

ETHNOMATHEMATICS AND DIGITAL TECHNOLOGY INTEGRATION IN PROBABILITY INSTRUCTIONAL DESIGN: DEVELOPMENT AND FEASIBILITY STUDY FOR EIGHTH-GRADE MATHEMATICS

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Abstract

This study addresses the weak probabilistic reasoning of Indonesian junior high school students, the most challenging competency within the Data and Uncertainty domain, by developing an ethnomathematics-based instructional design integrated with digital technology. Using a research and development approach guided by the Dick and Carey model combined with Merrill's First Principles of Instruction, three traditional games containing authentic probabilistic structures Hompimpa, Dadu Koprok, and Congklak were transformed into a hierarchical learning sequence on the NumerasiBudaya e-learning platform. Data were gathered through needs-assessment interviews, expert validation, and a one-group pretest-posttest trial involving 24 eighth-grade students at SMP Labschool Cirendeu. Expert review indicated very high feasibility (97,33%), while the trial revealed a moderate gain in numeracy literacy (N-Gain = 0.399; $t(23) = 5.297$, $p < .001$, Cohen's $d = 1.081$). These findings suggest that culturally grounded, technology-integrated instructional design can meaningfully support junior high school students' probabilistic reasoning development.

Keywords: ethnomathematics; probability; instructional design; digital technology; numeracy literacy

INTRODUCTION

Numeracy is an individual's ability to read, use, and apply numbers and mathematical concepts to solve everyday problems, involving not only computational skills but also the ability to think logically, solve contextual problems, and make decisions based on numerical data (Dwirahayu et al., 2023; Purwanti et al., 2023). However, Indonesian students' numeracy literacy levels remain relatively low. The 2022 PISA results show that only 18% of Indonesian students reached the minimum level of mathematical proficiency (Level 2), far below the OECD average of 69% (OECD, 2023). This situation is further underscored by data from the 2023 Indonesian Education Report, which references the 2022 National Assessment, where the percentage of junior high school (SMP/MTs) students achieving numeracy competencies above the minimum level was only 40.63%.

Weaknesses in numeracy are most evident in the "Data and Uncertainty" domain, particularly in the topic of probability, which requires probabilistic reasoning, the interpretation of the probability of an event, and data driven decisionmaking competencies that most students have not yet mastered. Sari et al. (2023) found that students' greatest errors occur during the mathematical modeling stage of contextual situations; specifically, students are unable to identify mathematical structures in real-world situations and fail to translate contextual problems into formal mathematical models. These findings are also consistent with the research by Payadnya, Suwija, and Wibawa (2021), who analyzed junior high school students' ability to solve realistic math problems using the "What-If" ethnomathematics instrument: of the four types of errors identified, reasoning errors were the most common, accounting for 69.56% of all students, followed by errors in answering "What-If" questions at 65.21%. The study also found that teachers tend to focus their instruction on the presentation and application of formulas, while neglecting conceptual understanding and the development of students' problem solving skills based on realistic mathematical problems. These macro level findings are consistent with the actual conditions on the ground. The results of needs assessment interviews conducted with three 8th-grade mathematics teachers at SMP Labschool Cirendeu indicate that the learning process is still dominated by teacher-led explanations (PPT-based lectures) and routine practice (drilling on problems), while independent exploration through Student Worksheets (LKPD) based

on contextual problems is still rarely practiced; Student participation tends to be more active during problem-solving exercises than during concept-explanation sessions. All three teachers consistently stated that, of the four numeracy domains in the AKM framework (Numbers, Geometry & Measurement, Algebra, and Data & Uncertainty), reasoning is the most difficult cognitive level for students to master, whereas the “knowing” and “applying” levels are relatively easier because they require only an understanding of basic concepts and the substitution of formulas. Specifically, the domain of Data and Uncertainty which includes probability is identified as one of the most challenging areas, particularly in determining the sample space and interpreting the meaning of probability results in word problems; students tend to be able to perform calculations procedurally but struggle when they must model contextual situations into mathematical representations and reinterpret the results of their calculations within the context of the problem. Teachers also reported that the use of local cultural contexts in mathematics instruction has not yet been implemented on a regular basis; so far, it has only appeared occasionally in practice problems themed around batik or traditional games such as congklak, and has never been specifically developed for probability lessons. On the other hand, the three teachers have utilized various digital technologies such as GeoGebra, Desmos, Quizizz, and Gimkit for geometry and algebra lessons; however, the use of these technologies has not yet been directed toward probabilistic simulations or the visualization of cultural contexts in probability instruction.

Within the AKM and PISA numeracy literacy framework, student competencies are measured through three fundamental processes: formulate (formulating situations into mathematical models), employ (applying mathematical concepts, facts, procedures, and reasoning), and interpret (interpreting and evaluating mathematical results in context). Learning practices that remain predominantly procedural tend to focus solely on mechanically training the “employ” aspect, without providing students with sufficient opportunity to systematically develop their “formulate” and “interpret” skills. Ethnomathematics offers a strategic approach to addressing this gap. By using local cultural practices as a context for learning, ethnomathematics enables students to build mathematical understanding from familiar and meaningful experiences, while acknowledging that mathematics is a sociocultural construct rather than a discipline that is neutral and free of cultural values (Rosa & de Oliveira, 2020). Various local cultural contexts in Indonesia have been shown to contain rich mathematical structures that can be used as learning resources. Hanik, Efendy, Jannah, and Fatmawati (2024), for example, explored mathematical activities in the traditional salt-making process in Madura and identified elements of probability in the activity of “playing,” namely when salt farmers estimate the likelihood of a successful or failed harvest based on weather conditions an authentic probabilistic practice that has not yet been utilized as a context for teaching probability in schools. Similarly, Wiryanto, Primaniarta, and de Mattos (2022) show that the Javanese tradition of tedhak siten incorporates concepts of numeracy and geometry that can be integrated into junior high school mathematics instruction through calculating the dates of ceremonies and exploring the shapes of ceremonial implements.

Other empirical studies have also shown the positive impact of integrating ethnomathematics with technology and certain learning models. Kamid, Rohati, Kurniawan, Perdana, Chen, and Wulandari (2021) demonstrated that the integration of ethnomathematics with the TPACK (Technological, Pedagogical, Art, Content, and Knowledge) framework, combined with the Problem-Based Learning (PBL) model, resulted in higher learning outcomes in social arithmetic compared to ethnomathematics instruction without such integration. It also makes learning more flexible because students can directly observe and visualize what the teacher is explaining. These findings confirm that a combination of cultural context, systematic instructional models, and technological support can measurably enhance mathematics learning outcomes.

Nevertheless, a review of the ethnomathematics research corpus in Indonesia shows that the majority of studies including those on salt production in Madura, batik motifs in Yogyakarta, the Javanese tedhak siten tradition, and the integration of TPACK into social arithmetic remain concentrated on topics such as geometry, algebra, sets, or social arithmetic. No research has yet been found that specifically develops learning programs for probability by utilizing local cultural practices that naturally incorporate probabilistic elements, such as traditional games based on randomness, systems for determining auspicious days, or risk estimation in traditional agricultural and production activities, as found in the context of salt production in Madura. This situation stands in contrast to the urgency highlighted by the 2022 PISA and 2022 National Assessment data, in which the “Data and Uncertainty” domain was, in fact, the most prominent area of weakness. Based on this gap, this study aims to develop a mathematics instructional design that integrates the ethnomathematics approach with digital technology to improve junior high school students’ probabilistic reasoning skills. The novelty of this research lies in three aspects: first, the use of a local cultural context that incorporates probabilistic elements as an authentic basis for teaching probability; second, the systematic development of instructional design using the Dick & Carey model combined with Merrill’s First

Principles of Instruction; and third, the strategic integration of digital technology to support probabilistic simulations and the visualization of cultural contexts relevant to probability concepts.

METHOD

Research Design, Time, and Setting

This research and development (R&D) study developed a digital technology assisted, ethnomathematics based mathematics instructional design for eighth-grade probability material, employing the ten-stage Dick and Carey model (2015) combined with Gagne's Nine Events of Instruction as the syntax and Merrill's First Principles of Instruction as the pedagogical strategy. A mixed-methods approach was adopted (Creswell & Plano Clark, 2018): qualitative data were used for the needs analysis and formative evaluation, while quantitative data were used to assess theoretical feasibility (expert rating scale) and initial effectiveness (within-group N-Gain, without a control group). The study was conducted from January to October 2026 at SMP Labschool Cirendeu, selected purposively for its adequate digital facilities, the cultural diversity of its students, teachers' openness to innovation, and the school's full support.

Development Procedure

The procedure followed the ten stages of the Dick and Carey model: (1) identifying instructional needs through interviews covering six indicators with three teachers and an analysis of two textbooks, neither of which contained probability material, yielding one General Instructional Objective; (2) instructional analysis resulting in a Hierarchical Competency Map (Specific Instructional Objectives, TIK 1–12); (3) analysis of learners and contexts (entry behavior); (4) operationalization of the TIK (Bloom's C2–C6; the PISA formulate employ interpret processes); (5) development of summative assessment and process-evaluation instruments; (6) development of the instructional strategy (Gagne's Nine Events combined with Merrill's five principles); (7) development of materials and products (lesson plans/RPP, three student worksheets/LKPD, and the NumerasiBudaya platform); (8) formative evaluation (expert review in three fields, one-to-one, small-group, and field trials); (9) instructional revision; and (10) model effectiveness (pretest–posttest N-Gain in the field-trial group). Overall feasibility was synthesized from theoretical feasibility (expert scores) and empirical feasibility (trial responses), covering Stages 1–9.

Subjects and Research Instruments

Expert review was conducted by three reviewers according to their fields (instructional design, mathematics content, and media) from February to June 2026; the same three mathematics teachers served as both needs-analysis informants and practicality reviewers. User trials were conducted in stages: 5 students (one-to-one), 10 students (small group), and 30 students from Class VIII C (field trial); after data verification, 24 of the 32 students on the roster were analyzed for effectiveness. The instruments comprised: a semi-structured interview guide for the needs analysis and formative evaluation; an Expert Rating Scale (1–5, with a critique-and-suggestion column) for theoretical feasibility; a probability-numeracy-literacy pretest-posttest (15 items, five item formats, maximum score of 100, 60-minute duration, proportioned across the Knowing, Applying and Reasoning levels); and an LKPD rubric (0–5 scale) together with a discussion observation sheet for process assessment.

Data Analysis Techniques

Qualitative data were analyzed descriptively through data reduction, display, and verification, with source triangulation (Miles, Huberman, & Saldaña, 2014). Expert rating-scale data are typically converted to a feasibility percentage using the formula:

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

Categorized from very feasible (81–100%) to not feasible (0–20%) (Riduwan, 2015). Effectiveness was analyzed using the Normalized Gain (Hake, 1999):

$$N - \text{Gain} = \frac{\text{Posttest} - \text{Pretest}}{\text{Maximum} - \text{Pretest}}$$

categorized as high ($g \geq 0.70$), medium ($0.30 \leq g < 0.70$), and low ($g < 0.30$), reinforced with a paired-samples t-test and Cohen's d. All effectiveness analyses were within-group (field-trial group), without comparison data from a control group.

RESULTS AND DISCUSSION

Results of the Needs Analysis and Instructional Objectives

A needs analysis conducted through interviews with three 8th-grade mathematics teachers at Labschool Cirende Junior High School confirmed that reasoning skills in the Data and Uncertainty domain particularly the topic of probability are the most challenging for students to master, especially when determining sample spaces and interpreting probability results in contextual problems; meanwhile, the local cultural context has never been specifically utilized for this topic. These findings, combined with the results of instructional analysis and analysis of student characteristics, form the basis for formulating the general instructional objective, namely to improve junior high school students’ probabilistic reasoning skills through an ethnomathematics-based instructional design that integrates digital technology, Traditional games with elements of probability (Hompimpa, Dadu Koprok and Congklak) were identified as the primary cultural context because they are familiar to students, contain authentic mathematical structures of probability, and can be visualized digitally.

Hierarchical Competency Map and Specific Instructional Objectives (TIK 1–12)

Instructional analysis decomposed the General Instructional Objective into a Hierarchical Competency Map (Table 1): TIK 1–3 (parallel prerequisites) converge on TIK 4, continuing linearly to TIK 5–7 through the Hompimpa/Dadu Koprok context (Session 1); TIK 8–9 (parallel) are prerequisites for TIK 10, continuing to TIK 11–12 (terminal competencies) through the Congklak context (Session 2). This structure progressively reflects the three PISA/AKM numeracy-literacy processes TIK 1–4 formulate, TIK 5–9 employ, TIK 10–12 interpret moving from the applying level toward reasoning, consistent with the principal

Table 1. Specific Instructional Objectives (TIK) for Eighth-Grade Probability Material

TIK	Brief Statement	Bloom	PISA Process	Session
1	Identifying the cultural context (Hompimpa/Dadu Koprok) as a random experiment	C2	Formulate	1
2	Sorting relevant information from the contextual stimulus	C4	Formulate	1
3	Formulating event A in set notation	C3	Formulate	1
4	Constructing sample space S and finding the pattern $n(S) = k^n$	C4	Formulate	1
5	Determining $n(A)$ from the sample space	C3	Employ	1
6	Calculating $P(A) = n(A)/n(S)$, verified through simulation	C3	Employ	1
7	Applying the expected-frequency formula $= n \times P(A)$	C3	Employ	1
8	Calculating the union probability $P(A \cup B)$	C4	Employ	2
9	Calculating the complement probability $P(A') = 1 - P(A)$	C3	Employ	2
10	Evaluating the fairness of a probability distribution	C5	Interpret	2
11	Interpreting probability values into culturally contextual statements	C5	Interpret	2
12	Constructing a written probabilistic argument (Claim-Evidence-Analysis-Conclusion)	C6	Interpret	2

Product Development

The strategy and instructional materials development phase resulted in an integrated suite of products, consisting of: the NumerasiBudaya e-learning platform and its courses “Peluang: Probability Lab”, a guidebook (Buku Panduan Numerasi Budaya), three Student Worksheets (LKPD Hompimpa, LKPD Dadu Koprok, dan LKPD Congklak), a Lesson Plan (RPP) based on a hierarchical competency map, pretest-posttest instruments, as well as assessment rubrics for the worksheets and discussion observations. The learning platform can be accessed at numerasibudaya.id while supporting documents (handbooks, worksheets, lesson plans, and assessment tools) can be accessed at:

<https://drive.google.com/drive/folders/1Vg3ROHtu0EhE67-SRh81QpT6a-tWnZlr?usp=sharing> .

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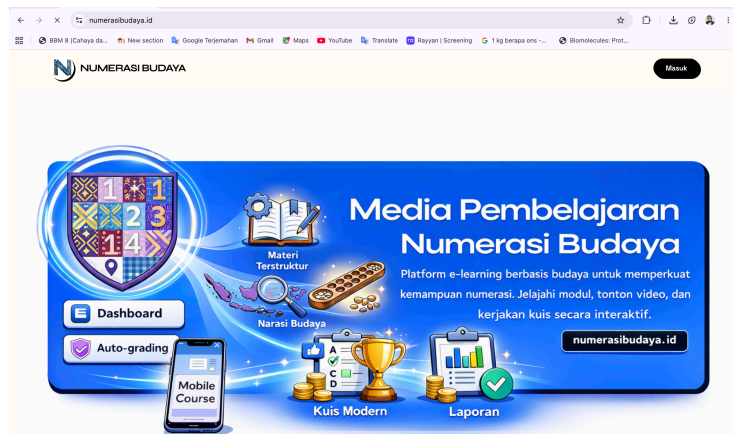
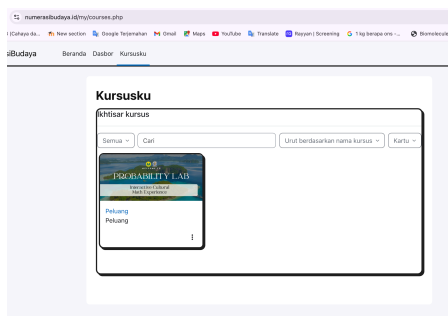
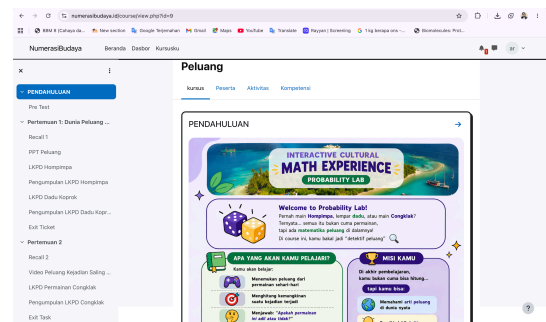


Figure 1. Home page of the NumerasiBudaya learning platform (numerasibudaya.id)

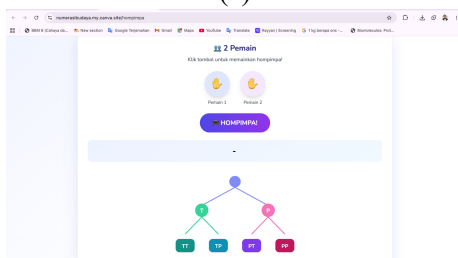
The results of the strategy and instructional materials development phase took the form of a digital learning design implemented on a culture-based e-learning platform called numerasibudaya.id. This platform offers seven main features that map Dick and Carey's components to digital media, namely structured content, cultural narratives (contextualization of ethnomathematics), modern quizzes with auto-grading and reports (to develop assessment tools and monitor formative evaluations), a dashboard for tracking learning progress, and mobile access to courses to support the flexibility of digital technology, as emphasized by Kilbane and Milman (2014).



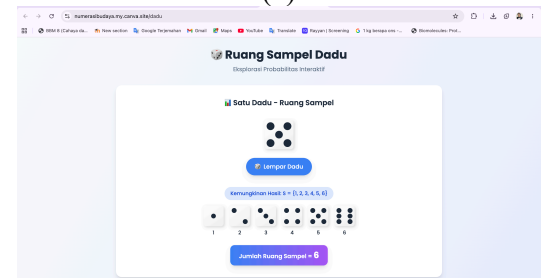
(a)



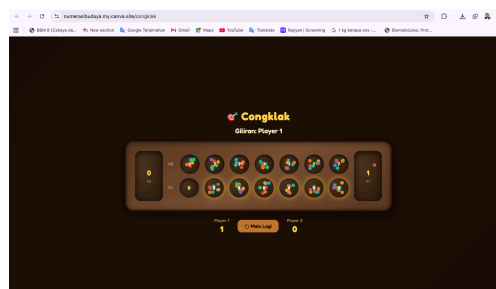
(b)



(c)



(d)



(e)

Figure 2. (a) The “Kursusku” page displays course; (b) The course structure on the numerasibudaya.id platform; (c) An interactive Hompimpa simulation; (d) An interactive simulation of a die’s sample space; (e) An interactive Congklak board simulation.

On this platform, a course titled “Peluang: Probability Lab Interactive Cultural Math Experience” consisting of one introductory session (Pre Test) and two core sessions. Session 1 (“Dunia Peluang”) includes Recall 1, a Probability PowerPoint presentation, the “Hompimpa” worksheet, the “Koprok Dice” worksheet, and an Exit Ticket; Session 2 includes Recall 2, a video on mutually exclusive events, the “Congklak” game worksheet, and an Exit Task. Each session includes an online assignment submission feature (Pengumpulan LKPD) that is linked to the auto grading system and reports on the teacher’s dashboard.

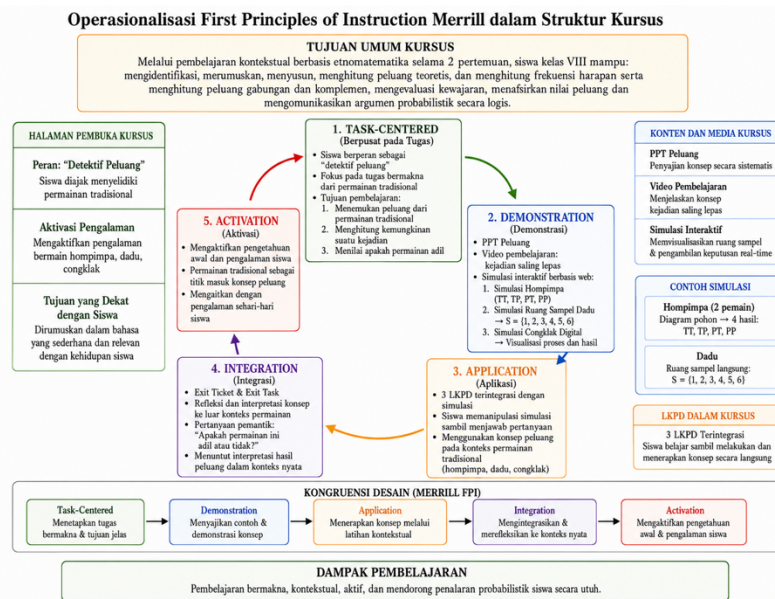


Figure 3. Structure of the “Peluang: Probability Lab” course on the NumerasiBudaya platform

The course structure explicitly applies Merrill’s five First Principles of Instruction. The Task-Centered and Activation principles are embodied on the course’s opening page, which invites students to take on the role of “detektif peluang” and using games such as “hompimpa,” dice, and “congklak” as entry points to the concept of probability, while formulating learning objectives in language that students can relate to (identifying probability in traditional games, calculating the likelihood of an event, and assessing whether a game is fair). The Demonstration Principle is implemented through the “Opportunities” PowerPoint presentation, an educational video on independent events, and three web-based interactive simulations (“rock-paper-scissors,” “dice sample space,” and “digital congklak board”) that visualize the sample space and the decision-making process in real time; for example, the “rock-paper-scissors” simulation displays a two-player decision tree that yields four possible outcomes (TT, TP, PT, PP), while the dice simulation directly displays the sample space $S = \{1, 2, 3, 4, 5, 6\}$ each time the “Roll Dice” button is pressed. The Application Principle is embodied through three worksheets that are directly integrated with these simulations, allowing students to manipulate the simulation while answering the worksheet questions. The Integration Principle is embodied through the Exit Ticket and Exit Task, which encourage students to reflect on their understanding of probability concepts beyond the game context, including through the reflective question “Is this game fair or not?”, which requires interpreting the results of probability calculations in a real-world context rather than merely applying formulas mechanically.

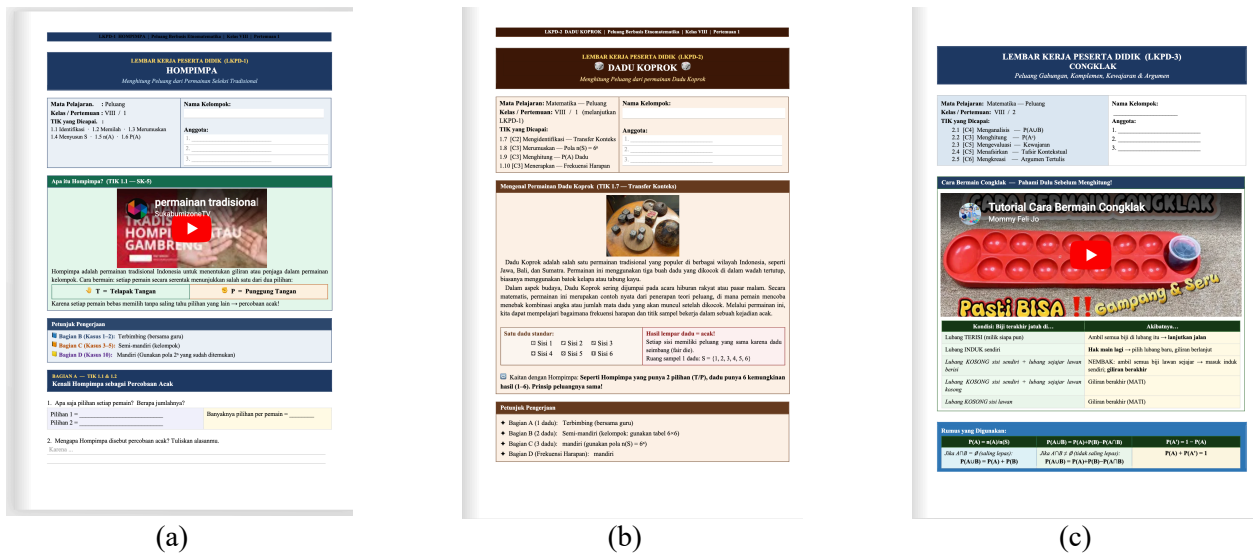


Figure 7. (a) LKPD-1 Hompimpa; (b) LKPD-2 Dadu Koprok; (c) LKPD-3 Congklak.

All three worksheets were designed with a hierarchical progression of Specific Instructional Objectives, consistent with the Dick and Carey (2015) principle of instructional analysis that emphasizes ordering sub-skills from simple to complex. LKPD-1 (Hompimpa) focuses on SIO level C2–C3 (identifying, sorting, formulating, constructing sample space S , calculating $n(A)$, and $P(A)$) using a two-choice game context (palm/back of hand), with a tiered task scheme: a teacher-guided part, a semi-independent group part, and an independent part using the pattern that has been discovered.

LKPD-2 (Dadu Koprok) continues at a more complex TIK level C2–C3 (transferring the context, formulating the pattern $n(S) = 6^n$, calculating $P(A)$, and applying expected frequency), and explicitly bridges students’ prior knowledge by stating that “just as hompimpa has 2 choices (palm/back of hand), a die has 6 possible outcomes (1–6); the probability principle is the same” a concrete example of applying Merrill’s Activation principle.

LKPD-3 (Congklak), used in Session 2, requires higher-order thinking at TIK level C4–C6 (analyzing the union probability $P(A \cup B)$, calculating the complement probability $P(A^c)$, evaluating the fairness of a game, interpreting results contextually, and constructing a written argument), drawing on the logic of the congklak game (filled holes, the home/store hole, and empty holes) as the basis for combined-probability reasoning. This progression from C2 to C4–C6 directly responds to the needs-analysis finding that reasoning and the interpretation of probability results are students’ principal weaknesses.

Results of Formative Evaluation, Feasibility, and Initial Effectiveness

Theoretical feasibility was measured through the assessments of three Expert Reviewers in their respective fields from March to June 2026: Prof. Dr. Benny Agus Pribadi, M.A. (Universitas Terbuka) as the Instructional Design Expert Reviewer (ERDP), Prof. Dr. Sugilar, M.Pd. (Universitas Terbuka) as the Mathematics Content Expert Reviewer (ERM), and Dr. Mario Emilzoli, M.Pd. (Universitas Pendidikan Indonesia) as the Media Expert Reviewer (ERMD), using an Expert Rating Scale (1–5) analyzed as a feasibility percentage and categorized according to Riduwan’s (2015) criteria.

Table 2. Validation Results of the Instructional Design Expert Review (ERDP)

Aspect	Percentage	Category
Instructional Characteristics and Design (Merrill's Framework)	100%	Very Feasible
Instructional Strategy (Gagne's Nine Events & Merrill's FPI)	100%	Very Feasible
Language and Communication	100%	Very Feasible
Practicality	90%	Very Feasible
AVERAGE	99%	Very Feasible

Table 3. Validation Results of the Mathematics Content Expert Review (ERM)

Aspect	Percentage	Category
Mathematics Content and Material (including dichotomous items)	97,50%	Very Feasible
Ethnomathematics	90%	Very Feasible
Language and Communication	100%	Very Feasible
AVERAGE	94,67%	Very Feasible

Table 4. Validation Results of the Media Expert Review (ERMD)

Aspect	Percentage	Category
Digital Technology	100%	Very Feasible
Language and Communication	100%	Very Feasible
Visual	95%	Very Feasible
AVERAGE	98.33%	Very Feasible

All three Expert Reviewers rated every aspect as Very Feasible (Tables 2–4), with an overall mean of 97,33% across the ERDP (99%), ERM (94,67%), and ERMD (98.33%). Two minor notes (a score of 4 out of 5) arose regarding the practicality of the two-session time allocation (ERDP) and the readability of font/text contrast (ERMD), though neither lowered the overall feasibility category. Qualitatively, all three experts judged the instructional design comprehensive and the NumerasiBudaya platform to have met all required components, suggesting the addition of a learning-analytics feature as a recommendation for further development beyond the scope of this study.

Table 5. Summary of Empirical Feasibility Across the Three User-Trial Stages

Stage	Subjects	Outcome
One-to-One	5 students	Understood the learning objectives; the LMS was rated attractive and easy to operate; no significant technical problems.
Small Group	10 students	Most students agreed/strongly agreed; the Dadu Koprok simulation was perceived as helpful; discussion assisted confused students.
Field Trial	30 students	Procedural errors decreased compared with the small group; student impressions were positive; auto-save prevented data loss.

Theoretical feasibility (99.11%) and empirical feasibility (positive responses across all three trial stages) reinforced one another, indicating that the product is feasible for use as instructional material on probability within the Data and Uncertainty domain. Initial effectiveness was measured through N-Gain in the field-trial group (Class VIII C) using the probability-numeracy-literacy instrument (15 items, maximum score of 100). Of the 32 students on the roster, data verification yielded 24 students with complete pretest-posttest data for analysis; the remaining students were excluded for incomplete test participation, non-completion status, or because they could not be identified on the roster. The N-Gain results are presented in Tables 6–7.

Table 6. N-Gain Pretest-Posttest Results for Class VIII C (N = 24)

Statistic	Value
Mean Pretest	35.13
Mean Posttest	60.99
Mean Gain (Posttest – Pretest)	25.86
Mean N-Gain (individual average)	0.390
N-Gain of class mean (Hake’s method)	0.399
N-Gain Category	Medium

Table 7. Distribution of Individual N-Gain Categories for Class VIII C (N = 24)

N-Gain Category	Number of Students	Percentage
High ($g \geq 0.70$)	7	29.2%
Medium ($0.30 \leq g < 0.70$)	6	25.0%
Low ($g < 0.30$)	11	45.8%
TOTAL	24	100%

The mean score increased from 35.13 (pretest) to 60.99 (posttest), with an N-Gain of 0.399 (Medium category). At the individual level: 7 students (29.2%) reached the High category, 6 students (25.0%) the Medium category, and 11 students (45.8%) the Low category, indicating wide variation in improvement. A paired-samples t-test and Cohen’s d, presented as a complementary analysis, are reported in Table 8.

Table 8. Paired-Samples t-Test and Effect Size Results for the Pretest-Posttest, Class VIII C

Statistic	Value
t value	5.297
Degrees of freedom (df)	23
p value (2-tailed)	0.0000224 ($p < .001$)
Cohen’s d	1.081 (large effect)

The pretest-posttest difference was statistically significant ($t = 5.297$; $df = 23$; $p < .001$) with Cohen’s $d = 1.081$, classified as a large effect (Cohen, 1988). These results are within-group (one-group pretest-posttest) without a comparison control group; interpretation of the N-Gain variation and design limitations are presented in the Discussion.

CONCLUSION

This study has produced an ethnomathematics-based mathematics instructional design integrated with digital technology for eighth-grade probability material, developed through the ten-stage Dick and Carey model combined with Merrill’s First Principles of Instruction. Three traditional games containing authentic probabilistic structures Hompimpa, Dadu Koprok, and Congklak were organized into a hierarchical sequence of twelve Specific Instructional Objectives (TIK 1–12), progressing from the formulate and employ levels (C2–C3) toward the interpret level (C4–C6), and were implemented through the NumerasiBudaya e-learning platform together with its supporting lesson plans, worksheets, and assessment instruments. Theoretical feasibility, validated by three experts in instructional design, mathematics content, and media, reached an average of 97,33% in the Very Feasible category, and was reinforced by consistently positive responses across the one-to-one, small-group, and field-trial stages of empirical testing. The initial effectiveness trial further indicated a moderate improvement in students’ probability-related numeracy literacy (N-Gain = 0.399), with a statistically significant pretest-posttest difference and a large effect size ($t(23) = 5.297$, $p < .001$, Cohen’s $d = 1.081$). These findings indicate that an instructional design grounded in authentic local cultural practices, structured systematically, and supported by digital simulation can serve as a feasible and promising alternative for strengthening junior high school students’ probabilistic reasoning within the Data and Uncertainty domain.

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