

Integrating liveworksheets for multirepresentational probability learning: A study on design validity and instructional effectiveness

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ABSTRACT

Mathematical representation is essential for students' understanding, especially in probability which requires visual symbolic and verbal interpretation. However many digital worksheets lack integration across these modes. This study aimed to develop and evaluate a multirepresentational electronic worksheet using the Liveworksheets platform to enhance students' representational skills in probability. The study applied the ADDIE development model which included curriculum analysis expert validation and classroom implementation through a pretest and posttest design. The worksheet combined interactive charts symbolic equations and explanatory prompts into a unified learning experience. Panels of experts consisting of subject-matter specialists media experts and psychometricians validated the content usability and alignment with educational objectives. Students who participated in pilot activities responded positively and reported high levels of engagement. The pretest and posttest results demonstrated improvements in students' visual symbolic and verbal representation skills. These outcomes indicate that integrating multiple representation modes into a digital learning tool can effectively support deeper conceptual understanding. The study concludes that the developed worksheet is educationally valid engaging for learners and practical for classroom use. It offers a promising approach to support differentiated instruction in mathematics and enrich students' learning experiences particularly in mastering abstract probability concepts.

INTRODUCTION

In recent years, digital tools have reshaped how mathematics is taught by moving instruction beyond static, paper-based activities. Interactive platforms give students immediate feedback and adaptive hints that guide them toward mastery at their own pace (Barana et al., 2021; Ginting et al., 2024). They also allow learners to revisit challenging problems as often as needed, which helps build confidence. Despite these advantages, many online worksheets feel like simple scans of print materials (Evans & Cleghorn, 2022). They lack the multimedia elements and real-time insights that make digital learning powerful. Thoughtful design is required to transform basic digitization into engaging experiences. When educators weave in videos, interactive graphs, and prompts that adapt to student responses, technology can spark genuine curiosity (Cirneanu & Moldoveanu, 2024). Over time, well-designed digital resources can become central learning tools rather than optional add-ons.

Representing mathematical ideas in visual diagrams, symbolic expressions, and verbal explanations is crucial for deep understanding. Each mode offers unique benefits: diagrams highlight relationships and patterns, symbols convey precision, and words clarify reasoning steps. Research shows that students who practice translating among these forms develop stronger conceptual connections (Delgado-Rebolledo & Zakaryan, 2020; Erath et al., 2021; Fries et al., 2021). However,

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many digital worksheets focus on only one representation at a time, such as drag-and-drop images or fill-in algebraic fields (Esen et al., 2023). This fragmented approach can leave learners unable to connect the dots between a picture and an equation or between an equation and a written explanation. Integrating multiple modes into a cohesive learning activity helps students build mental bridges (McCrudden et al., 2022; Nathan et al., 2013). It supports diverse learning preferences and promotes a more complete grasp of mathematical concepts.

Probability presents particular hurdles because it requires flexible thinking across different representations. Students often struggle to interpret charts or tree diagrams that depict sample spaces and event likelihoods (Ingram et al., 2024; Zorzos & Avgerinos, 2023). Converting those visuals into symbolic expressions like fractions and ratios adds another layer of difficulty. Explaining their reasoning in clear sentences can expose still-unresolved misconceptions. Although platforms such as Liveworksheets offer interactive probability exercises, they rarely combine visual, symbolic, and verbal tasks in a single workflow. As a result, learners miss key “aha” moments that occur when they see the same problem through multiple lenses. Addressing these gaps calls for materials that scaffold each representation mode. Such resources can guide students step by step from diagram to formula to explanation.

This study responds to the need for an integrated digital resource by designing a multirepresentational electronic worksheet for probability instruction. The project will create activities that present a chart, a corresponding equation, and a verbal explanation all linked to the same problem. Subject-matter experts and media specialists will review each task to ensure accuracy and engagement. Pilot tests in small and large classroom settings will gather data on student reactions and usability. A one-group pretest-posttest design will measure gains in visual, symbolic, and verbal representation skills. Analysis of these results will inform guidelines for designing effective multirepresentational worksheets. Ultimately, this work aims to provide teachers with an evidence-based, plug-and-play tool that enhances probability learning and supports diverse learners.

Various studies have shown that combining multiple modes of representation with digital media can enrich mathematics learning. In computational fields, researchers have demonstrated that leveraging diverse representations improves data processing and dynamic graph modeling accuracy, although these advances have yet to be applied in classroom settings (Pang et al., 2022; Sadeghi & Armanfard, 2024). In middle schools, interactive worksheets delivered through Liveworksheets have been found to boost student engagement, yet they do not systematically integrate visual and symbolic elements (Effendi et al., 2024). Broader ICT tools have maintained learning continuity during remote instruction but often lack intentional design for multiple representations (Rudenko et al., 2021). Studies on electronic worksheets aimed at basic mathematical literacy confirm their effectiveness, but they rarely combine graphical and symbolic formats in a cohesive way (Jannati & Sumardi, 2023). Pedagogical approaches like Discovery Learning paired with computational experiments deepen understanding of advanced concepts, yet they typically do not take the form of structured worksheets (Kyriazis et al., 2009). Even inclusive learning frameworks proposed in recent conferences remain largely conceptual without empirical evaluation of specific digital resources. To date, no research has specifically created, validated, and tested the impact of a multirepresentational electronic worksheet on probability topics using Liveworksheets, particularly from the perspectives of expert review, student engagement, and gains in visual, symbolic, and verbal representation skills through a one-group pretest-posttest design.

Address this gap and advance the field, this study offers a significant contribution to the development of educational technology and mathematics education research. By integrating visual, symbolic, and verbal representations within a single interactive digital tool, this research bridges theoretical concepts of representation with practical classroom implementation. It not only addresses a well-documented gap in existing literature but also provides empirical evidence for how multirepresentational scaffolding can enhance conceptual understanding in probability learning. The findings are expected to inform future instructional designs and support the broader adoption of intelligent digital worksheets in diverse educational settings. This study therefore aims to: (1) validate the worksheet’s suitability through panels of subject-matter and media experts, (2) measure student reactions and engagement in both small-scale and larger-scale pilot groups, (3) Evaluate improvements in students’ visual, symbolic, and verbal representation skills using a one-group pretest-posttest design.

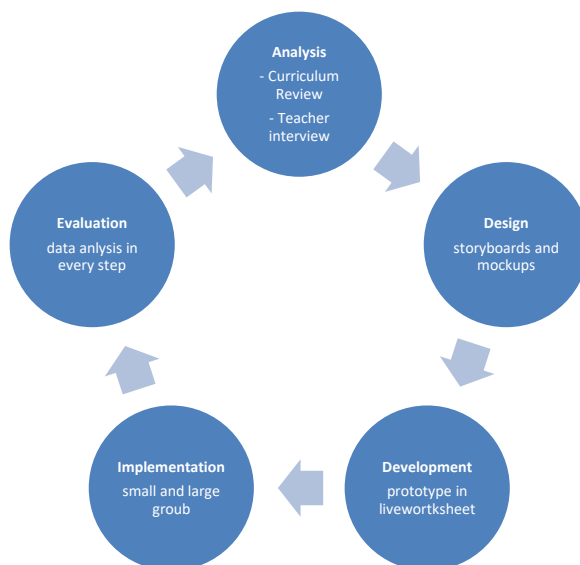


Figure 1. ADDIE research Model

METHODS

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) commonly used for the systematic development of educational products (Figure 1). The use of the ADDIE framework is considered essential in this study as it ensures a structured, iterative process that aligns pedagogical goals with technological design, particularly suitable for developing digital learning tools that require both content validity and usability.

In the Analysis stage, we began by reviewing the 2013 mathematics curriculum and conducting structured interviews with Grade VIII teachers at a secondary public school in Lampung Regency. These steps uncovered specific student difficulties in interpreting probability diagrams, translating scenarios into symbolic form, and articulating reasoning verbally. Insights from this phase informed the selection of key content areas and shaped the learning objectives that the E-Worksheet must address.

Moving into Design, we translated analysis findings into low-fidelity storyboards and mockups. Each storyboard linked a probability chart, its symbolic representation, and a concise explanatory prompt for the same scenario. We refined layout ideas, interaction flows, and feedback mechanisms to ensure clarity and engagement before committing to full development.

During Development, the prototype took shape on the Liveworksheets platform. We embedded interactive elements—such as drag-and-drop diagrams, auto-scoring formula fields, and text boxes for verbal explanations—alongside multimedia prompts. Adaptive hints were configured to guide students who struggled at each representation mode, offering real-time support without revealing answers outright.

The Validation phase involved three expert panels. Subject-matter experts assessed mathematical accuracy, alignment with learning standards, and conceptual clarity. Media specialists evaluated the interface, navigation, and overall user experience. A separate panel reviewed the pretest–posttest instrument, checking item validity with product-moment correlations, reliability via Cronbach’s alpha, and item difficulty and discrimination indices. Feedback from each group led to iterative refinements of both the worksheet and assessment tools. Three subject-matter experts, two media experts, and two psychometricians were involved in the validation process.

Implementation unfolded in two rounds with Grade VIII classes. First, a small group of fifteen students engaged with the E-Worksheet in a ninety-minute session, after which they completed an attractiveness survey and a brief structured interview. Next, thirty different students repeated the



Figure 2. Worksheet

lesson under identical conditions, allowing us to observe consistency in engagement patterns and identify any remaining usability issues. All sessions followed a standardized facilitation guide to maintain instructional uniformity.

In the Evaluation stage, we administered a one-group pretest–posttest to measure gains in visual, symbolic, and verbal representation skills. The assessments mirrored worksheet tasks but were delivered on paper to isolate learning effects from platform familiarity. Quantitative analysis reported expert validation percentages and mean attractiveness scores, while Cohen’s *d* quantified the magnitude of learning improvements. Finally, thematic analysis of interview transcripts and observation notes highlighted common user experiences and areas for further enhancement. Ethical approval was granted by the UIN Raden Intan Lampung Education Faculty Ethics Committee, and informed consent was obtained from all participants.

Description of the multirepresentational worksheet

Before assessing the worksheet’s validity and instructional effectiveness, it is essential to describe its concrete form. The developed multirepresentational E-Worksheet was created using the Liveworksheets platform. It integrates visual elements such as probability tree diagrams and bar charts, symbolic equations for calculating probabilities, and verbal prompts that guide students to explain their reasoning. The worksheet includes interactive features such as drag-and-drop components, auto-correct formula fields, and text boxes for written explanations, allowing students to navigate between multiple representation modes seamlessly. A screenshot of one worksheet item is provided in Figure 2 to illustrate the integration of these representational forms. Additionally, the complete worksheet can be accessed publicly through the following [link](http://journals2.ums.ac.id/index.php/jramathedu). This digital worksheet format exemplifies the study’s goal of providing students with cohesive access to visual, symbolic, and verbal representations of probability concepts within a single interactive tool.

FINDINGS

The outcomes are presented in three parts (expert validation, student engagement, and learning effectiveness) with each section introduced by a brief contextual statement and supported

Table 1.
Expert validation summary

Panel	Key Criteria Evaluated	Mean Score	Category
Material Experts (n=3)	Content accuracy, curriculum alignment, representational clarity	88.3%	Highly Suitable
Media Experts (n=3)	Layout, navigation, multimedia integration, usability	84.5%	Highly Suitable
Instrument Panel (n=3)	Item validity, reliability, difficulty, discrimination	—	Suitable

Table 2.
Student engagement scores

Pilot Group	N	Mean Score	Category
Small-Scale (Pilot 1)	15	88.3%	Very Engaging
Large-Scale (Pilot 2)	35	84.5%	Very Engaging

by summary tables. All pilot activities and assessments took place during July 2024 at SMP Negeri in Lampung.

Expert validation

The multirepresentational electronic worksheet was evaluated by three subject-matter experts, two media specialists, and two psychometricians. The experts rated the content highly in terms of curriculum alignment, mathematical accuracy, and clarity of representational transitions. The media experts commended the interface design and interactivity, while the psychometricians confirmed the validity and reliability of the assessment instruments. All experts provided written suggestions, particularly on refining terminology and improving navigation prompts. These suggestions were incorporated into the final version of the E-Worksheet. Overall, the validation results indicate that the product meets the standards for both pedagogical quality and user experience.

Expert feedback included specific revision notes, such as simplifying certain instructions, adjusting the sequence of tasks for better cognitive flow, and enhancing the clarity of symbols used in visual prompts. To establish pedagogical and technical soundness, three panels of experts reviewed the materials in March 2024. Material experts confirmed that content accuracy, curriculum alignment, and clarity of visual, symbolic, and verbal representations met high standards. Media specialists judged the interface design, navigation flow, and interactive features to be very appropriate for classroom use. A dedicated instrument panel verified that pretest–posttest items achieved acceptable validity (all item–total correlations > 0.30), reliability (Cronbach's $\alpha = 0.82$), and optimal difficulty and discrimination indices as shown in Table 1.

Student engagement

Table 2 shows that pilot sessions gauged how real learners responded to the E-Worksheet. In the small-scale trial ($n = 15$), students completed the tool in a 90-minute lesson and then rated its attractiveness and usability. Three weeks later, a larger group ($n = 30$) repeated the process under identical conditions. Both cohorts consistently awarded mean engagement scores above 89%, praising the seamless integration of graphics, formulas, and prompts. Minor suggestions (e.g., button placement, additional practice items) have already been incorporated into the prototype.

Learning effectiveness

A one-group pretest–posttest measured representational skills before and after instruction with the E-Worksheet. Baseline scores highlighted common challenges in visual, symbolic, and verbal modes. Immediately following the lesson, posttest performance showed substantial gains across all

Table 3.
Pretest–posttest results and effect sizes

Mode of Representation	Pretest (%)	Posttest (%)	Cohen's <i>d</i>	Effect
Visual	31.9	87.9	0.70	Medium
Symbolic	40.4	79.4	0.65	Medium
Verbal	42.3	80.2	0.69	Medium

three modes. Cohen's *d* effect sizes (visual 0.70; symbolic 0.65; verbal 0.69) fell into the medium range, confirming an educationally meaningful impact as shown in Table 3.

All of the results demonstrate that the multirepresentational E-Worksheet is validated as pedagogically robust, consistently engages students, and produces measurable improvements in probability representation skills. These findings support broader implementation and highlight the value of integrating visual, symbolic, and verbal modes within digital mathematics tools.

DISCUSSION

The multirepresentational E-Worksheet developed in this study has clear strengths in design, engagement, and learning outcomes. Expert reviewers praised its accuracy, alignment with national curriculum standards, and the seamless integration of visual, symbolic, and verbal components (Adie et al., 2020). Students responded enthusiastically, with engagement scores consistently above 89 percent across both small and large pilot groups, even within brief ninety-minute sessions. Their feedback emphasized how encountering a probability scenario in chart form, then as an equation, and finally in a written explanation helped ideas “click” in ways that single-mode tasks did not. The medium effect sizes (Cohen's $d \approx 0.68$) show that a single lesson can yield substantial gains in representational fluency, surpassing more modest improvements reported for conventional e-worksheets. Together, these results suggest that thoughtful scaffolding among representation modes enhances both motivation and conceptual mastery. The rapid development cycle (where each item was refined through expert feedback) also illustrates a practical method for producing high-quality digital learning materials.

From a theoretical perspective, these findings reinforce core principles of multimedia learning. Dual-coding theory holds that combining images and words forms richer memory traces (Paivio, 1991, 2013). Cognitive load theory explains that breaking complex ideas into interconnected visual, symbolic, and verbal segments reduces mental strain (Kalyuga & Singh, 2016; Sweller, 2011). In our worksheet, adaptive prompts guided attention toward essential features, encouraging active problem solving rather than passive acceptance and supporting germane cognitive load. This work extends previous research by demonstrating how these theories can be applied within a fully online worksheet environment rather than slide-based lectures or standalone simulations. It shows that multirepresentational scaffolding is more than a theoretical ideal and can lead to measurable classroom impact.

Comparisons with existing literature highlight the distinct advantages of our approach. Earlier studies found that image-rich worksheets improved visual reasoning but did not track gains in symbolic or verbal domains (Setiawati et al., 2021). Investigative E-Worksheet research reported benefits in critical thinking but did not link multiple representations in the same activity (Esen et al., 2023; Prasetya & Sugiyarto, 2023; Puspita & Dewi, 2021). Digital worksheets without explicit multirepresentational design achieved lower engagement scores in the low-80 percent range, suggesting that novelty alone cannot account for the higher scores we observed. In contrast, our tool intentionally weaves all three modes into each problem, requiring students to move among diagrams, equations, and explanations. This integration appears to create synergistic effects, with understanding in one mode reinforcing the others more strongly than when treated separately.

In practical terms, these results offer clear guidance for educators and curriculum planners. Teachers can adopt a similar multirepresentational framework by designing digital tasks that link a chart, a formula, and a textual prompt around the same scenario. These principles are not limited to probability; they can enrich algebra, geometry, and statistics lessons as well. Professional development should include workshops that guide teachers through storyboard creation, platform

use, and the incorporation of adaptive prompts. School leaders should provide time and technical support for educators to pilot and refine their own worksheets. Over time, a community of practice could emerge to share templates and best practices across grade levels and subjects.

This study does have limitations that suggest directions for future work. The one-group pretest–posttest design did not include a control group, so we cannot definitively attribute learning gains to the multirepresentational design rather than novelty or instructor effects. Future research should compare this tool with traditional digital and print worksheets using randomized trials. Conducting the study in multiple schools and regions would strengthen generalizability. Longitudinal follow-up studies could examine whether gains in representation skills persist over weeks or transfer to new mathematical topics. Finally, investigating how individual differences, such as working memory capacity or prior content knowledge, interact with multirepresentational scaffolding will help tailor interventions for diverse learners. By addressing these questions, the field can refine and scale multirepresentational strategies to maximize student understanding.

CONCLUSIONS

This study investigated a multirepresentational electronic worksheet on probability that integrates diagrams, equations, and written explanations. Expert reviewers confirmed that the worksheet met high standards for content accuracy, curriculum alignment, and user interface design. The validation process involved subject-matter experts, media specialists, and psychometricians who assessed the E-Worksheet in terms of mathematical accuracy, curricular relevance, clarity of representation transitions, interface design, and item quality in the accompanying assessment. The experts provided constructive feedback, such as simplifying technical language and enhancing the flow of activities, which led to several revisions before final implementation. These validation outcomes confirm that the worksheet not only meets high educational standards but is also pedagogically sound and user-friendly. Student engagement consistently exceeded eighty-nine percent in both small- and large-scale pilots, demonstrating strong receptivity to the integrated format. Following a single ninety-minute lesson, learners exhibited notable gains in visual, symbolic, and verbal representation skills. Effect size calculations revealed medium-level improvements, indicating meaningful educational impact within a limited instructional period. The scaffolded transitions among representation modes appeared to support rapid concept construction. Development processes that included layered storyboarding and iterative expert feedback ensured clarity and cohesion across tasks. These results confirm the feasibility of implementing such a tool in regular classroom settings. Overall, the multirepresentational worksheet proved effective at enhancing students' understanding of probability concepts.

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AUTHOR'S DECLARATION

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|---|---|--|
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