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Development of Gamification-Based E-Learning Media in a Blended Learning Model to Enhance High School Students' Motivation in Learning Probability

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ABSTRACT

This study aims to develop gamification-based e-learning media within a blended learning model and examine whether it is associated with higher high school students' motivation to learn probability compared to conventional instruction. Despite the documented potential of digital learning technologies, a critical gap remains regarding how structured gamification combined with blended delivery can address persistently low motivation in probability learning, a topic widely perceived as abstract by students. Using the ADDIE development model and a quasi-experimental, posttest-only design ($n = 36$ per group), this study compared the post-intervention motivation scores of students learning through gamified interactive videos on Google Classroom versus those taught through conventional lecture methods. Data were collected using a validated Likert-scale motivation questionnaire (Cronbach's alpha = 0.87) and analyzed using an independent samples t-test. The experimental group achieved a significantly higher mean motivation score ($M = 84.02$, $SD = 5.62$) compared to the control group ($M = 74.68$, $SD = 6.25$), with $t(70) = 6.67$, $p < 0.001$, and a large effect size (Cohen's $d = 1.57$). These findings indicate that the gamified blended learning group demonstrated significantly higher post-intervention motivation than the conventional group, suggesting that integrating gamification elements including points, badges, leaderboards, and immediate feedback within a blended learning approach is associated with higher student motivation in probability learning. The novelty of this study lies in the systematic development and empirical validation of a gamified blended learning environment tailored specifically for probability topics at the senior high school level.

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INTRODUCTION

The rapid advancement of digital technology has spurred widespread pedagogical innovation, particularly through the integration of game-based elements into online learning environments. Among these, gamification is defined as the application of game design elements such as points, badges, and leaderboards in non-game contexts (Deterding et al., 2011). Theoretical frameworks such as Self-Determination Theory (SDT) propose that gamification can satisfy three fundamental psychological needs: competence, autonomy, and relatedness, thereby fostering both intrinsic and extrinsic motivation (Ryan & Deci, 2000; Landers, 2014). However, Hanus and Fox (2015) caution that poorly implemented gamification may undermine intrinsic motivation if students focus on rewards rather than learning; this underscores the importance of deliberate, theory-informed design.

Blended learning, which combines face-to-face and online instruction, complements gamification by offering structured flexibility. Empirical evidence supports its effectiveness: Thaheem et al. (2021) demonstrated that blended learning significantly improved mathematics achievement compared to traditional methods (p = 0.001; SMD = 0.67), while also enhancing student attitudes. When an LMS is integrated with gamified activities, students gain extended practice opportunities beyond classroom hours (Biantoro et al., 2024). Kapp (2012) further argues that the combination of structured game mechanics with systematic instructional design produces optimal conditions for engagement and knowledge acquisition.

Despite these promising findings, the literature reveals a critical gap: most gamification studies address general motivation outcomes without systematically examining how gamified blended environments affect motivation in conceptually challenging topics such as probability. Probability is widely reported as one of the most abstract and demotivating topics in secondary mathematics (Lanuza et al., 2020). Students frequently struggle with its theoretical underpinnings and real-world relevance, compounding motivational difficulties. A small number of studies have begun targeting this gap, and read together they reveal a consistent pattern: gamification interventions for probability and statistics have so far concentrated on physical or app-based tools delivered as standalone interventions, rather than on integrated blended learning designs. Lanuza et al. (2020) and Malabayabas et al. (2024) both relied on tangible or app-based gamification manipulatives combined with lesson study, and the Math-GALING mobile application, respectively and reported gains in understanding, participation, or academic performance, but neither embedded these tools within a structured online-offline delivery model or examined motivation as a primary outcome. Magat (2023) similarly developed gamified mobile courseware for statistics and probability and obtained favorable instructional-design ratings from educators, yet this evaluation centered on product quality rather than on measured learning or motivational impact among students. Lampropoulos and Sidiropoulos (2024) offer the strongest evidence that gamification aligned with SDT can sustain improvements in success rates, grades, and retention over time, but their study was not subject-specific to probability and did not test gamification within a blended learning structure. Taken together, these studies establish that gamification can benefit probability and statistics learning in isolated formats, but leave unresolved how gamification performs when systematically combined with blended learning delivery and whether such a combination can specifically address the motivational deficits documented for probability as a topic.

A second strand of literature complicates this picture by showing that gamification's benefits for mathematics learning are neither automatic nor uniform, which underscores why design quality and contextual fit matter as much as the mere presence of game elements. Sailer and Homner's (2020) meta-analysis found that the effects of gamification vary considerably depending on which game elements are used and how learners experience them, while Gonowon (2024) reported that some students' motivation actually declined when gamification elements were poorly explained, pointing specifically to the risk of misalignment between game design and student characteristics. Mekler et al. (2017) add a further caution: extrinsic rewards may produce short-term performance gains without fostering the deeper conceptual engagement that probability learning requires. At the level of mathematics education broadly, the meta-analytic evidence is mixed in magnitude—Sofroniou et al. (2025) found that technology-based interventions in general produce significant gains, with game-based approaches yielding modest but consistent improvements, whereas Tokac et al. (2019) reported only a small effect (d = 0.13) for game-based learning across 24 mathematics studies. Read alongside the probability-specific studies above, this body of work suggests two unresolved issues that the present study is positioned to address: first, that gamification effects on motivation appear highly sensitive to implementation design rather than guaranteed by gamification per se, and second, that no prior study has examined whether a carefully designed, SDT-aligned gamification system embedded in a blended learning model can produce a substantively larger motivational effect for probability specifically than the small-to-modest effects typically reported for game-based mathematics learning in general.

Figure 1. Game Elements In Content Gamification

Figure 1 illustrates the game elements integrated into content gamification. In this model, learning materials are restructured to include levels, narrative storylines, and challenges. It is important to note that while these elements give materials a game-like quality, the primary goal remains educational: game components serve as motivational scaffolding rather than transforming the curriculum into a game. This distinction is critical for ensuring students remain focused on conceptual understanding rather than mere competition (Mekler et al., 2017; Plass et al., 2015). Building directly on these unresolved issues, the present study addresses the gap by systematically developing and empirically validating gamification-based e-learning media within a blended learning framework specifically for probability at the senior high school level. Unlike prior probability-focused studies, which examined gamification through standalone tools or apps without a blended delivery structure (Lanuza et al., 2020; Magat, 2023; Malabayabas et al., 2024), this study integrates gamification elements directly into a Google Classroom-based blended learning environment, allowing the interaction between gamified design and blended delivery to be examined as a single, coherent intervention.

Unlike the broader mathematics gamification literature, where effects on motivation are reported as small to modest and highly dependent on implementation quality (Sailer & Homner, 2020; Tokac et al., 2019; Sofroniou et al., 2025), this study responds to the call for theory-informed design by grounding the gamification system explicitly in SDT, with each game element (points, badges, leaderboard, mission-based progression) mapped to the psychological needs of competence, autonomy, and relatedness. The contribution is therefore twofold: (1) methodologically, the structured application of the ADDIE model to produce a four-mission gamified blended learning environment offers a replicable design template for conceptually difficult mathematics topics; and (2) empirically, the comparison of motivation outcomes between this gamified blended learning approach and conventional instruction provides evidence on whether a deliberately designed, theory-aligned intervention can produce a larger motivational effect for probability than the modest effects typically observed for game-based mathematics interventions in general. The research question is: Does gamification-based e-learning media within a blended learning model significantly enhance high school students' motivation in learning probability?.

METHOD

Research Design and Development Model

This study employed the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation) to guide the systematic development of gamification-based e-learning media. The ADDIE model was selected for its cyclical, iterative structure, which ensures each development phase informs the next, producing pedagogically sound and technically feasible media (Dick et al., 2015). A quasi-experimental design with a non-equivalent control group posttest-only structure was used to compare motivation outcomes between the gamified blended learning group and the conventional instruction group (Campbell & Stanley, 1963). This design was appropriate because random assignment was not feasible in the school context; pre-equivalence between groups was established through preliminary analysis of prior semester mathematics academic grades (t(70) = 0.43, p = 0.67), confirming no significant baseline differences in academic performance. It should be noted that this baseline equivalence pertains to prior academic achievement rather than to learning motivation, as no pretest motivation measure was administered; consequently, the design supports comparison of post-intervention motivation between groups but does not permit conclusions about within-group change in motivation from baseline.

Participants and Sampling

Participants were selected using purposive sampling from SMAN 1 Bandar Lampung, a representative urban senior high school with sufficient digital infrastructure for blended learning. Two eleventh-grade classes were assigned as the experimental group (n = 36) and control group (n = 36), totaling 72 students aged 16 to 17 years with a balanced gender composition (experimental: 19 female, 17 male; control: 20 female, 16 male). The same teacher delivered instruction to both groups to control for instructor variability. While purposive sampling limits random generalizability, the controlled conditions and group equivalence support internal validity. Replication across multiple schools and socioeconomic contexts is recommended in future research.

Gamification-Based E-Learning Media

The gamified e-learning platform was implemented via Google Classroom integrated with interactive video content. Content was structured into four missions with six progressive levels: (1) Mission 1 - Basic Exercises: sample spaces and simple probabilities; (2) Mission 2 - Complex Cases: compound probability including mutually exclusive, independent, and conditional events; (3) Mission 3 - Accurate Predictions: expected values through data simulations; (4) Mission 4 - Final Project: collaborative group analysis of fictional data integrating all skills. Each level incorporated gamification elements including points for task completion, three-tier badges (Rookie Agent, Statistics Master, Top Secret Agent), and a class leaderboard. Immediate feedback was provided upon task submission. Both groups received three learning sessions of 90 minutes each, covering identical probability topics. The control group received conventional lecture-based instruction without digital media.

Research Instrument

Learning motivation was measured using a researcher-developed Likert-scale questionnaire (1 = strongly disagree to 5 = strongly agree), consisting of 25 items across four validated dimensions: intrinsic motivation (8 items), extrinsic motivation (7 items), self-efficacy (5 items), and engagement (5 items). Table 1 presents the instrument structure. Content validity was assessed by two educational psychology experts (Content Validity Ratio = 0.87). The instrument was piloted with 30 students not included in the main study. Item-total correlations ranged from 0.42 to 0.71, and Cronbach's alpha reached 0.87, indicating good internal consistency (George & Mallery, 2003). Scores were converted to a 0-100 scale for comparative analysis.

Table 1 . Structure and Reliability of the Learning Motivation Questionnaire

No.	Dimension	Indicators	No. of Items
1	Intrinsic Motivation	Curiosity, self-challenge, enjoyment	8
2	Extrinsic Motivation	Recognition, competition, rewards	7
3	Self-efficacy	Confidence in task completion	5
4	Engagement	Active participation, persistence	5
Total	**Total Items**		**25**
Reliability (Cronbach's alpha)			0.87 (Good)

Data Analysis

Descriptive statistics (mean, standard deviation) were calculated for both groups. Before inferential testing, the Shapiro-Wilk test was used to assess normality and Levene's test assessed homogeneity of variances. Both assumptions were met (normality: $p > 0.05$; homogeneity: $p > 0.05$), supporting the use of an independent samples t-test. Analyses were conducted using SPSS v.26 and confirmed using Python (scipy.stats). Hypotheses tested: H0: There is no significant difference in motivation between the experimental and control groups; H1: There is a significant difference in motivation between groups. Statistical significance was set at alpha = 0.05. Cohen's d was computed as the effect size metric to quantify practical significance, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively (Cohen, 1988).

Ethical Considerations

This study was conducted in accordance with ethical principles for research involving human participants. Formal permission to conduct the study was obtained from the principal and mathematics teacher of SMAN 1 Bandar Lampung prior to data collection, and the research procedures were scheduled to align with the regular curriculum to minimize disruption to instruction. Because participants were senior high school students aged 16–17 years, information about the study's purpose, procedures, and use of data was provided to students and, through the school, to their parents or guardians, and consent for participation was obtained accordingly. Students were informed that participation was voluntary, that they could withdraw at any stage without academic consequence, and that their decision would not affect their grades or standing in class. All questionnaire responses and academic records used for the equivalence analysis were anonymized prior to analysis, with data securely stored and accessible only to the research team, ensuring the confidentiality of student data throughout the study.

RESULTS AND DISCUSSION

Media Development and Validation

The development process followed the five ADDIE stages systematically. During the Analysis phase, student surveys and teacher interviews confirmed that probability was perceived as abstract and demotivating, and that students had consistent smartphone and internet access. In the Design phase, the four-mission structure was aligned with 11th-grade mathematics curriculum competency standards. During Development, interactive videos and gamification elements were produced and integrated into Google Classroom. Implementation involved the three-session teaching experiment described above. Evaluation was conducted through expert validation, practicality testing, and motivation measurement.

Media validation was conducted by two educational technology experts and one subject matter expert using Likert-scale questionnaires covering visual design, navigation, operational reliability, content accuracy, curriculum alignment, and higher-order thinking development. Results in Table 2 indicate an average media expert score of 3.80/4.0 and subject matter expert score of 3.70/4.0, both within the highly valid to valid range. The highest-scored dimension was operational reliability (3.9), reflecting platform stability on Google Classroom. The lowest score was curriculum alignment (3.6); reviewers recommended more explicit connections to competency descriptors. These scores exceed the 3.5 threshold for highly valid classification, confirming the media is suitable for classroom use pending minor refinements.

Table 2. Expert Validation of Gamification-Based E-Learning Media

Evaluation Aspect	Indicator	Media Expert Score (0–4)	Subject Matter Score (0–4)	Category
Design	Visual appearance, consistency	3.8	–	Highly valid
Navigation	Ease of use	3.7	–	Valid
Operational	Access speed, stability	3.9	–	Highly valid

Content Accuracy	Conceptual accuracy	–	3.8	Highly valid
Curriculum Alignment	Relevance to competency standards	–	3.6	Valid
Higher-Order Thinking	Analytical skills	–	3.7	Valid

Practicality Assessment

Practicality testing involved 8 teachers who reviewed the media before implementation and 36 experimental students who evaluated it during learning. As shown in Table 3, teachers gave an average practicality score of 93% and students gave 89%, with all dimensions rated very practical. Teachers highlighted that the gamified structure reduced lesson preparation time and facilitated structured feedback delivery. Students valued the clear navigation and motivating leaderboard display. The slightly lower student ease-of-use score (87%) reflects initial orientation challenges with the platform's navigation, which diminished by Session 2. Overall, these scores indicate that the media meets the practical requirements for regular classroom implementation (Malabayabas et al., 2024).

Table 3. Media Feasibility (Practicality) Test Results

Practicality Dimension	Indicator	Teacher (%)	Student (%)	Interpretation
Appeal	Visual design, interactivity	95	88	Very practical
Ease of Use	Navigation, clear instructions	90	87	Very practical
Benefits	Supports understanding & motivation	94	91	Very practical
Average		93	89	Very practical

Motivation Test Results

After three probability learning sessions, motivation questionnaires were administered to all 72 participants. Descriptive statistics are presented in Table 4, and inferential statistics for the group comparison are presented in Table 5. The experimental group ($M = 84.02$, $SD = 5.62$) achieved a substantially higher mean motivation score than the control group ($M = 74.68$, $SD = 6.25$), a difference of 9.34 points (95% CI: 6.51, 12.17). Both groups met normality (experimental: $W = 0.97$, $p = 0.43$; control: $W = 0.96$, $p = 0.26$) and homogeneity of variances ($F = 0.91$, $p = 0.34$) assumptions. The independent samples t-test yielded $t(70) = 6.67$, $p < 0.001$ (two-tailed), confirming rejection of the null hypothesis. The effect size Cohen's $d = 1.57$ represents a large effect, indicating the motivational advantage of the gamified blended learning group over the conventional group was not only statistically significant but practically substantial (Cohen, 1988).

Table 4. Descriptive Statistics of Learning Motivation Scores

Group	n	Mean Score	Standard Deviation
Experimental	36	84.02	5.62
Control	36	74.68	6.25

Note. Motivation scores were measured immediately post-intervention using the validated Likert-scale questionnaire described above; n = 36 per group. Corresponding inferential statistics for the between-group comparison are reported in Table 5.

Table 5. Inferential Statistics for the Difference in Post-Intervention Motivation Scores

Mean Difference	95% CI of Difference	t	df	p	Cohen's d
9.34	6.51, 12.17	6.67	70	< .001	1.57

Note. Independent samples t-test, two-tailed; positive mean difference indicates higher motivation in the experimental (gamified blended learning) group. Cohen's d: 0.2 = small, 0.5 = medium, 0.8 = large effect (Cohen, 1988); d = 1.57 represents a large effect.

Discussion

The large effect size (Cohen's $d = 1.57$) and highly significant p-value ($p < 0.001$) demonstrate that the gamified blended learning environment produced a meaningful motivational advantage over conventional instruction. These findings are consistent with the broader gamification literature but substantially exceed Tokac et al.'s (2019) average effect of d = 0.13 across 24 game-based mathematics studies. The larger effect observed here may be attributed to the comprehensiveness of the gamification design: rather than adding isolated game elements, this study embedded points, badges, a narrative mission structure, and a leaderboard within a coherent pedagogical sequence explicitly aligned with SDT (Ryan & Deci, 2000).

From an SDT perspective, the large effect size is explicable through three mechanisms. First, the mission structure and badge system addressed the need for competence by providing clear mastery milestones and progressive challenge. This aligns with Lampropoulos and Sidiropoulos (2024), who found that SDT-aligned gamification produced stronger motivation outcomes than designs addressing only extrinsic factors. Second, the leaderboard and collaborative Mission 4 task satisfied the need for relatedness by creating social learning dynamics, consistent with a systematic review by Sal-de-Rellan et al. (2025), who found that gamification in physical education improved relatedness and social skills among adolescents. Third, student-controlled navigation and self-paced video review addressed autonomy needs, as proposed by Kapp (2012) and corroborated by Sailer and Homner (2020), who found autonomy-supporting elements produced larger motivational effects in their meta-analysis.

The practicality scores (93% teacher, 89% student) further suggest that the media was perceived as effective and feasible for regular use within the context of this study. Teachers' reported reduction in preparation time aligns with Biantoro et al. (2024), who demonstrated that LMS-gamification integration streamlines instructional workflows. The slightly lower student ease-of-use score reflects a commonly observed learning curve with new digital platforms (Magat, 2023), which resolved within the intervention period. Given that these practicality results were obtained from a single school over a three-session intervention, they should be interpreted as evidence of promising feasibility for broader classroom trials rather than confirmation of readiness for wide-scale deployment; further studies across different schools, longer intervention periods, and more diverse student contexts are still needed before stronger claims about institutional scalability can be made.

Several limitations must be acknowledged. First, the single-school design and three-session duration limit generalizability. Gonowon (2024) noted that student familiarity with gamification design affects outcomes, and longer interventions may produce different motivational trajectories. Second, motivation was assessed immediately post-intervention without delayed follow-up; Mekler et al.'s (2017) warning about temporary extrinsic reward effects remains relevant and warrants longitudinal investigation. Third, with only two media experts and one subject matter expert, validation breadth was limited; broader validation incorporating end-user perspectives would strengthen credibility. Fourth, the study measured motivation as the sole outcome variable; future research should examine whether motivational gains translate into improved conceptual understanding and academic achievement in probability.

CONCLUSION

This study developed and empirically validated gamification-based e-learning media within a blended learning model for probability instruction at the senior high school level. The media received high validation scores from media experts (M = 3.80/4.0) and subject matter experts (M = 3.70/4.0) and was rated very practical by both teachers (93%) and students (89%). Students in the gamified blended learning group demonstrated significantly higher post-intervention motivation than those receiving conventional instruction (Cohen's d = 1.57), a large effect that, given the absence of pretest motivation data, reflects a between-group difference rather than a within-group gain from baseline.

Theoretically, this study contributes evidence that SDT-aligned gamification design is applicable to probability learning, a topic underrepresented in the gamification literature. Practically, the developed media offers a design template that mathematics teachers may adapt for structured gamified blended instruction; given that these findings derive from a single school and a three-session intervention, the media shows promising feasibility for broader classroom trials rather than readiness for immediate wide-scale deployment.

Key limitations are the single-school context, the three-session intervention duration, the absence of delayed follow-up, and the focus on motivation as the sole outcome variable. Future research should replicate these findings across more diverse school and socioeconomic settings, evaluate motivational persistence through delayed post-tests, examine the differential effects of individual gamification elements, measure probability learning outcomes alongside motivation, and extend this gamified blended learning approach to other abstract mathematics topics such as calculus and trigonometry.

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AUTHOR CONTRIBUTION STATEMENT

K.F.A. contributed to the conceptualization, methodology, investigation, data collection, formal analysis, visualization, and preparation of the original draft. M.N. contributed to the conceptualization, methodology, supervision, validation, and review and editing of the manuscript. D.M.F. contributed to the validation, data analysis, investigation, and review and editing of the manuscript. D.Y. contributed to the supervision, methodology, validation, interpretation of the findings, and review and editing of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.

AI DISCLOSURE STATEMENT

Generative artificial intelligence (AI) tools were used solely to assist with language refinement, grammatical correction, and improvement of the readability of the manuscript. AI tools were not used to generate research data, conduct statistical analyses, interpret the results, or make scientific conclusions. All AI-assisted content was critically reviewed and verified by the authors, who take full responsibility for the accuracy, originality, and integrity of the final manuscript.

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