness, the results show that the interactive, PMRI-based E-LKPD improved pupils' learning outcomes, as indicated by an N-gain value of 0.66, which is in the moderate range. This improvement suggests that using the E-LKPD positively impacted pupils' understanding of fraction concepts, though it has not yet reached the highest category. This finding is consistent with the study by Hidayat and Suryadi (2023), who assert that interactive digital learning media can significantly improve learning outcomes for students. Sekarwangi et al. (2021) also reported an N-gain value of approximately 0.6 for an e-LKPD based on scientific literacy, categorised as moderate. Furthermore, Sukendra et al. (2023) discovered that an e-module rooted in realistic learning can positively enhance students' mathematical abilities.

Comparing the N-gain value obtained in the present study with those of previous research indicates that the PMRI-based E-LKPD is broadly consistent with earlier findings in terms of effectiveness. However, the results also suggest scope for enhancement, for instance through enriching the content, adding a greater variety of activities or integrating supplementary learning strategies, such as differentiation or collaborative learning. Furthermore, analysing curriculum documents in this study reinforced the alignment between the developed product and Kurikulum Merdeka standards. Utilising documents such as the ATP, teaching modules and LKPD as the basis for development attests to the product's theoretical validity and practical relevance. This finding aligns with the conclusions of Pak et al. (2020), who emphasised the importance of coherence between teaching materials and the curriculum to optimise instructional efficacy.

Overall, the results of this study suggest that the interactive PMRI-based E-LKPD is of a high standard in terms of validity, practicality and effectiveness. These findings are consistent with previous research showing that using digital teaching materials based on contextual and realistic approaches can improve the quality of mathematics instruction. At the same time, this study strengthens the existing literature by demonstrating that integrating PMRI into an E-LKPD is an effective strategy for supporting numeracy learning in primary schools. For future research, it is recommended that testing be conducted with a larger sample, employing inferential statistical analysis or effect size calculations to obtain a more comprehensive picture of effectiveness. Additionally, subsequent studies could focus on developing more innovative interactive features to optimise student learning outcomes.

CONCLUSION

This study concludes that developing an interactive E-LKPD based on Indonesian Realistic Mathematics Education (PMRI) for the topic of fractions successfully achieved the objective of producing valid, practical, and effective teaching materials to enhance primary school pupils' conceptual understanding. This research is novel in its integration of the PMRI approach with interactive digital media, systematically designed based on the needs of pupils and teachers, and aligned with the Kurikulum Merdeka. The resulting product presents the material in a contextual and engaging manner and develops pupils' numeracy skills, including fraction representation, problem solving, and mathematical communication. This study contributes to the development of innovative digital teaching materials relevant to twenty-first-century learning. This is achieved by demonstrating a high level of validity and practicality, as well as an N-gain value of 0.66, which falls within the moderate category. The sample size was limited to one class of 25 pupils, which precludes the possibility of making sweeping generalisations at this stage. Furthermore, factors such as differences in pupils' initial abilities, their prior experience with technology, and the role of the teacher in implementing the E-LKPD were not controlled in depth, which may have influenced the outcomes. It is therefore recommended that future research employ larger and more diverse samples and utilise

research designs that permit the control of confounding variables. Further studies could also examine the long-term effectiveness of the E-LKPD and develop more adaptive interactive features with a view to enhancing the quality of learning. The use of this E-LKPD has the potential to facilitate the creation of learning experiences that are more contextual, interactive, and student-centred, thereby enhancing both engagement and comprehensive understanding. Furthermore, developers of teaching materials are advised to continue integrating contextual approaches, such as PMRI, with digital technology in order to produce more innovative learning media suited to learners' needs. It is imperative that adjustments to content, visual design, and interactive activities are carried out on an ongoing basis so that the E-LKPD can be applied flexibly across diverse school contexts and student characteristics.

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