Enhancing Elementary Students' Digital Numeracy through a Moodle-Based Virtual Product Digital Learning System (VPDLS): Development, Gamification Design, and Practical Evaluation

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***Abstract*—Elementary mathematics education in Indonesia faces persistent challenges including low student digital numeracy and limited teacher capacity in digital pedagogy. This study developed and evaluated a Moodle-based Virtual Product Digital Learning System (VPDLS) integrating gamification to enhance students' digital numeracy while providing teachers with a practical tool for game-based instruction in resource-constrained contexts. Using a Research and Development approach with the ADDIE model, data were collected through validation sheets assessed by five experts, in-depth teacher interviews, questionnaires from 300 Grade 5 students and 15 mathematics teachers, and pretest-posttest assessments across five public schools in Cirebon Regency. Quantitative and qualitative analyses, including descriptive statistics, Wilcoxon signed-rank tests, and effect size calculation (r = 0.59), demonstrated the platform's high feasibility (S-CVI/Ave = 0.99), practicality (91.27%), and significant improvements in student learning outcomes (p < 0.001). The VPDLS core components, namely the Game Based Pedagogy Toolkit, Gamified Practice Engine, and lightweight web architecture, effectively support engaging, personalized, and structured learning. These findings have important implications for curriculum developers and policymakers, demonstrating that well-designed, gamified digital platforms can promote equitable and effective mathematics instruction. Overall, this study presents a scalable Moodle-based gamification model that enhances digital numeracy in elementary education while providing actionable guidance for teachers and decision-makers in implementing technology-supported pedagogy.**

***Keywords*—elementary education, digital learning system, digital numeracy, gamification, instructional design, mathematics education, Moodle**

I. Introduction

Elementary digital numeracy education in Indonesia faces persistent challenges: limited teacher competence in digital pedagogy [1, 2] and low student performance in digital numeracy [3–5]. While students exhibit strong interest in digital games, most existing platforms fail to leverage this potential for meaningful mathematical learning [6, 7]. Teachers often struggle to adopt game-based methods due to insufficient training, lack of resources, and the absence of integrated systems tailored to learners' developmental levels [8, 9]. Additionally, few platforms combine adaptive features with developmentally appropriate pedagogy that promotes engagement and conceptual understanding [10, 11].

Although tools such as Wordwall, Scratch, and LiveWorksheet offer basic gamified features, they lack adaptive difficulty, integrated analytics, and pedagogical scaffolding [12, 13]. Prior studies have confirmed the motivational value of gamified learning but often fall short in building digital numeracy skills [14, 15]. Moodle, as an open-source learning management system, holds significant potential for elementary education due to its flexibility and compatibility with tools like H5P and real-time progress tracking [16, 17]. Although Moodle is often associated with higher education, the participating schools had sufficient infrastructure, students were able to operate the platform effectively, and prior use of simpler gamified tools showed basic familiarity. In this study, Moodle was further adapted with simplified navigation, scaffolding, and gamified features, making it developmentally appropriate and supportive for elementary learners and teachers.

A preliminary needs analysis was conducted with 300 Grade 5 students and 15 mathematics teachers from five public elementary schools in Cirebon Regency. The findings indicated that 67% of teachers lacked competence in designing interactive digital content, and only 20% demonstrated the ability to connect gamified activities with curriculum objectives. From the student side, 72% reported using digital devices mainly for entertainment rather than structured learning, and fewer than 25% had prior experience with learning through gamified platforms. These conditions indicate an urgent need for a gamified learning platform that can simultaneously support teachers' pedagogy and enhance students' digital numeracy, with the present study focusing specifically on geometry as a foundational domain within elementary mathematics.

Despite the availability of various gamified tools, no prior research has developed a Moodle-based platform specifically targeting elementary students' digital numeracy in Indonesia. This study addresses four critical gaps: (1) teachers' limited digital pedagogy and lack of gamified practice resources (practical); (2) absence of Moodle-based gamification research for Indonesian elementary numeracy (contextual); (3) predominance of motivation-focused studies without adaptive pedagogy (theoretical); and (4) lack of classroom-tested dual-layer integration (methodological). To bridge these gaps, we developed the Virtual Product Digital Learning System (VPDLS), featuring three core components: a Game Based Pedagogy Toolkit offering micro-training

resources, an adaptive Gamified Practice Engine that personalizes learning paths, and a lightweight web architecture ensuring accessibility in low-connectivity environments.

The VPDLS platform integrates Moodle as the core LMS, managing course shells, quizzes, H5P activities, gradebook, and analytics, alongside a standalone Laravel-based gamification module hosted at vp-dls.com/gamifikasi. Operating in parallel, Moodle provides structured instructional management, while the Laravel module delivers gamification features, including 3D previews and interactive calculators, to enhance student learning. Although not technically integrated, the gamification module complements the main platform, reinforcing engagement and supporting differentiated learning paths. Designed as both a digital learning tool and a scalable pedagogical intervention, VPDLS aligns with national curricula and adapts to varied infrastructural conditions. This study systematically analyzed pedagogical needs, developed and validated the platform, and evaluated its practicality and effectiveness in classroom contexts, offering theoretical and practical contributions to technology-integrated elementary mathematics education [6, 18–20]. The dual-layer structure ensures flexibility, accessibility, and a coherent learning experience while promoting active, gamified, and curriculum-aligned numeracy instruction.

Unlike previous studies that have examined gamification in general mathematics learning [6, 7, 14, 15] or applied Moodle as a conventional Learning Management System (LMS) [16, 17, 21, 22], this study introduces a unique integration of Moodle with a gamified practice engine specifically designed to enhance elementary students' digital numeracy. While prior research often focused on engagement or motivation [12, 23], our approach advances the field by embedding adaptive difficulty levels, teacher-oriented pedagogical support, and a lightweight web architecture designed [19, 20].

The study addresses three research questions:

1) What is the competency profile of elementary school teachers in implementing game-based pedagogy?
2) How to design a gamification-based VPDLS that is gamified practice for student numeracy?
3) How do teachers perceive the practicality and usefulness of the Virtual Product-Digital Learning System (VPDLS) in enhancing game-based pedagogy and improving students' digital numeracy?

II. Literature Review

A. Moodle-Based Mathematics Learning Platforms

Moodle, an open-source LMS, offers structured tools for course design, assessments, and progress tracking, supporting self-paced and blended learning [24]. In mathematics, it enables interactive modules like H5P and GeoGebra, fostering conceptual understanding and individualized feedback [16, 21, 25, 26]. However, elementary students often struggle with text-heavy or abstract content lacking gamified scaffolds, leading to low engagement and superficial numeracy learning in Indonesia [17, 22, 27, 28]. These limitations highlight the need to integrate Moodle with practical, child-friendly gamification, motivating the development of VPDLS, which leverages Moodle's strengths while addressing its constraints through engaging and scaffolded digital learning experiences.

B. Gamification and Its Role in Enhancing Digital Numeracy

Gamification, through elements such as badges and immediate feedback, enhances motivation and learning outcomes [6]. In mathematics, it supports procedural fluency and conceptual understanding via repeated practice and experiential learning [7, 14]. Platforms like Wordwall, Quizizz, and Kahoot have improved engagement in drill-based tasks [12, 15, 23], yet they present limitations: Wordwall lacks structured learning paths and cumulative assessment [29], Kahoot emphasizes speed over depth [11], and Scratch, while creative, is not tailored for numeracy and depends on stable internet [13]. The VPDLS addresses these gaps by integrating a gamified practice engine and a lightweight web architecture designed to remain accessible on low-connectivity environments. This design situates gamification within geometry-focused digital numeracy, ensuring inclusive, scalable, and curriculum-aligned mathematics learning for elementary students.

C. Digital Numeracy in Elementary Education

Digital numeracy involves interpreting, manipulating, and applying mathematical concepts using digital tools. In Indonesia, low digital numeracy persists, particularly in rural and under-resourced schools [3, 5] contributing to weak STEM achievement, limited problem-solving skills, and susceptibility to misinformation [4, 30]. Fully online programs relying on passive content, such as videos or slides, often fail to foster deep understanding due to limited interactivity and feedback [10, 31]. In contrast, blended or hybrid approaches, combining technology with teacher-guided instruction, improve learning outcomes, especially when integrated with gamified practice and embedded assessments [32, 33]. The VPDLS builds on this evidence by combining adaptive digital numeracy tasks with teacher-supported modules, delivering content via lightweight, device-accessible platforms. This approach emphasizes not merely technological use but pedagogically thoughtful design, positioning VPDLS as an innovative framework to enhance digital numeracy and active learning in elementary education.

D. Pedagogical Innovation through the VPDLS Framework

Pedagogical innovation involves redesigning teaching to align with learners' needs and goals [18, 34] VPDLS advances this by embedding a Game-Based Pedagogy Toolkit with microtraining modules, instructional templates, and exemplars to support teachers in implementing gamified strategies effectively [8, 9]. Unlike platforms such as Canva [35], Doratoon [36], or Genially [37], which lack adaptivity and subject-specific structure, VPDLS integrates assessments and personalized feedback aligned with national curriculum goals, representing a novel, feasible, and scalable solution for enhancing digital mathematics instruction in elementary education.

III. Materials and Methods

A. Research Design

This study employed a Research and Development (R&D)

approach [38] to develop the VPDLS, a game-based platform for enhancing elementary students' digital numeracy. The R&D process involved iterative design, expert validation, and field testing to ensure the platform's validity and practicality. For impact evaluation, the research utilized a one-group pretest-posttest design, comparing students' numeracy skills before and after the VPDLS intervention to measure its effectiveness. A control group was not used due to practical constraints in accessing equivalent classroom settings with similar digital infrastructure and instructional conditions.

B. Framework: The ADDIE Model as Developmental Guide

The VPDLS architecture employed a dual-layer structure: Moodle as the core LMS managing course shells, H5P quizzes, gradebook, and analytics, and a Laravel-based gamification module deployed independently at vp-dls.com/gamifikasi. Without API or authentication integration, Moodle delivered structured instruction and assessments, while the Laravel module functioned as a standalone extension offering 3D previews, interactive calculators, and adaptive quizzes to reinforce numeracy skills. Development followed the ADDIE model [39], encompassing Analysis of learner needs, Design of pedagogy and interface, iterative Development with expert validation, classroom Implementation, and Evaluation of effectiveness and usability, ensuring alignment, structured flexibility, and continuous refinement. The stages of the ADDIE model are illustrated in Fig. 1 below.

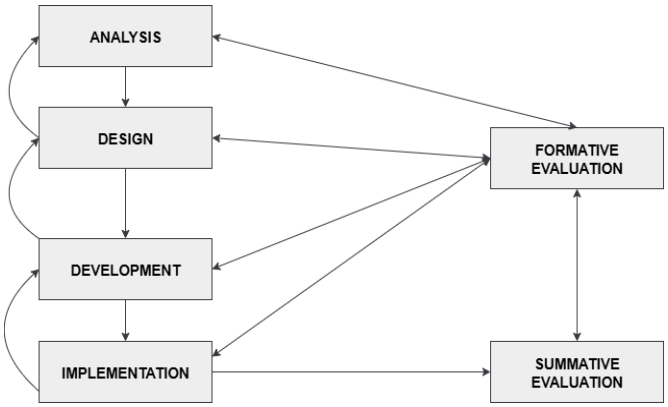

Fig. 1. ADDIE model.

C. Research Procedure

The study utilized the ADDIE development model to ensure a structured and iterative process across five phases: Analysis, Design, Development, Implementation, and Evaluation. The research procedure is visualized in Fig. 2.

1) Analysis phase

Classroom observations, teacher interviews, and student surveys were conducted to identify instructional needs. These findings informed the design of the VPDLS framework, which consisted of three core components: a pedagogical toolkit, a gamified practice engine, and a hybrid delivery model.

2) Design phase

Based on the needs analysis, a conceptual design was prepared, detailing how Moodle would serve as the core LMS and how gamification features would be embedded. Specific instructional strategies, user interface considerations, and technical specifications were outlined in this phase.

3) Development phase

A prototype of the platform was constructed and validated by experts to refine both content and interface. At this stage, the Laravel-based gamification engine functioned as a practice tool, offering five multiple-choice or short-answer items with automatic scoring. At this stage, item difficulty was static and manually assigned. The system did not yet adapt difficulty based on student performance; thus, it functioned as gamified practice rather than fully adaptive learning, the prototype demonstrated the feasibility of integrating gamification. The adaptive algorithm remained central to the VPDLS design, intended for future progression based on student performance thresholds.

4) Implementation phase

Pilot testing was carried out in schools, where teachers received training on how to use the platform. The prototype was made accessible primarily online, though offline features in the gamification module and Moodle integration were not yet fully developed. Students engaged with the VPDLS for four 60-minute sessions, while teachers received a two-hour training workshop. Implementation fidelity was monitored, and all five schools followed the designed procedures with minor variations.

5) Evaluation phase

The platform was evaluated through expert judgments, user feedback, and classroom observations. Findings from this stage informed revisions and provided direction for future enhancements, particularly the inclusion of low capabilities. Planned improvements include the adoption of Moodle Mobile caching or Progressive Web App strategies to expand accessibility and inclusivity across diverse school contexts.

D. Participants

The participants of this study were selected using purposive sampling, based on accessibility, school readiness for digital implementation. A total of 300 Grade 5 elementary students (aged 10–11) and 15 mathematics teachers from five public elementary schools in Cirebon Regency were involved throughout the research. Teachers were chosen for their willingness to participate in innovation-based instruction, and students represented a mix of urban and semi-urban school profiles. Before the study began, all participants and school administrators received detailed explanations of the research objectives, procedures, and ethical considerations. Parental consent was obtained for all student participants, and anonymity and data confidentiality were strictly upheld throughout the research process in accordance with ethical standards of educational research. This research was submitted for IRB approval by the Institute for Research and Community Service (LPPM) of the Prima Bangsa Institute and approved on June 7, 2024. The IRB Approval ID number is 001/SKP2/LPPM-IPBCIREBON/VI/2025.

E. Data Analysis

Data analysis in this study evaluated the feasibility, practicality, and effectiveness of the VPDLS platform in authentic classroom contexts. Feasibility was assessed through expert evaluations by a panel of five specialists (three

content experts and two media experts) using validation sheets with 14 items rated on a 4-point Likert scale. Content validity was quantitatively established using the Content Validity Index (CVI), with both item-level (I-CVI) and scale-level (S-CVI/Ave) calculations following Polit *et al.* [40], where scores ≥0.80 and ≥0.90 respectively indicate excellent validity. Final feasibility scores were converted into percentages following Arikunto [41], where 81–100% is classified as Very Feasible. Practicality was examined through teacher and student questionnaires. The teacher questionnaire included 18 items across four dimensions (motivation, activity design, learning improvement, and engagement) on a 4-point scale. The questionnaires demonstrated high internal consistency ($\alpha = 0.91$ for teachers). Data were interpreted using Lestari & Yudhanegara [42], where scores of 81–100% indicate Very Practical.

Effectiveness was analyzed using pretest–posttest data from 300 students on a 15-item geometry-focused digital numeracy assessment that showed good reliability ($\alpha = 0.78$). Scores were dichotomously coded (1 = correct, 0 = incorrect) with a maximum of 15 points. Due to the non-normal distribution of data and purposive sampling, the Wilcoxon Signed-Rank Test was used to determine statistical significance. Effect size was calculated using the Wilcoxon r formula ($(r = \frac{|z|}{N}$), following Cohen's convention: $r \approx 0.1$ small, $r \approx 0.3$ medium, $r \geq 0.5$ large [43]. These benchmarks provided clear, objective interpretations confirming that the VPDLS platform is both implementable and capable of significantly improving elementary students' digital numeracy skills while maintaining alignment with pedagogical and usability standards.

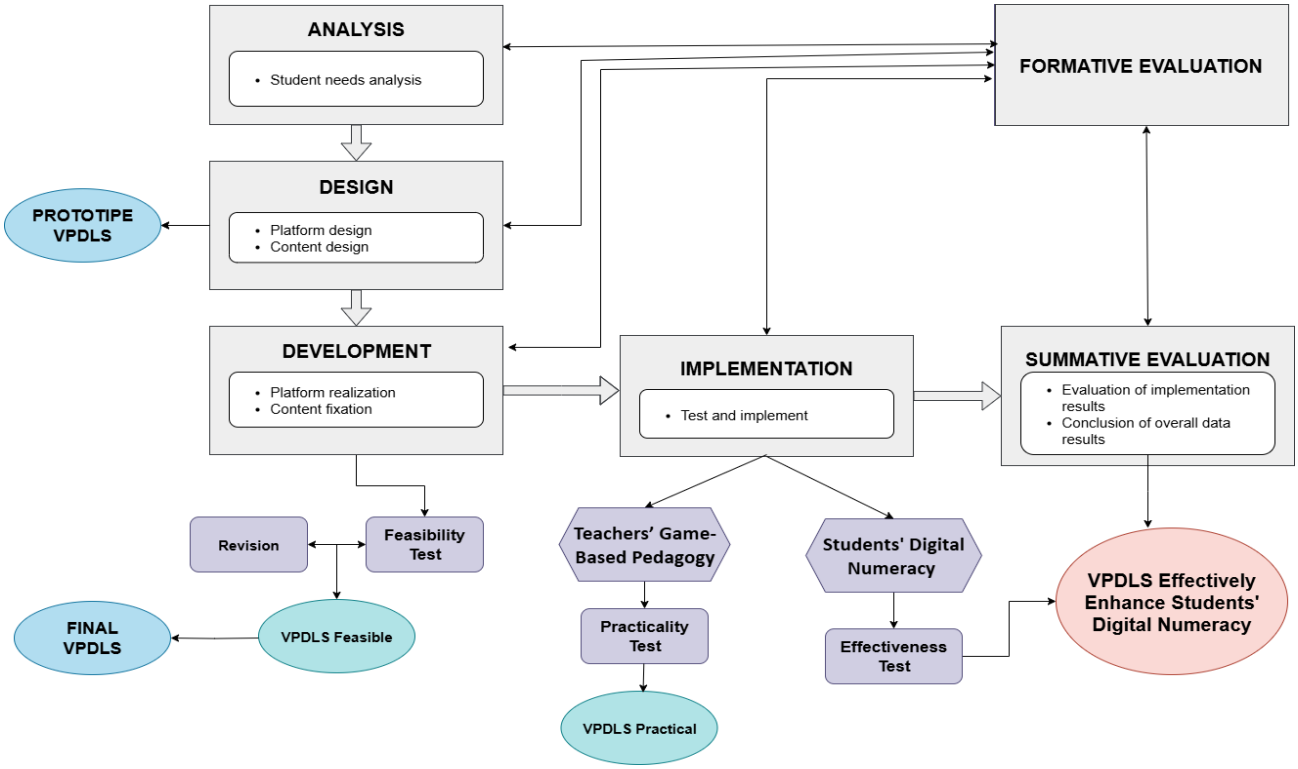

Fig. 2. Research procedure.

F. Instruments

The study employed both quantitative and qualitative instruments developed and validated to address the research questions. Data collection involved interviews, validation sheets, questionnaires, and a digital numeracy test. To address the First Research Question (RQ1) on teachers' competency profiles, semi-structured interviews were conducted with all 15 participating teachers. The interview protocol was adapted from the Technological Pedagogical Content Knowledge (TPACK) framework [44], focusing on their ability to design, implement, and align game-based strategies with mathematics curriculum objectives. The Second and Third Research Questions (RQ2 & RQ3), concerning the design, practicality, and effectiveness of the VPDLS, were examined using the following instruments:

1) Expert validation sheets

Two distinct 14-item sheets were used to assess feasibility, one for content experts and another for media/instructional design experts. Items were rated on a 4-point Likert scale (1 = Not Feasible to 4 = Very Feasible). The validation process was strengthened by a panel of five experts (two mathematics education lecturers, two media experts, and one master teacher) to ensure robust content validity. The Item-Content Validity Index (I-CVI) and Scale-Content Validity Index/Average (S-CVI/Ave) were calculated, yielding excellent scores of 0.99 for both sheets, confirming each item's relevance and the overall instrument's validity.

2) Practicality questionnaires

Separate questionnaires measured practicality for teachers (18 items), rated statements on a 4-point agreement scale (1 = Strongly Disagree to 4 = Strongly Agree). The questionnaires demonstrated high internal consistency, with Cronbach's alpha of 0.91 for teachers.

3) Digital numeracy assessment

A 15-item multiple-choice test was administered as pre-test and post-test. The test was designed with a blueprint

aligned to the Indonesian Minimum Competency Assessment (AKM) [45], mapping items to key digital numeracy facets: Interpreting (5 items), Applying (6 items), and Reasoning (4 items). The assessment showed good content validity (S-CVI/Ave = 1.00) and acceptable reliability (α = 0.78). Items were dichotomously scored (1 = correct, 0 = incorrect), with a maximum score of 15.

IV. Result and Discussion

A. Result

1) Research Question 1: What is the competency profile of elementary school teachers in implementing game-based pedagogy?

Based on in-depth interviews with 15 elementary school teachers from five public schools in Cirebon Regency, the study revealed varied understandings and practices in applying game-based pedagogy. The findings are presented in Table 1.

Table 1. Teacher competency in implementing game-based pedagogy

Competency Level	*N*	Percentage
High (able to design games aligned with curriculum)	3	20%
Moderate (use of ready-made platforms with limited alignment)	5	33%
Low (incidental or hesitant use, more entertainment-focused)	7	47%

Some teachers demonstrated strong familiarity with gamified platforms and were able to design learning activities that integrated digital games with curriculum objectives. A total of 20% of teachers demonstrated high competence, showing the ability to design gamified learning activities aligned with curriculum objectives. One teacher explained, "*I usually design my own small games in Wordwall to match the math topic, so students are not just playing but really learning*" (Teacher 3, Interview). About one-third (33%) of teachers displayed moderate competence, typically relying on ready-made gamified platforms such as Kahoot for drills and assessments, but with limited curricular alignment. As one teacher admitted, "*I like using Kahoot for quick quizzes, but I'm not sure how to make it connect with the curriculum objectives*" (Teacher 7, Interview).

The remaining 47% showed low competence, using games only incidentally or with hesitation, often perceiving them more as entertainment than structured pedagogy. For instance, one teacher remarked, "*Games are fun, but I don't think they can really be part of serious math learning*" (Teacher 11, Interview). Across the interviews, key challenges were identified, including the lack of hands-on training, limited access to digital tools, and uncertainty about how game-based activities align with curriculum requirements. These findings highlight the need for more targeted, practice-oriented professional development to strengthen teachers' ability to apply game-based pedagogy effectively and sustainably in elementary classrooms.

2) Research Question 2: How to design a gamification-based VPDLS that is gamified practice for student numeracy?

The development of a Moodle-based learning platform uses the ADDIE model, which includes five stages: Analysis, Design, Development, Implementation, and Evaluation. The stages of analysis, design, and development are addressed in Research Question 2, while the implementation and evaluation stages are covered in Research Question 3.

a) Analysis

The analysis phase revealed key challenges in implementing the Kurikulum Merdeka and digital pedagogy in elementary schools. While the curriculum grants teachers autonomy to design active and collaborative learning, its effectiveness varies by modality. Face-to-face learning supports engagement, but online instruction is limited by weak interaction and unequal digital access. Although most schools have adequate facilities, these are often underutilized due to teachers' limited skills in creating interactive content and students' tendency to use technology for entertainment. As a result, digital tools are used passively, lacking collaborative and engaging features. This highlights the urgent need for structured training to enhance digital literacy and pedagogical competence among teachers and students.

b) Design

VPDLS delivers structured content that guides students from basic concepts to applied understanding of plane geometry. Each topic begins with a definition, followed by 3D visualizations, types of shapes, and relevant formulas. Real-life applications link theory to context, while interactive calculators enable students to explore and verify calculations independently. Each unit ends with quizzes or practice tasks to reinforce learning. This sequence ensures logical progression, promotes active engagement, and strengthens digital numeracy through visual, conceptual, and practical components.

The initial phase of VPDLS emphasized the design stage, starting with defining learning objectives and selecting core geometry topics, which were further divided into subtopics and organized into a pedagogically sound sequence. Supporting materials, including explanatory texts, 3D models, calculator scripts, and evaluation items, were developed to align with the learning flow. A detailed flowchart was created to illustrate user navigation and content interaction within the platform. At this stage, front-end and back-end technologies (HTML, TailwindCSS, JavaScript, and Laravel) were chosen to guide technical implementation. This structured design process laid the foundation for the development phase, where planned components and features were realized into a functional digital learning platform ready for classroom deployment and testing. This stage is illustrated in Fig. 3 and Fig. 4.

c) Development

In the development phase, the previously designed components were translated into a fully functional digital platform. All visual, textual, and interactive elements were integrated using the selected technologies to realize the intended learning experience.

The home page features a main dashboard that includes access to the homepage content, learning materials, and an on/off music toggle for user comfort. An admin page is not included, as the platform is designed solely for direct student use without requiring backend content management.

The material design section of VPDLS presents a selection of plane geometric shapes that students can choose to explore.

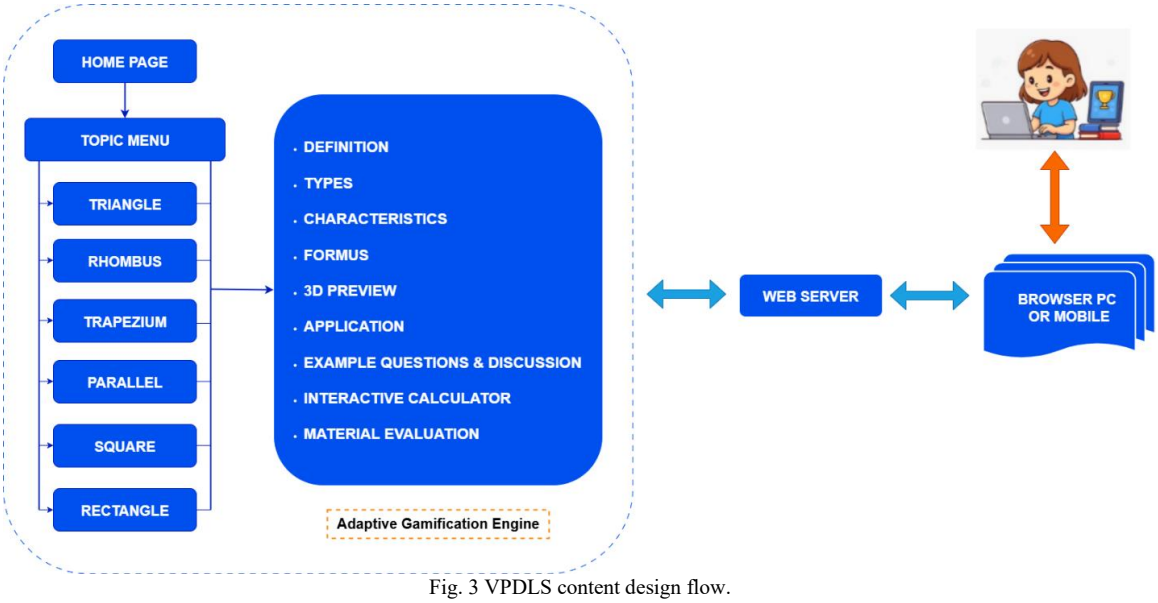

Fig. 3 VPDLS content design flow.

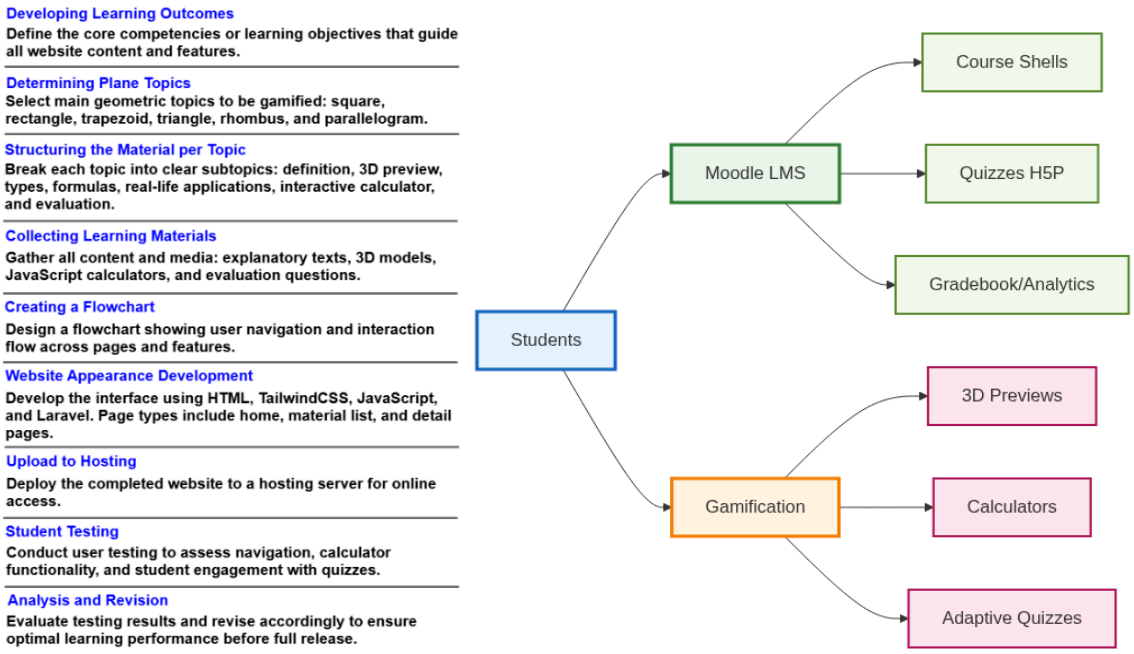

Fig. 4. VPDLS design flow.

Each selected shape contains a structured sequence of interactive learning steps, guiding students through key components. These include the definition, 3D previews, types of shape, formulas, real-life applications, an interactive calculator, and an evaluation section. Figs. 5–7 illustrate the Laravel-based gamification module, which was developed as an independent extension to enhance student engagement. Meanwhile, the Moodle environment (not shown here) served as the primary system for delivering structured courses, quizzes, and gradebook functions.

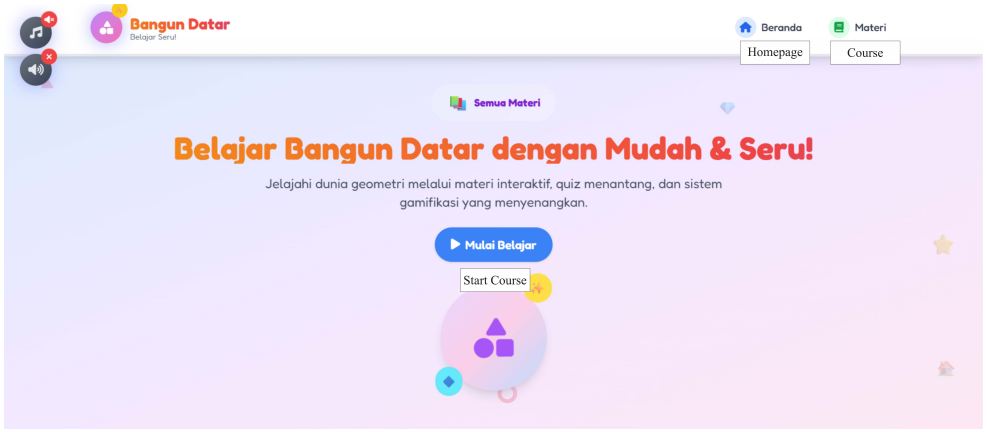

Fig. 5. VPDLS home page.

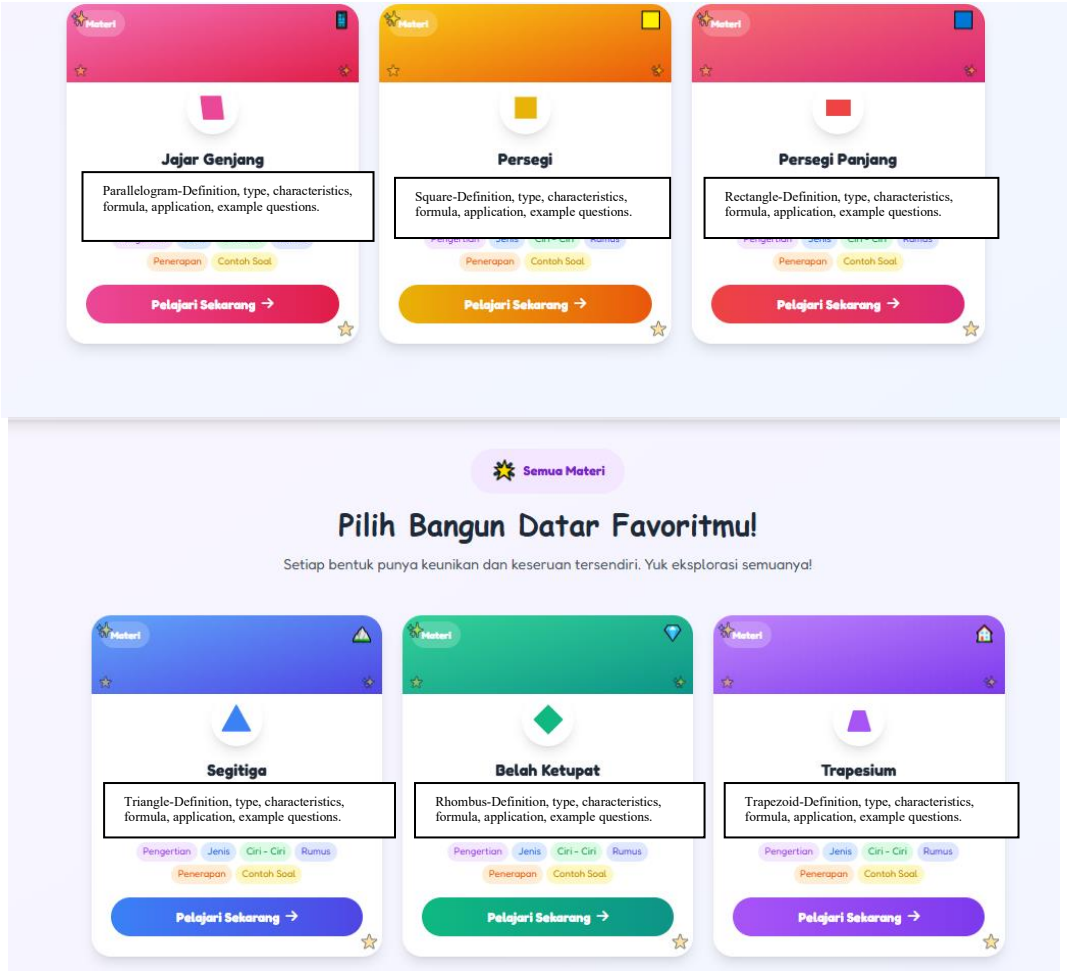

Fig. 6. VPDLS material display.

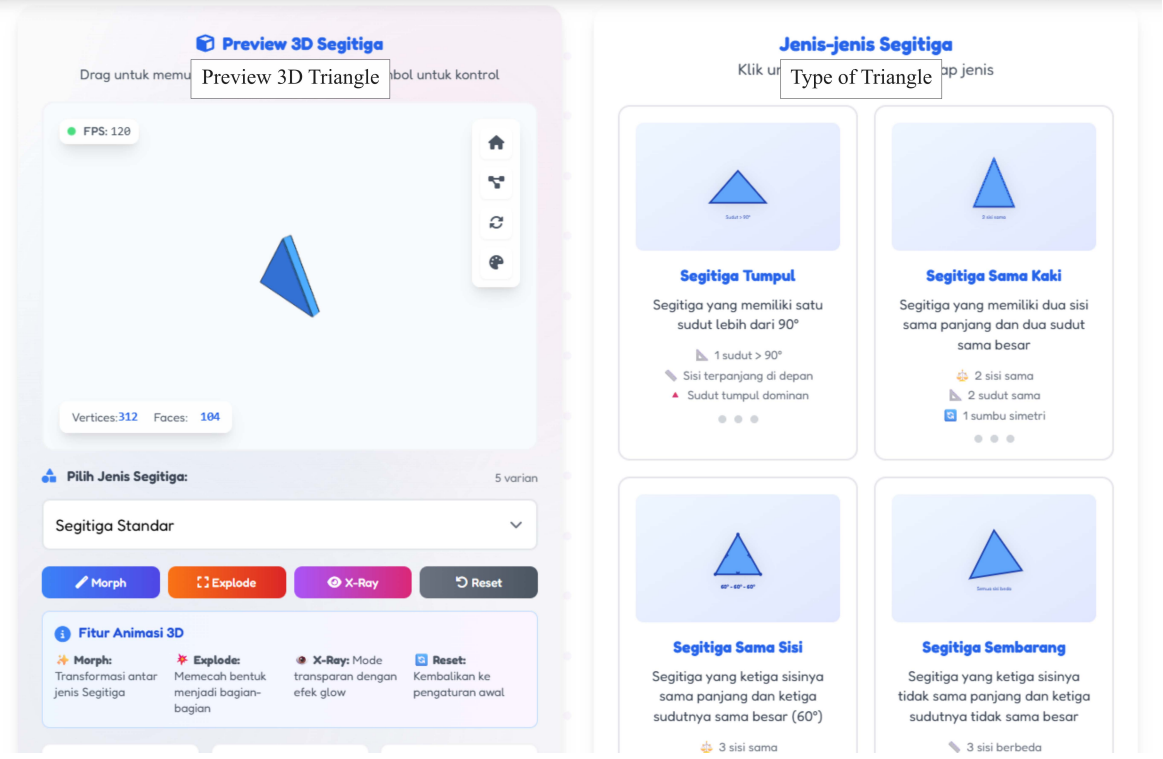

Fig. 7. VPDLS material content.

In the Moodle course framework, geometry-focused digital numeracy content was delivered through H5P-based interactive quizzes consisting of three items, two in multiple-choice format and one in short-answer format, all equipped with automatic scoring and immediate feedback. An example of this H5P feature is shown in Fig. 8. Each item provided explanations for incorrect responses and served as a formative assessment integrated within the platform. These

quizzes illustrated Moodle's role as a structured learning management system by supporting curriculum alignment, automated scoring, and integrated analytics.

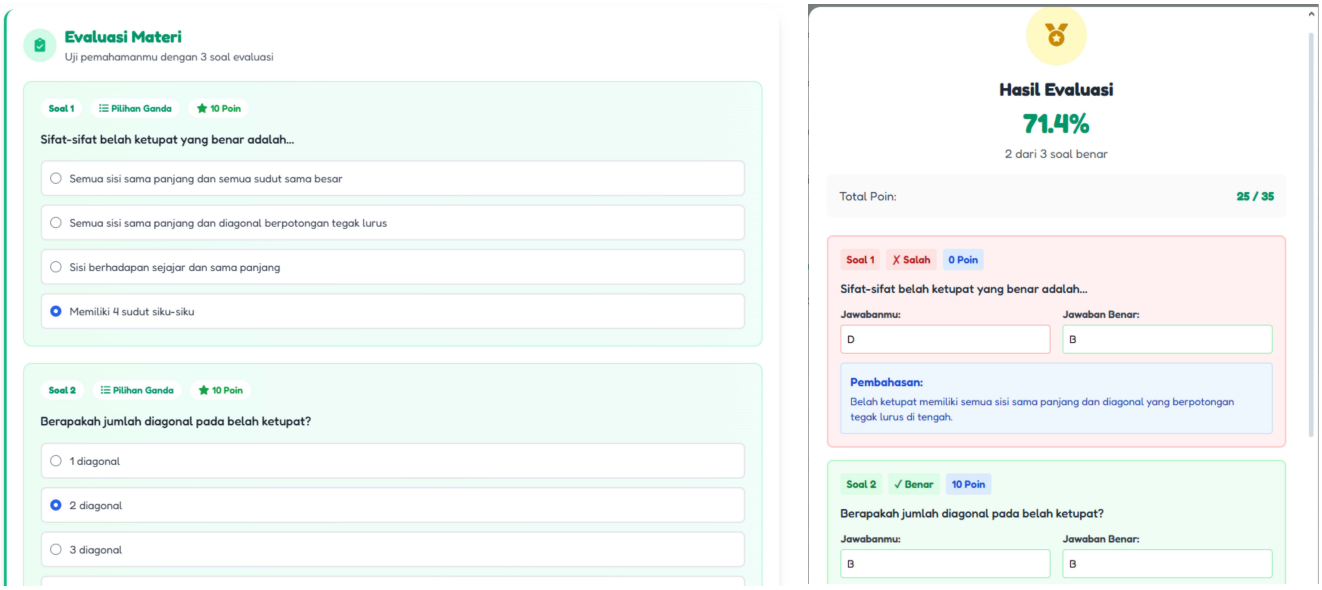

Fig. 8. H5P features (Interactive Quizzes).

Validation involved five experts (three content experts and two media experts). The validation results are presented in Table 2. The CVI analysis showed excellent results, with S-CVI/Ave of 0.99 for both instruments. While the platform was deemed "Very Feasible" overall, experts suggested minor improvements in Operation and Usability aspects, which were implemented in the final design.

Table 2. Results of validation tests by experts

Expert	Aspect	Score Obtained	Max Score	Percentage	Decision
Content Expert	Material Quality	37	44	84.09%	Very Feasible
	Usefulness	18	20	90%	Very Feasible
	Total/Average	55	64	85.94%	Very Feasible
Media Expert	Display	17	20	85%	Very Feasible
	Operation	15	20	75%	Feasible
	Font	20	20	100%	Very Feasible
	Usability	8	12	66.67%	Feasible
	Total/Average	60	72	83.33%	Very Feasible

3) Research Question 3: How do teachers perceive the practicality and usefulness of the Virtual Product-Digital Learning System (VPDLS) in enhancing game-based pedagogy and improving students' digital numeracy?

To address the third research question, this section presents the implementation of VPDLS in real classrooms. Data from teacher questionnaires and student assessments reveal the platform's practicality and effectiveness.

a) Implementation

The implementation phase of the VPDLS platform involved not only students but also teachers, as both groups played a critical role in evaluating its classroom integration. Teachers were responsible for guiding students through the digital learning process while also interacting directly with the platform's features to deliver instruction. Teachers reported that the game-based elements effectively increased student engagement, while the interactive components supported more dynamic and student-centered teaching practices. Overall, the platform was perceived as a practical tool for facilitating mathematics instruction within a digital environment. This is explained in Table 3 below.

Table 3. Results of practical tests by teachers

Aspect	Score Obtained	Max Score	Percentage	Decision
Motivating and Inspiring Students through Playful Learning	56	60	93.33%	
Designing Structured and Interactive Game-Based Activities	67	72	93.06%	
Improving Student Learning Skills	54	60	90%	Very Practical
Actively Engaging in Subsequent Learning	53	60	88.33%	
Overall Practicality	230	252	91.27%	

Quantitative results from teacher practicality assessments (91.27% overall) significantly boosting student motivation (93.33%) while promoting interactive engagement and critical thinking through its structured yet adaptable design. The high practicality scores convince teachers that the platform's easily adaptable features and ready-to-use resources can strengthen their implementation of game-based strategies. In practice, the platform sustained high engagement among 300 students through intuitive gamified tasks, was enthusiastically adopted with minimal technical

issues, and demonstrated strong pedagogical relevance and technical feasibility for diverse elementary classrooms.

The results of the normality test using the Kolmogorov-Smirnov method indicated that both pretest and posttest scores were not normally distributed, as reflected by significance values of less than 0.001 for each. These results are presented in Table 4. The test revealed a statistically significant improvement in scores following the implementation of the VPDLS platform, with a $Z = -10.231$ and a p-value < 0.001. This suggests that the platform had a meaningful effect on students' digital numeracy. Based on this calculation, the effect size was $r = 0.59$, which represents a large effect, indicating not only statistical significance but also a strong practical impact of the VPDLS intervention on students' digital numeracy development.

Table 4. Results of effectiveness tests by students

Test Type	Variable	Statistic	Value	Interpretation
Normality Test	Pretest	Kolmogorov-Smirnov	0.000	Data not normally distributed
	Posttest		0.000	Data not normally distributed
Wilcoxon Signed-Rank	Posttest–Pretest	Z	−10.231	Significant difference in scores
		Asymp. Sig. (2-tailed)	0.000	$p < 0.001$, statistically significant
Effect Size	Posttest–Pretest	r	0.59	Very large effect size

b) Evaluation

The evaluation phase in the ADDIE model is essential for ensuring the developed product meets learning objectives and user expectations. In this study, evaluation was conducted before and after VPDLS implementation, following framework [39]. Pre-implementation, expert and teacher feedback informed revisions to improve interface, content clarity, and navigation. Post-implementation, student and teacher responses and learning outcomes were analyzed to assess effectiveness. Results showed that VPDLS effectively enhanced students' digital numeracy and supported teachers in applying game-based pedagogy, confirming its quality and potential for broader use.

B. Discussion Result

The significant improvement in students' digital numeracy ($p < 0.001$, $r = 0.59$) following VPDLS implementation demonstrates the efficacy of integrating game-based learning into elementary mathematics instruction, corroborating previous findings on digital games enhancing engagement and cognitive processing through interactive environments [46, 47]. Unlike prior motivation-focused studies [6, 14, 15], VPDLS uniquely combines adaptive pedagogy with curriculum-aligned content, addressing a critical theoretical gap. Its multimodal approach, featuring real-life applications, 3D visualizations, and adaptive learning paths, transforms abstract geometry into concrete experiences, particularly crucial for young learners' conceptual development.

The platform's high practicality rating (91.27%) underscores its alignment with game-based pedagogy principles emphasizing motivation, curiosity, and autonomy [48]. Teachers reported that VPDLS facilitated active participation and gradual mastery through structured exploration, reflecting usability frameworks prioritizing clarity and accessibility. This addresses persistent challenges in Indonesian elementary education, where teachers' limited digital pedagogy often leads to passive instruction [3, 5]. VPDLS serves dual roles: as a student learning tool and teacher professional support, strengthening technology integration competencies while fostering digital numeracy as a core 21st-century skill [49].

A key innovation lies in VPDLS's dual-layer architecture, integrating Moodle for curricular management [16, 17, 21] with a Laravel-based gamification engine for adaptive features. This hybrid model enables personalized scaffolding, for example, students struggling with Moodle quizzes receive targeted game-based support with visual aids, while advanced learners tackle contextual problems. This approach operationalizes Vygotsky's zone of proximal development through digital scaffolding, sustaining engagement via synergistic accountability-motivation mechanisms.

The study advances existing research in two ways. First, it moves beyond higher education Moodle applications [16, 17, 22] and non-adaptive gamification [6, 7, 14, 15] by delivering a tailored solution for elementary numeracy. Second, its lightweight architecture surpasses online-only platforms (e.g., Wordwall, Quizizz [12, 15, 23]) in accessibility for low-connectivity settings, promoting equitable digital transformation.

Limitations include the one-group design's susceptibility to history/maturation effects and the absence of direct teacher competence measures. However, strong practicality scores and teacher perceptions suggest VPDLS's potential to enhance pedagogical practices systematically. Future studies should employ controlled designs and longitudinal measures to validate causal impacts on both student learning and teacher development.

V. Conclusion

This study developed and validated the VPDLS platform, demonstrating its effectiveness in enhancing digital numeracy through game-based pedagogy in elementary mathematics. Following the ADDIE model, the platform achieved excellent feasibility (S-CVI/Ave = 0.99) through expert validation and high practicality (91.27%) from teacher assessments. Significant improvements in student learning outcomes ($p < 0.001$, $r = 0.59$) confirmed the platform's efficacy in transforming abstract concepts into engaging learning experiences through adaptive gamification, 3D visualizations, and curriculum-aligned content. The findings establish that well-designed gamified tools effectively promote active learning, student engagement, and teacher adoption of innovative practices. VPDLS specifically addresses critical gaps in digital numeracy education by integrating Moodle's structured management with responsive gamification, offering a scalable model for resource-constrained environments. Study limitations include the one-group pretest-posttest design's vulnerability to history and maturation effects, geographic specificity to Cirebon Regency, short-term implementation, and absence of long-

term retention data. These factors limit generalizability and causal inference. Future research should employ randomized controlled designs, expand to diverse educational contexts, incorporate longitudinal assessments, and examine factors like learner motivation and digital infrastructure variability. Despite these limitations, VPDLS provides a validated foundation for advancing technology-integrated mathematics instruction, offering meaningful insights for educators, curriculum developers, and policymakers pursuing equitable digital transformation in elementary education.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Siti Sharonih conceptualized the research, designed the methodology, and wrote the original draft of the paper. Mochamad Guntur managed the project and reviewed and edited the manuscript. Aep Saepudin curated the data and provided resources. Sofie Savitri was responsible for visualization and validation. Anasya Putri Febgiyo handled the software, performed the formal analysis, and conducted the investigation. All authors had approved the final version.

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