ISEJ Indonesian Science Education Journal

ISSN Online: 2716-3350
https://siducat.org/index.php/isej/
Published by Yayasan Darussalam Bengkulu
This article licensed under CC BY 4.0 International
OPEN ACCESS ARTICLE

Development of Interactive Multimedia Integrating Problem-Based Learning and Banjar Ethnomathematics to Improve Mathematics Learning Outcomes among Second-Grade Elementary Students

Ritwanto[1], Sukiyanto[2], Pardimin[3], Elyas Djufri[4], Wachid Pratomo[5]
Universitas Sarjanawiyata Tamansiswa[1,2,3,4,5]
E-mail Corresponding: ritwanto91@guru.sma.belajar.id

Received: December 2, 2025	Revised: December 27, 2025	Accepted: January 22, 2026

Abstract
Mathematics learning in elementary education continues to present significant challenges, particularly in fraction concepts that require young learners to transition from concrete experiences toward abstract relational understanding. This study aimed to develop and evaluate an interactive multimedia learning product integrating Problem-Based Learning (PBL) and Banjar ethnomathematics to improve second-grade elementary students' mathematics learning outcomes in fraction learning. The study employed a Research and Development (R&D) approach using the ADDIE instructional design model, encompassing analysis, design, development, implementation, and evaluation phases. Data were collected through teacher interviews, teacher and student needs analysis questionnaires, expert validation sheets, teacher and student practicality questionnaires, and learning outcome assessments covering cognitive, affective, and psychomotor domains. Expert validation involved three validators representing content, instructional media, and classroom practice expertise. The developed multimedia demonstrated strong overall validity (92.75%) and high practicality based on teacher (91.11%) and student (84.60%) evaluations. Reliability analysis indicated acceptable to excellent internal consistency across the evaluation instruments (Cronbach's alpha = 0.716–0.925). Effectiveness testing using a paired-samples t-test revealed a statistically significant improvement in students' cognitive learning outcomes, with mean scores increasing from 14.7 (pretest) to 23.7 (posttest), $t(167) = -33.2$, $p < .001$, with a very large effect size (Cohen's $d = 2.56$). Complementary findings also indicated positive affective ($M = 8.14$) and psychomotor ($M = 11.93$) learning outcomes. These findings suggest that the intentional integration of interactive multimedia, scaffolded problem-based pedagogy, and culturally contextualized Banjar ethnomathematics can create an effective, engaging, and contextually meaningful instructional environment for supporting elementary fraction learning.

Keywords: interactive multimedia; Problem-Based Learning; Banjar ethnomathematics; fraction learning; elementary mathematics education; culturally contextualized learning

INTRODUCTION

Mathematics plays a fundamental role in developing logical reasoning, problem-solving ability, and quantitative literacy, making it one of the most essential subjects in elementary education (National Research Council, 2001; Rittle-Johnson et al., 2020). Early mathematics learning serves as a critical foundation for students' future academic achievement because conceptual understanding developed during the elementary years strongly influences later mathematical competence (Jordan et al., 2021). However, mathematics remains one of the most challenging subjects for young learners, particularly when instructional practices rely heavily on abstract explanation, symbolic procedures, and teacher-centered delivery with limited meaningful representation (Hillmayr et al., 2020; Wijaya et al., 2021). These challenges become

especially significant when learners are required to understand concepts involving relational reasoning and abstraction.

Among elementary mathematics topics, fractions are consistently recognized as one of the most cognitively demanding concepts for children to master. Recent studies indicate that fraction learning remains a persistent challenge because students must move beyond whole-number reasoning toward understanding proportional and relational quantities (Braithwaite et al., 2020; Reinhold et al., 2020). Learners frequently experience conceptual misconceptions when interpreting fraction magnitude, part-whole relationships, and symbolic representations, often due to difficulties coordinating visual, verbal, and symbolic forms simultaneously (Fazio et al., 2021; Van Hoof et al., 2021). These difficulties are particularly concerning because strong fraction understanding is closely associated with broader mathematics achievement trajectories and long-term academic development (Rittle-Johnson et al., 2020; Jordan et al., 2021).

The selection of fraction learning as the focus of this study is therefore both pedagogically and developmentally justified. For second-grade elementary students, concepts such as one-half and one-quarter represent early encounters with proportional reasoning, making this developmental stage particularly critical for establishing strong conceptual foundations. At this level, learners generally understand mathematical ideas more effectively when instruction is supported by concrete representation, meaningful contextualization, and active engagement rather than abstract symbolic explanation alone (National Research Council, 2001; Lamon, 2012). When early conceptual misunderstandings are not adequately addressed, students may develop procedural habits without genuine mathematical understanding, potentially constraining subsequent mathematical learning progression.

The urgency of this study is further reinforced by persistent classroom instructional challenges. Conventional mathematics teaching in elementary classrooms often remains dominated by explanation-based delivery, repetitive exercises, and procedural task completion, providing limited opportunities for conceptual exploration and active learner engagement. Although such approaches may support short-term procedural familiarity, they are often insufficient for developing deep conceptual understanding, particularly for abstract concepts such as fractions. For young learners, instructional environments that fail to provide adequate multimodal cognitive support may result in passive learning participation and weak conceptual retention (Mayer, 2020). These pedagogical realities highlight the urgent need for instructional innovation that is developmentally appropriate, conceptually meaningful, and responsive to learners' needs.

One promising response to this challenge is the use of interactive multimedia learning. Interactive multimedia enables the integration of visual representation, narration, simulation, learner interaction, and immediate feedback within a unified instructional environment, making abstract mathematical concepts more concrete and accessible (Clark & Mayer, 2016; Mayer, 2020). Recent empirical studies indicate that digital learning environments can significantly improve mathematics learning outcomes when instructional design is pedagogically meaningful rather than technologically decorative (Hillmayr et al., 2020; Bond, 2022; Zhang et al., 2023). The growing importance of meaningful digital learning ecosystems in contemporary education has also been emphasized in broader international educational reports (OECD, 2021; UNESCO, 2023). For elementary learners, interactive multimedia is particularly relevant because it can transform abstract mathematical representations into visually interpretable, engaging, and developmentally accessible learning experiences (Trouche et al., 2020; Drijvers, 2020).

However, technology alone does not automatically guarantee meaningful learning improvement. Educational technology may remain merely presentational if learners are positioned as passive recipients rather than active participants in knowledge construction. Therefore, pedagogical structuring becomes equally important. One instructional approach strongly aligned with these needs is Problem-Based Learning (PBL), which emphasizes

authentic problem engagement, guided inquiry, collaborative reasoning, and learner-centered conceptual exploration. Recent evidence suggests that PBL contributes positively to conceptual understanding, critical thinking, and problem-solving performance when implemented with appropriate scaffolding (Chen & Yang, 2023; Dolmans et al., 2022; Liu et al., 2022; Anazifa & Djukri, 2021). In mathematics education, this is particularly relevant because conceptual mastery depends on active engagement with mathematical relationships rather than memorization of isolated procedures.

Beyond pedagogy and technology, meaningful mathematics learning also requires contextual relevance. Ethnomathematics provides an important framework for connecting formal mathematical concepts with learners' cultural experiences, recognizing mathematics as knowledge embedded in everyday practices, traditions, and human activity (D'Ambrosio, 2001; Rosa & Orey, 2016). For young learners, culturally contextualized instruction can reduce abstraction barriers, strengthen conceptual accessibility, and improve engagement by grounding learning within recognizable lived experiences (Banks, 2015; Gay, 2018). Recent studies further indicate that culturally responsive mathematics instruction contributes positively to learner motivation, conceptual understanding, and educational relevance (Prahmana & D'Ambrosio, 2020; Fitriani et al., 2022).

Within the Indonesian context, local cultural resources provide significant opportunities for contextual mathematics learning. In South Kalimantan, Banjar culture offers meaningful mathematical representations through familiar cultural objects such as *wadai bingka*, *apem*, and *sasirangan*, which naturally embody concepts of partitioning, proportion, and visual structure relevant to fraction learning. Recent ethnomathematics studies in Indonesia demonstrate the pedagogical potential of integrating culturally meaningful contexts into mathematics learning environments (Fairuz et al., 2020; Prahmana & D'Ambrosio, 2020; Fitriani et al., 2022). However, the pedagogical integration of Banjar ethnomathematics specifically for early elementary fraction learning remains insufficiently explored.

Despite growing scholarship on educational technology, Problem-Based Learning, and ethnomathematics, important research gaps remain. Existing multimedia studies frequently emphasize technological effectiveness without sufficiently integrating structured inquiry-oriented pedagogy appropriate for young learners (Zhang et al., 2023). Conversely, Problem-Based Learning studies often focus on pedagogical processes without leveraging interactive multimedia environments capable of supporting visual mathematical conceptualization (Liu et al., 2022). Ethnomathematics research, meanwhile, commonly emphasizes cultural contextualization without systematically integrating digital instructional design and problem-based pedagogical frameworks (Fitriani et al., 2022). As a result, empirical evidence regarding the coherent integration of interactive multimedia, Problem-Based Learning, and ethnomathematics within a unified intervention for early elementary fraction learning remains limited.

The novelty of this study lies in this intentional integration. Unlike prior studies that tend to examine technology, pedagogy, or cultural contextualization independently, this study develops a unified instructional intervention combining interactive multimedia as the representational platform, Problem-Based Learning as the pedagogical engagement mechanism, and Banjar ethnomathematics as the contextual-cultural bridge. Additional novelty lies in the focus on second-grade elementary learners, a population that remains relatively underrepresented in integrated digital ethnomathematics intervention research, particularly within fraction learning contexts.

Accordingly, this study aims to develop, validate, and evaluate the effectiveness of an interactive multimedia learning product integrating Problem-Based Learning and Banjar ethnomathematics to improve second-grade elementary students' mathematics learning outcomes in fraction learning.

METHODS

This study employed a Research and Development (R&D) approach (Sugiyono, 2019) using the ADDIE instructional design model, which consists of five systematic phases: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009; McKenney & Reeves, 2019). The ADDIE model was selected because it provides a structured and iterative framework for developing, validating, implementing, and evaluating educational products systematically, particularly instructional multimedia resources (Branch, 2009; Plomp & Nieveen, 2013; Van den Akker et al., 2006).

The product developed in this study was an interactive multimedia learning application integrating Problem-Based Learning (PBL) and Banjar ethnomathematics to improve second-grade elementary students' mathematics learning outcomes in fraction learning.

Research Design

To evaluate the effectiveness of the developed multimedia product, this study employed a one-group pretest–posttest design, a commonly used pre-experimental design for assessing changes in participant outcomes before and after an intervention (Campbell & Stanley, 1963). The design is represented as follows:

$$\mathbf{O_1 - X - O_2}$$

where $\mathbf{O_1}$ represents the pretest, $\mathbf{X}$ denotes the implementation of the developed multimedia intervention, and $\mathbf{O_2}$ represents the posttest. This design enabled the researchers to examine changes in students' mathematics learning outcomes following exposure to the intervention.

Research Setting and Participants

This study was conducted in three public elementary schools located in Mantewe District, Tanah Bumbu Regency, South Kalimantan, Indonesia, an area contextually relevant to the integration of Banjar ethnomathematics in elementary mathematics learning.

The participating schools were SD Negeri 1 Sukadamai, SD Negeri 1 Rejosari, and SD Negeri 2 Bulurejo. Participants consisted of 168 second-grade elementary students, selected through purposive sampling based on contextual relevance, accessibility, and implementation feasibility (McKenney & Reeves, 2019). Participant distribution is presented in Table 1.

Table 1. Participant Distribution

School	Total
SD Negeri 1 Sukadamai	88
SD Negeri 1 Rejosari	50
SD Negeri 2 Bulurejo	30
Total	**168**

The implementation was conducted in two stages. Preliminary implementation was carried out at SD Negeri 1 Sukadamai involving 88 students, followed by broader field implementation at SD Negeri 1 Rejosari and SD Negeri 2 Bulurejo, involving 80 students. Effectiveness testing included all participating students.

Expert validation involved three validators, consisting of one content expert, one instructional media expert, and one practitioner expert (elementary school teacher).

Product Development Procedure

The multimedia product was developed through the five phases of the ADDIE model.

Analysis Phase

In the analysis phase, instructional problems, learner needs, and contextual opportunities for multimedia development were identified. Data were collected through semi-structured teacher interviews, supported by teacher and student needs questionnaires. The analysis

focused on identifying students' difficulties in understanding fraction concepts, limitations of existing instructional media, teachers' needs for interactive instructional resources, and students' preferences for engaging digital learning environments. Findings from this phase served as the basis for instructional design and multimedia development.

Design Phase

In the design phase, the instructional architecture of the multimedia product was constructed by integrating multimedia learning principles (Clark & Mayer, 2016; Mayer, 2020), Problem-Based Learning principles (Chen & Yang, 2023; Dolmans et al., 2022; Liu et al., 2022), ethnomathematics perspectives (D'Ambrosio, 2001; Rosa & Orey, 2016), and elementary mathematics learning objectives.

The multimedia was designed with six core components: Home, Menu, Learning Materials, Interactive Simulation, Interactive Practice, and Evaluation. Instructional content focused specifically on fraction concepts, particularly one-half (1/2) and one-quarter (1/4). Banjar ethnomathematics was integrated through culturally contextualized mathematical representations involving familiar local objects such as wadai bingka, apem, and sasirangan to support contextual understanding.

Development Phase

During the development phase, the multimedia application was produced as an interactive digital learning environment integrating text, images, audio narration, contextual storytelling, interactive simulations, practice exercises, and embedded evaluation features.

The developed product was validated by three experts consisting of one mathematics content expert, one instructional media expert, and one practitioner expert. Validation assessed instructional content appropriateness, pedagogical suitability, media functionality, usability, interactivity, and classroom implementation suitability. Feedback from the validators was used to revise and improve the product before implementation.

Implementation Phase

The implementation phase involved classroom use of the validated multimedia product in mathematics learning activities. Instructional implementation operationalized Problem-Based Learning through contextual problem presentation, guided concept exploration, simulation-supported mathematical reasoning, interactive learner practice, teacher-facilitated classroom discussion, and reflective evaluation activities. PBL was selected because it promotes active learning, conceptual reasoning, collaborative inquiry, and contextual problem-solving (Chen & Yang, 2023; Dolmans et al., 2022). Practicality data were collected through teacher and student response questionnaires.

Evaluation Phase

In the evaluation phase, the multimedia product was assessed in terms of validity, practicality, reliability, and effectiveness. Effectiveness evaluation covered cognitive, affective, and psychomotor learning outcomes. Cognitive effectiveness was measured through pretest–posttest comparison, while affective and psychomotor domains were evaluated descriptively as complementary indicators of instructional impact.

Research Instruments

Multiple instruments were employed in this study to support product development and evaluation.

During the analysis phase, a semi-structured interview guide was used to collect qualitative information regarding instructional challenges, classroom learning conditions, and multimedia learning needs. Teacher and student needs questionnaires were administered to identify instructional requirements and learner preferences.

During the development phase, expert validation sheets were used to assess content

appropriateness, pedagogical suitability, multimedia functionality, usability, interactivity, and implementation feasibility.

During implementation, teacher and student practicality questionnaires were used to evaluate ease of use, attractiveness, learner engagement, instructional usefulness, and classroom feasibility.

Students' learning outcomes were assessed across three domains. The cognitive domain was measured using a 30-item multiple-choice mathematics achievement test assessing fraction conceptual understanding and contextual mathematical reasoning. The affective domain assessed students' learning attitudes and engagement, while the psychomotor domain involved performance-based assessment of students' observable learning activities.

Instrument reliability was examined using Cronbach's alpha coefficient, which is widely used to assess internal consistency in educational measurement (Taber, 2018). Reliability analysis indicated acceptable to excellent internal consistency across the main evaluation instruments.

Data Analysis

Data analysis was conducted using jamovi statistical software, following commonly accepted statistical analysis procedures in educational research (Field, 2018; Pallant, 2020).

Qualitative interview data were analyzed descriptively through thematic interpretation to identify instructional needs and classroom learning challenges.

Quantitative descriptive data obtained from needs analysis, expert validation, practicality questionnaires, affective assessment, and psychomotor assessment were analyzed using mean scores, percentages, standard deviations, and categorical interpretation.

Percentage scores were calculated using the following formula:

$$P = \frac{X}{X_{max}} \times 100$$

where **P** represents the percentage score, **X** represents the obtained score, and **Xmax** represents the maximum possible score.

To determine the effectiveness of the developed multimedia product, students' cognitive pretest and posttest scores were analyzed using descriptive and inferential statistics.

The normality assumption for paired difference scores was assessed using the Shapiro–Wilk test. Although the normality test indicated statistical deviation from normality, the paired-samples t-test was retained due to the relatively large sample size and the established robustness of parametric procedures under such conditions (Field, 2018; Pallant, 2020).

To measure the magnitude of the intervention effect, Cohen's d effect size was calculated following established interpretation criteria (Cohen, 1988), where 0.20 indicates a small effect, 0.50 indicates a medium effect, and 0.80 indicates a large effect.

Statistical significance was determined at $\alpha = 0.05$.

RESULT AND DISCUSSION

Results

Needs Analysis Findings

The needs analysis identified several instructional challenges in fraction learning among second-grade elementary students across the participating schools. Data obtained from semi-structured teacher interviews revealed that students experienced substantial conceptual difficulty in understanding basic fraction concepts, particularly one-half (1/2) and one-quarter (1/4). Teachers reported that many students tended to memorize mathematical procedures without fully understanding the underlying concepts, resulting in weak conceptual interpretation during learning activities.

The analysis also revealed limitations in existing instructional practices. Mathematics instruction was predominantly delivered through explanation-based teaching supported by

textbooks and board-based demonstrations. Interactive instructional media were rarely used, particularly for abstract mathematical topics such as fractions. Teachers indicated that such conventional approaches often failed to sustain students' attention and were less effective in helping learners visualize mathematical relationships concretely.

Teacher questionnaire findings further indicated a strong instructional need for digital learning media capable of presenting mathematical concepts in more concrete, interactive, and engaging ways. Teachers emphasized the importance of instructional resources that could support classroom engagement while remaining practically usable within elementary classroom contexts.

Student questionnaire findings similarly showed positive preferences toward visually attractive and interactive learning environments. Students appeared more responsive to learning activities involving visual stimulation, interaction, and concrete representation compared with conventional explanation-based instruction. In addition, contextual analysis suggested that students responded more positively when mathematical examples were connected to familiar real-life experiences and culturally recognizable objects from their surrounding environment.

Overall, the needs analysis findings indicated clear pedagogical, technological, and contextual gaps in existing fraction instruction, thereby providing a strong empirical basis for the development of an interactive multimedia learning intervention integrating Problem-Based Learning and Banjar ethnomathematics.

Product Development Outcome

The development process resulted in an interactive multimedia learning product specifically designed to support fraction learning for second-grade elementary students. The product was developed as a digital learning application integrating mathematical instructional content, interactive visual representation, contextual problem-solving activities, learner practice, and embedded evaluation within a unified instructional environment.

The multimedia consisted of six main features: Home, Menu, Learning Materials, Simulation, Practice, and Evaluation. The Home feature served as the introductory interface, presenting the opening display designed to attract students' initial attention. The Menu feature functioned as the central navigation interface, allowing learners to access each instructional component efficiently.

The Learning Materials section presented fraction concepts, particularly one-half (1/2) and one-quarter (1/4), through visual explanations, simplified instructional narration, and contextual examples adapted to elementary learners' cognitive level. The Simulation feature provided interactive visual manipulation, allowing students to explore fraction representation dynamically through guided learning interaction. The Practice feature provided structured exercises designed to reinforce conceptual understanding through guided learner engagement, while the Evaluation feature included cognitive assessment activities intended to measure students' understanding following instructional use.

The multimedia also incorporated Banjar cultural contexts through the use of culturally familiar objects and contextual mathematical representations embedded within instructional content and problem scenarios. In addition, the instructional flow was designed to reflect Problem-Based Learning principles, enabling students to engage with contextual mathematical situations, explore representations, and participate actively in guided problem-solving activities.

The main interfaces and instructional features of the developed multimedia product are presented in Figure 1.

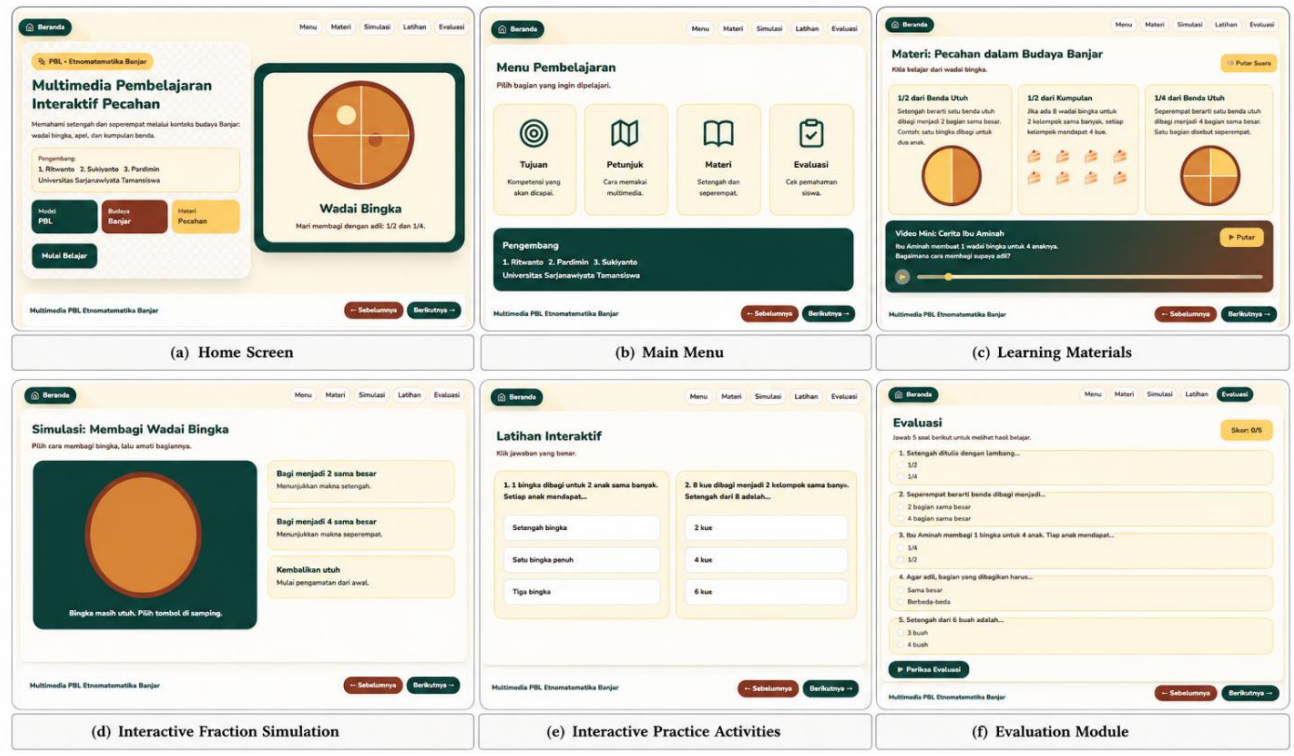

Figure 1. Main Interfaces and Instructional Features of the Developed Interactive Multimedia Product: (a) Home Screen, (b) Main Menu, (c) Learning Materials, (d) Interactive Fraction Simulation, (e) Interactive Practice Activities, and (f) Evaluation Module.

Overall, the development phase successfully produced an integrated interactive multimedia learning product combining instructional content, learner interaction, cultural contextualization, and embedded assessment for elementary fraction learning.

Expert Validation Results

The developed multimedia underwent expert validation prior to classroom implementation to assess its instructional quality, media usability, and classroom implementation suitability. Validation involved three expert validators representing mathematics content, instructional media, and classroom practice.

The validation results indicated a high level of overall product validity, as presented in Table 2.

Table 2. Expert Validation Results of the Developed Multimedia Product

Validator	Number of Items	Mean Score	Percentage (%)	Category
Content Expert	11	4.45	89.09	Highly Valid
Media Expert	8	4.62	92.50	Highly Valid
Practitioner Expert	12	4.83	96.67	Highly Valid
Overall	—	**4.63**	**92.75**	**Highly Valid**

As shown in Table 2, all expert evaluations indicated that the multimedia achieved a high level of validity. The highest validation score was provided by the practitioner expert (96.67%), indicating strong classroom implementation suitability. The media expert evaluation also demonstrated strong technical and usability quality (92.50%), while the content expert assessment confirmed strong instructional appropriateness (89.09%).

Overall, the validation findings indicate that the developed multimedia met the required instructional, technical, and implementation standards for classroom application.

Product Practicality

The practicality of the developed multimedia was evaluated following classroom implementation to assess usability, instructional feasibility, and user acceptance from both teacher and student perspectives.

Table 3. Product Practicality Evaluation Results

Respondent Group	Number of Respondents	Mean Score	Percentage (%)	Category
Teachers	3	4.56	91.11	Highly Practical
Students	168	4.23	84.60	Highly Practical

Teacher responses indicated a high level of product practicality, with an overall practicality score of 91.11%, categorized as Highly Practical. This suggests that teachers considered the multimedia operationally feasible, instructionally useful, and suitable for classroom implementation.

Student responses similarly indicated strong acceptance, with an overall practicality score of 84.60%, also categorized as Highly Practical. These findings suggest that students responded positively to the visual attractiveness, interactivity, and usability of the multimedia learning environment.

Overall, the practicality findings indicate that the developed multimedia was positively received by both teachers and students and was considered suitable for classroom use.

Product Effectiveness

The effectiveness of the developed multimedia was evaluated through a one-group pretest–posttest design involving 168 second-grade elementary students. Students' cognitive mathematics learning outcomes were measured before and after the implementation of the multimedia intervention. Descriptive statistics indicated notable improvement following instructional implementation.

Table 4. Descriptive Statistics of Cognitive Learning Outcomes

Variable	N	Mean	Median	SD	SE	Min.	Max.	Shapiro–Wilk W	p
Pretest	168	14.7	15.0	3.35	0.259	7	22	0.982	.026
Posttest	168	23.7	24.0	4.41	0.340	13	30	0.955	< .001

As shown in Table 4, the mean pretest score was 14.7, whereas the mean posttest score increased to 23.7, indicating an average improvement of approximately 9.0 points following the instructional intervention.

Before inferential analysis, the normality assumption for paired difference scores was examined using the Shapiro–Wilk test, which indicated statistical deviation from normality (**W = 0.972, p = .002**). However, given the large sample size (**N = 168**), the paired-samples t-test was retained, as parametric procedures are generally considered robust under such conditions (Field, 2018; Pallant, 2020).

The inferential analysis results are presented in Table 5.

Table 5. Effectiveness and Complementary Learning Outcome Results

Measure	t	df	p	Mean Difference	SE Difference	Cohen's d
Cognitive (Pre–Post)	-33.2	167	< .001	-9.02	0.271	2.56

As presented in Table 5, the paired-samples t-test revealed a statistically significant difference between pretest and posttest cognitive scores, $t(167) = -33.2$, $p < .001$. The mean difference indicates substantially higher posttest performance compared with baseline achievement. The calculated effect size (Cohen's $d = 2.56$) indicates a very large intervention effect (Cohen, 1988).

Complementary learning outcome findings are presented in Table 6.

Table 6. Complementary Learning Outcome Results

Domain	Mean	SD	Minimum	Maximum
Affective	8.14	1.21	5	10
Psychomotor	11.93	1.64	7	15

As shown in Table 6, students demonstrated positive complementary learning outcomes beyond cognitive achievement. The average affective score (8.14) suggests generally positive learning attitudes, engagement, and classroom responsiveness during instructional implementation. The average psychomotor score (11.93) similarly suggests satisfactory learner participation and observable performance during mathematics learning activities.

Overall, the effectiveness findings indicate that the developed multimedia intervention contributed positively to multidimensional mathematics learning outcomes among second-grade elementary students.

Discussion

The needs analysis findings indicate that the development of the interactive multimedia product was grounded in authentic instructional challenges rather than technological experimentation alone. Students' substantial conceptual difficulties in understanding one-half (1/2) and one-quarter (1/4) are consistent with contemporary evidence showing that fraction learning remains one of the most cognitively demanding areas in elementary mathematics because learners must transition from whole-number reasoning toward proportional and relational understanding (Braithwaite et al., 2020; Fazio et al., 2021; Reinhold et al., 2020). Young learners frequently struggle when mathematical concepts are presented primarily through symbolic forms without adequate representational or contextual scaffolding.

The observed dominance of explanation-based teaching, textbook examples, and board demonstrations further indicates limited opportunities for learners to engage with fractions through multimodal conceptual representation. Effective early mathematics learning requires visual, symbolic, verbal, and contextual integration to support conceptual meaning construction rather than procedural memorization (Lamon, 2012; Mayer, 2020). When such instructional support is absent, students may complete procedural tasks without adequately understanding the underlying mathematical relationships.

The findings also revealed a clear demand for more engaging and practically usable instructional media from both teachers and students. This aligns with multimedia learning perspectives emphasizing that meaningful learning is strengthened when verbal explanations are integrated with relevant visual representation and learner interaction (Clark & Mayer, 2016; Mayer, 2020). Recent educational technology research similarly suggests that interactive digital learning environments can improve conceptual understanding and learner engagement when instructional design is pedagogically purposeful rather than technologically decorative (Hillmayr et al., 2020; Zhang et al., 2023).

The identified need for culturally familiar instructional examples further supports the integration of Banjar ethnomathematics. Ethnomathematics emphasizes the importance of connecting formal mathematical concepts with learners' cultural practices and lived experiences to improve accessibility and meaning-making (D'Ambrosio, 2001; Rosa & Orey, 2016). In this study, familiar Banjar cultural objects such as *wadai bingka*, *apem*, and *sasirangan* served as contextual bridges that reduced abstraction barriers between formal mathematics and students' everyday experiences.

Product Validity and Practicality

The high validation score (92.75%) indicates that the developed multimedia achieved strong instructional coherence across content appropriateness, pedagogical design, technical usability, and classroom implementation suitability. In educational product development, strong validity reflects not merely technical functionality, but theoretical consistency between

instructional design, learner needs, and intended educational outcomes (Branch, 2009; McKenney & Reeves, 2019).

From a content perspective, the multimedia product was intentionally designed to align with the cognitive developmental characteristics of second-grade learners by emphasizing concrete visual representation, gradual conceptual progression, and contextual mathematical interpretation. Fraction learning requires instructional support that helps learners move from intuitive concrete understanding toward symbolic abstraction (Lamon, 2012). The integration of culturally familiar Banjar objects strengthened conceptual accessibility by embedding mathematical meaning within recognizable contexts. As illustrated in Figure 1, the multimedia integrated structured visual navigation, interactive simulations, guided practice, and contextual instructional components specifically designed to support conceptual fraction learning among young learners.

From a pedagogical perspective, the multimedia demonstrated strong validity because its instructional structure actively engaged learners in contextual exploration, guided reasoning, and conceptual interaction rather than passive information reception. The embedded Problem-Based Learning architecture supported active learner participation, which is consistent with recent evidence suggesting that scaffolded problem-based approaches strengthen conceptual understanding and academic performance (Chen & Yang, 2023; Dolmans et al., 2022; Liu et al., 2022).

The multimedia design also reflected evidence-based multimedia learning principles through the integration of narration, structured navigation, visual representation, simulation, and learner interaction. Such multimodal instructional environments are particularly relevant for young learners because they can reduce abstraction barriers and support more meaningful cognitive processing (Clark & Mayer, 2016; Mayer, 2020).

The practicality findings further demonstrate that the developed product was operationally feasible in authentic classroom settings. High teacher practicality ratings (91.11%) suggest that the multimedia was perceived as instructionally useful, manageable, and compatible with classroom implementation realities. This is particularly important because educational technology interventions frequently encounter implementation barriers when they impose excessive operational demands on teachers.

Student practicality findings (84.60%) similarly indicate strong usability and positive learning experiences. Recent studies show that interactive digital learning environments can enhance motivation, engagement, and learner participation when students perceive instructional experiences as meaningful, accessible, and enjoyable (Hillmayr et al., 2020; Zhang et al., 2023). The slightly lower student ratings compared with teacher ratings are developmentally understandable, as second-grade learners are still developing digital navigation independence, attention regulation, and structured interaction skills.

Overall, the findings suggest that the multimedia product successfully achieved a practical balance between instructional quality, learner usability, and classroom feasibility.

Product Effectiveness

The effectiveness findings indicate that the developed multimedia intervention substantially improved students' mathematics learning outcomes, particularly in the cognitive domain, while also producing positive affective and psychomotor learning indicators. The increase in mean cognitive scores from 14.7 to 23.7, accompanied by a very large effect size (Cohen's $d = 2.56$), suggests strong instructional impact.

This finding is particularly meaningful given the persistent conceptual difficulty associated with fraction learning in elementary mathematics (Braithwaite et al., 2020; Fazio et al., 2021). Fraction learning requires learners to coordinate proportional reasoning, part–whole interpretation, and symbolic meaning simultaneously, making it especially vulnerable to misconception when instruction relies primarily on procedural explanation.

One explanatory factor lies in the multimedia learning architecture of the intervention.

The developed product transformed abstract fraction concepts into visually interpretable, interactive, and age-appropriate learning experiences through coordinated narration, simulation, guided practice, and embedded evaluation. Multimedia learning theory suggests that learners understand concepts more effectively when verbal and visual information are meaningfully integrated (Mayer, 2020). Recent digital learning studies similarly indicate that interactive multimedia environments can strengthen conceptual understanding and learning performance when instructional interaction is intentionally designed (Hillmayr et al., 2020; Zhang et al., 2023).

Complementary positive affective and psychomotor outcomes further suggest that the intervention supported multidimensional learning beyond cognitive achievement alone. Positive affective outcomes suggest learner engagement, attentiveness, and favorable responses toward the instructional experience, while psychomotor outcomes indicate active observable participation during learning activities. Together, these findings suggest that the intervention supported not only conceptual learning but also active learner involvement.

Contribution of Problem-Based Learning

Problem-Based Learning (PBL) contributed substantially to the effectiveness of the intervention by functioning as the pedagogical mechanism that transformed multimedia use from passive content delivery into active conceptual engagement. While multimedia provided the representational and interactive infrastructure, PBL supplied the instructional structure that required learners to engage with contextual mathematical problems, guided inquiry, and conceptual reasoning.

This distinction is important because multimedia alone does not automatically guarantee deep learning if learners remain passive observers. Recent evidence suggests that problem-based instructional approaches improve conceptual understanding, critical thinking, and academic achievement when supported by appropriate scaffolding and learner guidance (Chen & Yang, 2023; Dolmans et al., 2022; Liu et al., 2022).

In this study, PBL principles were operationalized through contextual problem scenarios, guided exploration, simulation-supported reasoning, and structured practice activities. Given the developmental characteristics of second-grade learners, PBL was implemented through scaffolded and guided interaction rather than fully open inquiry. This structured adaptation likely enabled young learners to engage actively in conceptual exploration while maintaining adequate instructional support.

Thus, PBL functioned as the cognitive engagement engine of the intervention, ensuring that learners actively constructed mathematical meaning rather than merely observing instructional content.

Contribution of Banjar Ethnomathematics

The integration of Banjar ethnomathematics represents one of the most distinctive contributions of this study in strengthening contextual and cultural relevance in elementary mathematics instruction.

A persistent challenge in early mathematics education is the abstraction of formal mathematical concepts, particularly fractions. When mathematical content is presented in decontextualized symbolic forms, young learners may perceive mathematics as cognitively distant and difficult to interpret.

Ethnomathematics offers a pedagogical response by connecting formal mathematics with familiar cultural practices and lived experiences (D'Ambrosio, 2001; Rosa & Orey, 2016). In this study, Banjar cultural objects served as meaningful conceptual anchors embedded within multimedia explanations, simulations, and contextual problem scenarios.

Rather than functioning as decorative cultural inclusion, Banjar ethnomathematics served as a conceptual accessibility mechanism that reduced abstraction barriers and strengthened contextual meaning-making. Recent studies similarly indicate that culturally contextualized

mathematics learning can improve engagement, conceptual accessibility, and instructional relevance (Prahmana & D'Ambrosio, 2020; Fitriani et al., 2022).

Thus, Banjar ethnomathematics contributed not merely as contextual enrichment, but as an instructional mechanism enhancing conceptual accessibility and cultural relevance.

Integrated Innovation and Research Contribution

One of the principal contributions of this study lies in the intentional integration of interactive multimedia, Problem-Based Learning, and Banjar ethnomathematics within a unified elementary mathematics intervention.

Although these instructional dimensions have each been independently examined in prior research, their systematic integration within a single intervention for early elementary fraction learning remains relatively underexplored. Within this integrated framework, interactive multimedia functioned as the representational platform, Problem-Based Learning as the pedagogical engagement mechanism, and Banjar ethnomathematics as the contextual-cultural mediator.

The substantial learning gains observed suggest that instructional effectiveness likely emerged from the synergy among these components rather than from any single instructional element alone. This integrated design contributes to elementary mathematics education by demonstrating that instructional innovation becomes more powerful when technology, pedagogy, and cultural contextualization are intentionally designed as a coherent instructional ecosystem.

Practical Implications, Limitations, and Future Research

The findings suggest that fraction learning in elementary classrooms may benefit from instructional approaches that move beyond explanation-based teaching toward interactive, visually supported, culturally contextualized, and learner-centered environments.

Several limitations should be acknowledged. First, the study employed a one-group pretest–posttest design without a control group, limiting the strength of causal inference. Second, the study focused specifically on fraction learning among second-grade elementary students within a particular socio-cultural context, which limits broader generalizability. Third, broader implementation may be influenced by contextual variables such as technological infrastructure, device availability, teacher digital competence, and classroom operational constraints.

Future research should extend this work through comparative experimental designs, broader implementation across diverse educational contexts, and exploration of similar integrated interventions across other mathematical domains.

Overall, despite its limitations, this study provides meaningful evidence that integrated instructional innovation combining technology, pedagogy, and cultural contextualization holds substantial promise for strengthening elementary mathematics learning.

CONCLUSION

This study developed and evaluated an interactive multimedia learning product integrating Problem-Based Learning (PBL) and Banjar ethnomathematics to support fraction learning among second-grade elementary students. The findings demonstrate strong performance across the core dimensions of educational development research, namely validity, practicality, and effectiveness. Expert validation confirmed that the multimedia met instructional, pedagogical, technical, and classroom implementation standards, while practicality evaluations indicated strong acceptance from both teachers and students in authentic elementary classroom settings. The intervention also produced substantial improvement in students' mathematics learning outcomes, particularly in the cognitive domain, accompanied by positive affective and psychomotor learning indicators.

The effectiveness of the intervention may be attributed not merely to the use of digital

technology itself, but to the intentional integration of interactive multimedia representation, scaffolded problem-based pedagogy, and culturally contextualized learning experiences. Interactive multimedia supported conceptual visualization and learner interaction, Problem-Based Learning promoted active engagement and guided reasoning, while Banjar ethnomathematics strengthened contextual accessibility by connecting formal mathematical concepts with learners' familiar cultural experiences. Together, these instructional elements helped reduce abstraction barriers commonly encountered in early fraction learning.

From a scholarly perspective, this study contributes to mathematics education and educational technology literature by demonstrating the instructional value of integrating technology, pedagogy, and cultural contextualization within a unified elementary mathematics intervention. The study offers an integrated instructional model in which interactive multimedia functions as the representational platform, Problem-Based Learning as the pedagogical engagement mechanism, and Banjar ethnomathematics as the contextual-cultural mediator. This integrated approach provides a meaningful framework for designing developmentally appropriate and contextually relevant mathematics instruction for young learners.

Practically, the findings suggest that abstract mathematical concepts may be learned more effectively through instructional environments that are interactive, visually supportive, culturally responsive, and learner-centered. However, the findings should be interpreted within the limitations of the one-group pretest–posttest design, the absence of a control group, and the contextual specificity of the implementation setting. Future research should examine similar integrated interventions using more rigorous comparative experimental designs, broader educational contexts, and different mathematical domains.

Overall, this study provides meaningful evidence that integrated instructional innovation combining technology, pedagogy, and local cultural contextualization shows considerable promise for strengthening elementary mathematics learning.

REFERENCES

Banks, J. A. (2015). *Cultural diversity and education: Foundations, curriculum, and teaching* (6th ed.). Routledge.

Braithwaite, D. W., Pyke, A. A., & Siegler, R. S. (2020). A computational model of fraction arithmetic. *Psychological Review, 127*(4), 603–625. https://doi.org/10.1037/rev0000183

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer. https://doi.org/10.1007/978-0-387-09506-6

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research*. Houghton Mifflin.

Chen, C.-H., & Yang, Y.-C. (2023). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review, 39*, 100510. https://doi.org/10.1016/j.edurev.2022.100510

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction* (4th ed.). Wiley. https://doi.org/10.1002/9781119239086

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

D'Ambrosio, U. (2001). *Ethnomathematics: Link between traditions and modernity*. Sense Publishers.

Dolmans, D. H. J. M., Loyens, S. M. M., Marcq, H., & Gijbels, D. (2022). Deep and surface learning in problem-based learning: A review of the literature. *Advances in Health Sciences Education, 27*(4), 989–1007. https://doi.org/10.1007/s10459-022-10122-0

Fairuz, F. R., Fajriah, N., & Danaryanti, A. (2020). Etnomatematika sasirangan: Eksplorasi konsep matematika dalam budaya Banjar. *EDU-MAT: Jurnal Pendidikan Matematika, 8*(1), 29–38. https://doi.org/10.20527/edumat.v8i1.8343

Fazio, L. K., Bailey, D. H., Thompson, C. A., & Siegler, R. S. (2021). Fractions: How should they be taught and learned? *Educational Psychology Review, 33*, 1–41. https://doi.org/10.1007/s10648-020-09566-9

Field, A. (2018). *Discovering statistics using IBM SPSS Statistics* (5th ed.). Sage.

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice* (3rd ed.). Teachers College Press.

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education, 153*, 103897. https://doi.org/10.1016/j.compedu.2020.103897

Jordan, N. C., Hansen, N., Fuchs, L. S., Siegler, R. S., Gersten, R., & Micklos, D. (2021). Developmental predictors of fraction concepts and procedures. *Journal of Experimental Child Psychology, 202*, 104996. https://doi.org/10.1016/j.jecp.2020.104996

Lamon, S. J. (2012). *Teaching fractions and ratios for understanding* (3rd ed.). Routledge.

Major, L., Francis, G. A., & Tsapali, M. (2021). The effectiveness of technology-supported personalised learning in low- and middle-income countries: A meta-analysis. *Educational Technology Research and Development, 69*, 885–912. https://doi.org/10.1007/s11423-021-09979-0

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E. (2020). *Multimedia learning* (3rd ed.). Cambridge University Press. https://doi.org/10.1017/9781316941355

McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research* (2nd ed.). Routledge. https://doi.org/10.4324/9781315105642

National Research Council. (2001). *Adding it up: Helping children learn mathematics*. National Academies Press. https://doi.org/10.17226/9822

Pallant, J. (2020). *SPSS survival manual* (7th ed.). Routledge.

Plomp, T., & Nieveen, N. (2013). *Educational design research*. SLO.

Prahmana, R. C. I., & D'Ambrosio, U. (2020). Learning geometry and values from patterns: Ethnomathematics on the batik patterns of Yogyakarta, Indonesia. *Journal on Mathematics Education, 11*(3), 439–456. https://doi.org/10.22342/jme.11.3.12949.439-456

Reinhold, F., Hoch, S., Werner, B., Richter-Gebert, J., & Reiss, K. (2020). Learning fractions with digital tools: A systematic review. *Educational Research Review, 30*, 100332. https://doi.org/10.1016/j.edurev.2020.100332

Rosa, M., & Orey, D. C. (2016). State of the art in ethnomathematics. In M. Rosa et al. (Eds.), *Current and future perspectives of ethnomathematics as a program* (pp. 11–37). Springer. https://doi.org/10.1007/978-3-319-30120-4_3

Sugiyono. (2019). *Metode penelitian dan pengembangan*. Alfabeta.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Trouche, L., Gueudet, G., & Pepin, B. (2020). The documentational approach to didactics and mathematics teaching with digital resources. *ZDM Mathematics Education, 52*, 1073–1085. https://doi.org/10.1007/s11858-020-01166-9

Van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (2006). *Educational design research*. Routledge.

Van Hoof, J., Verschaffel, L., & Van Dooren, W. (2021). Conceptual understanding of fractions in primary school students: A systematic perspective on learning difficulties and instructional implications. *Educational Studies in Mathematics, 108*(1–2), 123–145. https://doi.org/10.1007/s10649-021-10045-7

Wijaya, A., Van den Heuvel-Panhuizen, M., & Doorman, M. (2021). Opportunity-to-learn context-based tasks provided by mathematics textbooks. *Educational Studies in Mathematics, 106*(1), 41–65. https://doi.org/10.1007/s10649-020-09989-3

Zhang, X., Wang, M., & Zhu, Y. (2023). Interactive multimedia learning environments and mathematics achievement: A systematic review. *Computers & Education Open, 4*, 100124. https://doi.org/10.1016/j.caeo.2023.100124

Bond, M. (2022). Schools and emergency remote education during the COVID-19 pandemic: A living rapid systematic review. *Asian Journal of Distance Education, 17*(1), 191–247.

Anazifa, R. D., & Djukri. (2021). Project-based learning and problem-based learning: Are they effective to improve students' thinking skills? *Jurnal Pendidikan IPA Indonesia, 10*(3), 346–355. https://doi.org/10.15294/jpii.v10i3.29404

Liu, X., Gao, Y., & Zhang, M. (2022). Problem-based learning in mathematics education: A systematic review of recent empirical studies. *International Journal of STEM Education, 9*, 58. https://doi.org/10.1186/s40594-022-00358-4

OECD. (2021). *21st-century readers: Developing literacy skills in a digital world*. OECD Publishing. https://doi.org/10.1787/a83d84cb-en

Drijvers, P. (2020). Digital technology in mathematics education: Why it works (or doesn't). *Educational Studies in Mathematics, 104*(1), 1–20. https://doi.org/10.1007/s10649-020-09982-w

Rittle-Johnson, B., Fyfe, E. R., Loehr, A. M., & Miller, M. R. (2020). Beyond numeracy in early mathematics education. *Educational Researcher, 49*(9), 644–654. https://doi.org/10.3102/0013189X20948367

Fitriani, N., Turmudi, & Prabawanto, S. (2022). Ethnomathematics in Indonesian mathematics learning: A systematic literature review. *Journal on Mathematics Education, 13*(3), 527–548. https://doi.org/10.22342/jme.v13i3.19000

UNESCO. (2023). *Technology in education: A tool on whose terms? Global education monitoring report 2023*. UNESCO.