Digital Learning Media on Probability: Enhancing Twelfth-Grade Students' Conceptual Understanding and Learning Motivation at SMAN 1 Parakansalak

Abstract

This study was conducted to address the insufficient conceptual understanding and low learning motivation of twelfth-grade students in the topic of probability. The research specifically aims to (1) examine the effectiveness of interactive digital learning media—Quizizz, Liveworksheet, and Kahoot—in improving students' conceptual understanding of probability, and (2) analyze the extent to which these digital platforms influence students' learning motivation in mathematics. A mixed-methods approach was employed using a One-Group Pretest–Posttest design integrated into Classroom Action Research (CAR). Data were collected through a conceptual understanding test, a learning motivation questionnaire, an observation checklist, and structured interviews. Quantitative data were analyzed using the Wilcoxon test for conceptual understanding and the t-test for learning motivation, while qualitative data were analyzed descriptively. The findings demonstrate that the use of digital learning media significantly enhances students' conceptual understanding and positively impacts their learning motivation. Qualitative results further show that students responded enthusiastically to the integration of interactive digital platforms in mathematics learning. This study contributes to the advancement of technology-integrated mathematics instruction by providing empirical evidence on the role of interactive digital media in fostering conceptual mastery and motivating students.

Keywords: Digital Media, Learning Motivation, Conceptual Understanding, Classroom Action Research, Probability

Media Pembelajaran Digital pada Materi Peluang: Meningkatkan Pemahaman Konseptual dan Motivasi Belajar Siswa Kelas XII di SMAN 1 Parakansalak

Abstrak

Penelitian ini dilakukan untuk mengatasi rendahnya pemahaman konseptual dan motivasi belajar siswa kelas XII pada materi peluang. Penelitian ini secara khusus bertujuan untuk (1) mengkaji efektivitas media pembelajaran digital interaktif—Quizizz, Liveworksheet, dan Kahoot—dalam meningkatkan pemahaman konseptual siswa pada materi peluang, serta (2) menganalisis sejauh mana platform digital tersebut memengaruhi motivasi belajar matematika siswa. Penelitian ini menggunakan pendekatan mixed methods dengan desain One-Group Pretest–Posttest yang terintegrasi dalam Penelitian Tindakan Kelas (PTK)**.** Data dikumpulkan melalui tes pemahaman konseptual, angket motivasi belajar, lembar observasi, dan wawancara terstruktur. Data kuantitatif dianalisis menggunakan uji Wilcoxon untuk pemahaman konseptual dan uji *t* untuk motivasi belajar, sedangkan data kualitatif dianalisis secara deskriptif. Hasil penelitian menunjukkan bahwa penggunaan media pembelajaran digital secara signifikan meningkatkan pemahaman konseptual siswa serta memberikan dampak positif terhadap motivasi belajar mereka. Temuan kualitatif juga menunjukkan bahwa siswa memberikan respons yang antusias terhadap integrasi platform digital interaktif dalam pembelajaran matematika. Penelitian ini berkontribusi pada pengembangan pembelajaran matematika berbasis teknologi dengan memberikan bukti empiris mengenai peran media digital interaktif dalam meningkatkan penguasaan konsep dan motivasi belajar siswa.

Kata kunci: Media Digital, Motivasi Belajar, Pemahaman Konseptual, Penelitian Tindakan Kelas, Peluang

Media Pangajaran Digital dina Materi Peluang: Ningkatkeun Pamahaman Konseptual jeung Motivasi Diajar Siswa Kelas XII di SMAN 1 Parakansalak

Abstrak

Panalungtikan ieu dilaksanakeun pikeun ngungkulan handapna pamahaman konseptual jeung motivasi diajar siswa kelas XII dina materi peluang. Tujuan husus tina panalungtikan ieu nya éta pikeun (1) nalungtik efektivitas media pangajaran digital interaktif—Quizizz, Liveworksheet, jeung Kahoot—dina ningkatkeun pamahaman konseptual siswa dina materi peluang, sarta (2) nganalisis sabaraha gedé pangaruh platform digital éta kana motivasi diajar matematika siswa. Métode anu digunakeun nyaéta pendekatan mixed methods kalayan desain One-Group Pretest–Posttest anu dihijikeun dina Panalungtikan Tindakan Kelas (PTK)**.** Data dikumpulkeun ngaliwatan tés pamahaman konseptual, angket motivasi diajar, lambar observasi, sarta wawancara terstruktur. Data kuantitatif dianalisis maké uji Wilcoxon pikeun pamahaman konseptual jeung uji *t* pikeun motivasi diajar, sedengkeun data kualitatif dianalisis sacara déskriptif. Hasil panalungtikan nunjukkeun yén pamakean media pangajaran digital sacara signifikan mampuh ningkatkeun pamahaman konseptual siswa sarta méré pangaruh positif kana motivasi diajar maranéhna. Hasil kualitatif ogé némbongkeun yén siswa masihan réspon anu antusias kana integrasi platform digital interaktif dina pangajaran matematika. Panalungtikan ieu méré kontribusi kana pamekaran pangajaran matematika berbasis téknologi ku cara nyayagikeun bukti empiris ngeunaan peran media digital interaktif dina ningkatkeun pangaweruh konsép jeung motivasi diajar siswa.

Kecap konci: Media Digital, Motivasi Diajar, Pamahaman Konseptual, Panalungtikan Tindakan Kelas, Peluang

INTRODUCTION

A firm grasp of mathematical concepts is essential for students as it forms the foundation for acquiring more advanced mathematical knowledge. Strong fundamental understanding allows learners to better comprehend complex topics and develop higher-order problem-solving skills. Students who possess solid foundational concepts are therefore better equipped to interpret more complex material. As stated by Kristanti and Inarto (2019), conceptual understanding is an essential competency that students must develop. Herawati et al. (Inarto) also reported that the implementation of Project-Based Learning and Problem-Based Learning can enhance students' motivation and conceptual understanding because these approaches require students to be more active, and by presenting problems at the beginning of the lesson, students become more enthusiastic in learning mathematics (Herawati et al., 2026; Kristanti & Inarto, 2019).

The novelty of this study lies in the integration of three interactive digital learning platforms—Quizizz, Liveworksheet, and Kahoot—within a structured Classroom Action Research (CAR) design for probability instruction. Unlike previous studies that typically examine a single platform or focus solely on learning models such as PjBL or PBL, this research introduces a multiplatform digital ecosystem that systematically assigns each medium a specific instructional function. This combination not only strengthens students' conceptual understanding but also simultaneously enhances learning motivation, providing a new contribution to digital-based mathematics pedagogy.

Understanding the concept of probability poses its own challenges, particularly for twelfth-grade students at SMAN 1 Parakansalak. In the subtopic of probability, various contextual problems often confuse students when drawing conclusions or processing word problems. This situation is reflected in the relatively low learning outcomes in probability material prior to remedial sessions. One frequently observed issue is students' confusion in solving problems related to permutation and combination, especially in distinguishing their respective applications. Therefore, students require learning stimuli that can provide clear explanations about the differences in using permutation and combination concepts. Haji (2020) concluded that the use of Realistic Mathematics Education (RME)-based teaching materials can support the achievement of mathematics learning objectives, including improving conceptual understanding and students' learning motivation at the senior high school level. Meanwhile, Riansyah (2022) found that the application of the SQ3R method can significantly improve students' mathematical conceptual understanding compared to conventional learning, with higher improvement categories in classes that implemented it.

Learning motivation refers to the intrinsic force that propels learners toward accomplishing specific academic objectives. Previous studies have shown that high learning motivation can improve learning outcomes and increase student engagement in the learning process (Hamzah,

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2023). However, at SMAN 1 Parakansalak, some students exhibit low motivation in mathematics learning, particularly in probability topics. A contributing factor to this diminished motivation is the limited diversity of instructional media, which leads students to experience boredom and reduced engagement in the learning process.. This indicates that teachers need to use more engaging methods or media, such as digital-based media that can connect mathematical concepts with students' daily experiences.

he use of instructional media can also facilitate the development of students' conceptual understanding. Instructional media encompass various tools and materials that educators employ to deliver content and promote students' cognitive, emotional, and behavioral engagement in understanding concepts. According to Suwardi, Masni, and Rohayati (2014), the use of appropriate instructional media can assist both teachers and students in constructing a clearer understanding of mathematical ideas. Previous studies have shown that the integration of game-based and simulation-based digital environments in probability learning contributes positively to students' conceptual clarity and learning motivation (Anggoroa et al., 2025; Koparan, Inarto; Aprilia et al., 2024).

To strengthen the theoretical foundation, the role of digital media in this study is framed through Keller's ARCS Motivation Model, which emphasizes Attention, Relevance, Confidence, and Satisfaction as key factors influencing student motivation. Game-based platforms such as Quizizz and Kahoot capture students' attention and provide immediate feedback that builds confidence, while interactive worksheets such as Liveworksheet enhance relevance through authentic task engagement. Additionally, the study is grounded in digital constructivism, which posits that students construct mathematical understanding through active interaction with digital tools, exploration, and immediate feedback. In this theoretical lens, digital media act not merely as delivery tools but as cognitive scaffolds that shape the construction of conceptual understanding.

Thus, the connection between digital media, learning motivation, and conceptual understanding in this study is not only descriptive but situated within a clear conceptual model that explains how interactive media foster motivation, and how increased motivation subsequently supports deeper conceptual learning.

With the advancement of digital technology, digital-based instructional media have become one of the key innovations in the learning process. Examples of such media include Quizizz, GeoGebra Applet, Live Worksheet, YouTube, and others. These media can be developed using tools such as Google Sites. Digital instructional media integrate elements such as text, animation, images, and videos presented interactively to create a more engaging and authentic learning experience for students (Prastyo & Harton, 2020). The use of digital-based instructional media allows for more interactive and visual material delivery, helping students to better understand abstract mathematical concepts.

Several studies indicate that digital media based on gamification and interactive simulations, as well as local trajectory approaches, are highly effective in enhancing conceptual understanding of probability by utilizing real-world contexts and metacognition (Tinati et al., 2018; Šarić et al., 2022; Najib et al., 2022). In addition, online simulation models such as GDL also contribute to improving digital literacy and student motivation due to their interactive and participatory nature (Perdana et al., 2024; Moser et al., 2017).

Other research also demonstrates that the use of game-based learning and mathematical games has been proven effective in increasing students' motivation and conceptual understanding in mathematics (Djamilah & Ulfah, 2025; Wijaya, Elmaini, & Doorman, Inarto).

Based on the aforementioned problems, this study focuses on efforts to improve students' mathematical conceptual understanding and learning motivation, particularly in probability, through the use of digital-based instructional media.

METHOD

Research Design

The research employed a mixed-method design with a sequential explanatory strategy in which quantitative data were collected first, followed by qualitative data to provide deeper explanation and validation. The dominant methodological approach in this study was Classroom Action Research (CAR), as the primary purpose of the research was to improve instructional practice and enhance students' conceptual understanding and learning motivation through iterative cycles of intervention.

The CAR model adopted in this study followed the Kemmis and McTaggart framework, consisting of planning, action, observation, and reflection. Each cycle involved:

1. Planning – designing lesson plans integrating Quizizz, Kahoot, and Liveworksheet; preparing learning instruments and evaluation tools;
2. Action – implementing the digital-media–based learning activities in the twelfth-grade mathematics class;
3. Observation – collecting data on student engagement, motivation, and conceptual understanding through tests, questionnaires, and observation sheets;
4. Reflection – analyzing the results of each cycle to determine necessary revisions for the subsequent cycle.

Quantitative data were collected through pretest–posttest assessments administered at the beginning and end of each cycle. Although resembling a One-Group Pretest–Posttest structure, these tests functioned only as measurement tools within each CAR cycle, not as the primary

research design. The study involved one class of twelfth-grade students at SMAN 1 Parakansalak, and the CAR was conducted over two cycles during the academic term.

In the qualitative phase, data were gathered through open-ended interviews and classroom observations to capture students' and the teacher's perceptions of the implementation of digital media and to provide a deeper explanation of the quantitative improvements observed in conceptual understanding and motivation. This integration confirms that CAR served as the central design, with mixed-method analysis used to validate and strengthen the findings across cycles.

Research Subjects

This study involved twelfth-grade students from a public senior high school located in Sukabumi Regency, Indonesia, who shared similar profiles regarding academic performance and access to learning resources.. The class selection was carried out purposively based on subject teacher recommendations and preliminary observations. The number of students in each class ranged from 30 to 36. Prior to the intervention, both groups were administered a pretest to determine their initial ability in solving mathematical problems on the topic of triangles. After the intervention, a posttest was conducted to measure the differences in learning improvement between the two groups.

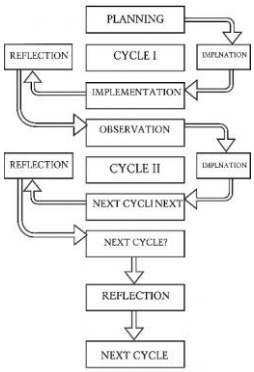

Figure 1. Siclus of research

Data Collection Techniques

Data for this study were collected through observations and assessments focusing on the enhancement of conceptual understanding and learning motivation among twelfth-grade students at SMAN 1 Parakansalak utilizing digital media. To ensure the data were sufficient and reliable,

multiple collection methods were employed. The techniques applied by the researcher are outlined in the table below..

his study employed several instruments for data collection. First, a conceptual understanding test was administered before and after the digital media–based instruction to measure students' mastery of probability concepts. The test consisted of 10 essay items, which were reviewed by two mathematics education experts to ensure content validity. The items were further examined using item analysis procedures, including difficulty level and discrimination index. Reliability was assessed using Cronbach's Alpha, yielding a coefficient of 0.82, indicating high internal consistency. Sample items from this test are provided in the appendix.

Second, a learning motivation questionnaire containing 20 Likert-scale statements (1 = strongly disagree to 5 = strongly agree) was used to examine students' motivation toward mathematics. The questionnaire was adapted from established motivation frameworks and validated by experts for construct and face validity. Reliability testing produced a Cronbach's Alpha of 0.88, demonstrating strong reliability. A selection of sample items is included in the appendix.

Third, observation sheets were utilized by an independent observer to document student engagement, digital media use, and interaction patterns during the learning process. The observation instrument included 12 indicators, covering behavioral, cognitive, and affective aspects of participation. These indicators were validated through expert judgment to ensure relevance to the objectives of the study.

Fourth, semi-structured interviews were conducted with selected students to gain deeper insights into their experiences with digital learning media. The interview protocol consisted of 8 guiding questions, developed based on the key themes emerging from the quantitative findings. Examples of interview prompts are also provided in the appendix.

If certain psychometric analyses beyond expert validation (such as factor analysis) were not conducted, this is acknowledged as a limitation of the study, and future research is recommended to perform more extensive validation procedures.

RESULTS AND DISCUSSION

In this classroom action research, the use of digital-based learning media was implemented. This became one of the differences compared to the previous learning method. In addition to using digital media, this study also expected that students' motivation in learning mathematics could increase, especially in the topic of probability. The documentation of the cycle activities as well as the pretest and posttest is presented in the following figures.

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Figure 2. Documentation of Cycle Activities

Condition Before the Action (Pretest)

Based on the pretest results, before the treatment using digital-based media was given, the students' motivation questionnaire results were processed using SPSS as follows.

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
TOTAL_X1	*33*	*28*	*37*	*31.67*	*2.677*
TOTAL_X2	*33*	*9*	*19*	*14.91*	*2.082*
TOTAL_X3	*33*	*10*	*20*	*14.45*	*2.306*
TOTAL_X4	*33*	*7*	*15*	*11.76*	*2.031*
TOTAL_X5	*33*	*8*	*15*	*12.06*	*2.249*
TOTAL_X6	*33*	*8*	*15*	*11.58*	*1.751*
TOTAL_X	*33*	*79*	*115*	*96.42*	*8.544*

Table 6. Descriptive Statistics of Pretest Motivation Questionnaire

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Next, the questionnaire results were categorized into three categories: low, medium, and high. Based on the previous figure, the mean of the variable TOTAL_X was 96.42, and the standard deviation was 8.544. This resulted in the following categorization.

The classification of students' learning motivation questionnaire results was divided into three categories. The low category was assigned to students who obtained a questionnaire score of less than 88. The medium category included students with scores ranging from 88 to less than 105. Meanwhile, the high category was assigned to students who obtained a score equal to or greater than 105. This categorization was used to facilitate the analysis of students' learning motivation levels before and after the learning process.

	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid				
rendah	3	9.1	9.1	9.1
sedang	23	69.7	69.7	78.8
tinggi	7	21.2	21.2	100
Total	33	100	100	

Table 7. Learning Motivation Categories

Based on Table 7, most students (69.7%) demonstrated a moderate level of learning motivation, while 21.2% showed high motivation and only 9.1% were in the low category. These results indicate that overall, students' learning motivation is fairly strong, with a promising portion

showing high enthusiasm, although some still require support to enhance their engagement in learning.

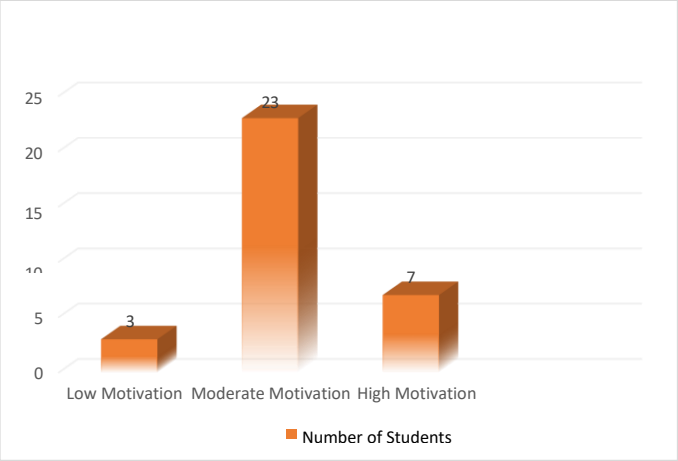

Figure 3. Bar Chart of Motivation Categories

The figure shows that most students fall into the medium motivation category. This indicates that out of 33 students, only 7 students had high motivation. Therefore, a strategy is needed to increase students' motivation in learning, one of which is by using digital-based learning media.

The pretest results on mathematical conceptual understanding revealed that the majority of students fell within the medium category, with a small proportion in the low category and the rest in the high category. These outcomes suggest that while most students possessed an adequate level of conceptual comprehension, further reinforcement was needed to achieve higher proficiency. This highlights the importance of implementing instructional approaches that can strengthen students' conceptual understanding in mathematics. One promising approach is the integration of interactive and engaging digital learning media, designed to foster greater motivation and active participation throughout the learning process..

A: red B: blue

P(A) = 6/10 = 3/5

P(B) = 4/(10–1) = 4/9

(Example of students' pretest answer)

For example, one of the students' answers shown in the figure above illustrates this issue. The student did not yet understand how to determine the probability of drawing consecutively without replacement. The problem asked was:

"In a bag there are 6 red balls and 4 blue balls. If 2 balls are drawn consecutively without replacement, what is the probability of getting 2 blue balls?"

The student still did not understand that when balls are drawn consecutively, the concept of combination can be applied. This indicates that students' understanding of the given problems has not yet shown comprehensive mastery of the principles of counting techniques.

Implementation of Cycle 1

Observations during the first cycle revealed several issues that help explain the modest quantitative gains recorded in this phase. Thematic analysis of observation notes and student interviews identified three dominant themes: (1) technical constraints, (2) adjustment to new digital tools, and (3) varying levels of learning motivation.

Theme 1: Technical Constraints.

Time limitations, unstable internet connectivity, and device-related difficulties hindered smooth implementation. Approximately 5% of students experienced repeated login failures or lag and required alternative devices in subsequent sessions. These disruptions were frequently mentioned in interviews, with students reporting that technical delays reduced their focus and slowed their pace in completing digital tasks. This theme helps explain why several students did not finish activities within the allocated time.

Theme 2: Adjustment to New Digital Tools.

Since Liveworksheet was newly introduced, many students expressed initial confusion in navigating the interface, especially in submitting responses and switching between question formats. Observers noted that students frequently sought clarification during early sessions, which consumed instructional time. This unfamiliarity contributed to the limited participation rate—23 out of 40 students (57.5%) were fully engaged in the first cycle.

Theme 3: Varying Levels of Learning Motivation.

Interviews revealed that students with higher initial motivation found the gamified elements of Quizizz and Kahoot stimulating, while those with lower motivation struggled to maintain attention when technical issues occurred. Some students reported feeling "less excited" in the first session because they were "still trying to understand the tools," indicating that motivation was influenced by their comfort level with the media.

These qualitative findings provide deeper insight into the quantitative results obtained in Cycle 1 and explain why the initial improvements in conceptual understanding and motivation were moderate. The descriptive statistical outcomes for this cycle are presented below using IBM SPSS.

Table 8. Descriptive Statistics of Cycle 1

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
SIKLUS_1	33	43	57	100	80.85	10.857	117.883
Valid N (listwise)	33						

The first cycle was the initial learning session conducted after the pretest. Since the learning process used mobile phone–based media, there were some minor issues related to the use of different devices among students, which required additional time to resolve. However, overall, the learning process ran smoothly from beginning to end without skipping any stages.

There were several improvements regarding students' understanding and motivation in comprehending and finding solutions to the given questions. Students' curiosity also improved compared to before. It was observed that students actively asked questions to both the teacher and their peers regarding the use of the media as well as understanding the material related to "Probability." Although the learning outcomes were not yet significant, students' enthusiasm and motivation had been fostered through the use of engaging, updated media that stimulated their curiosity in answering and understanding the material presented in digital form.

As an instructor, this serves as an important note for preparing the next cycle, which is to optimize students' motivation and learning spirit so that it becomes more directed and measurable, thereby improving the learning outcomes compared to the previous cycle.

Implementation of Cycle 2

Based on the observation results of the implementation of Cycle 2, it was found that during this cycle, all students were able to access the learning materials as they had prepared beforehand. However, students' accuracy still needed improvement. The implementation of Quizizz had been previously introduced to the students, and it was observed that they no longer experienced difficulties in using it.

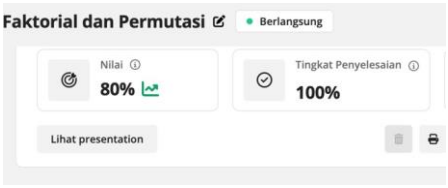

Figure 5. Achievement in Cycle 2

Students' enthusiasm was also more evident in using Quizizz. Based on the observation results, the presentation of student activity reached 27/40 = 67.5%. There was an increase of 10% from Cycle 1 to Cycle 2. The observed improvement can be attributed to the integration of the Quizizz platform, which students had been exposed to beforehand, enabling them to engage with the tool more confidently and effectively throughout the learning activities. The following is the descriptive statistical result using IBM SPSS:

Table 9. Descriptive Statistics of Cycle 2

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
SIKLUS_2	33	41	59	100	82.09	13.538	183.273
Valid N (listwise)	33						

The second cycle served as a learning phase focused on evaluating the first cycle, aiming to improve learning outcomes through the enthusiasm and motivation that had already been fostered. The instruction provided in this second cycle emphasized a more detailed discussion of the problems and was based on various contextual questions. Thus, it was expected that students would gain a deeper understanding of the topic of "Probability."

In this second cycle, the learning environment appeared more conducive and efficient than before, as students had become accustomed to using the medium that was previously unfamiliar to them. During this cycle, they also began to explore their understanding more extensively through the provided media.

This cycle also started to show an improvement in students' learning outcomes, as evidenced by the practice exercises they completed. Furthermore, when the teacher posed stimulating questions, many students actively responded correctly in line with the concepts taught.

Implementation of Cycle 3

Based on the observations of the third cycle conducted on January 6, 2025, it was found that students no longer experienced technical or non-technical difficulties related to the use of the provided learning media. In this cycle, the medium used was Kahoot. During this learning session, three practice questions were given, and more than 80% of the students answered the questions correctly.

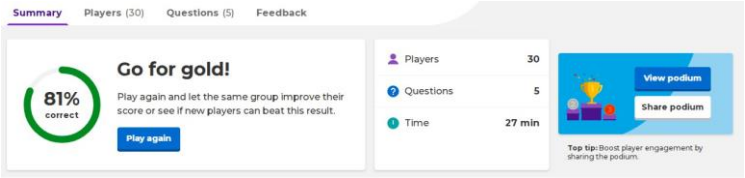

Figure 7. Achievement in Cycle 3

From the series of learning activities, it was evident that students were highly enthusiastic in completing the practice questions provided through the Kahoot application. Students were motivated to compete in answering the questions presented. Thus, overall, the third cycle ran smoothly and successfully. The following are the descriptive statistical results analyzed using IBM SPSS.

Table 10. Descriptive Statistics for Cycle 3

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
SIKLUS_3	33	35	65	100	81.06	7.882	62.121
Valid N (listwise)	33						

The descriptive statistics indicated an improvement in the students' mean scores, reflecting positive progress in the learning process. This outcome was consistent with the observation data, which revealed that 75% of student activities were actively engaged during the sessions utilizing digital-based media. The observation record for Cycle 3 is presented below.

Implementation of Cycle 4

In Cycle 4, which was conducted on January 13, 2025, observation results showed that students remained enthusiastic about following the material and completing the practice questions presented in the Quizizz application. The results of the practice test recap in this cycle indicated that more than 90% of students answered the questions correctly. In addition to practice questions, this cycle also presented material on compound probability through the Quizizz application. Thus, from the beginning to the end of the lesson, students remained focused on the Quizizz learning media. Below is the descriptive statistical result of Cycle 4 using IBM SPSS.

Table 11. Descriptive Statistics of Cycle 4

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
SIKLUS_4	33	20	80	100	91.06	4.802	23.059
Valid N (listwise)	33						

Increase in Average Score and Student Engagement

The increase in the average score aligns with observation findings showing that students became more interested and engaged in mathematics learning activities. This improvement can be understood through the lens of digital constructivism, which posits that interactive digital tools support students' active construction of knowledge by providing immediate feedback and varied representations of concepts. In the context of probability, digital media such as Quizizz, Kahoot, and Liveworksheet allow students to visualize random events, experiment with repeated trials, and receive instant corrections—features that are difficult to achieve with traditional methods. These affordances help students internalize abstract probability concepts more effectively.

Student productivity also increased substantially, with engagement reaching 82.5% in Cycle 4, surpassing the expected target. This aligns with Keller's ARCS motivational model, particularly in the elements of *Attention* and *Satisfaction*. The gamified features of Quizizz and Kahoot captured students' attention, while immediate scoring and feedback provided a sense of accomplishment that strengthened satisfaction and sustained motivation. Interviews reinforced this finding, as students expressed that the use of smartphones and interactive websites made the learning atmosphere "more enjoyable" and helped them stay motivated.

The post-test results, with an average score of 82.67, further confirmed the improvement in students' conceptual understanding of probability. This outcome is consistent with prior research by Anggoroa et al. (2025) and Aprilia et al. (2024), who found that game-based digital tools enhance both conceptual mastery and motivation. Similar to Koparan's study, the interactive nature of digital media enables students to engage in exploratory learning, which deepens their comprehension of probabilistic reasoning. However, this study extends previous findings by demonstrating that a multiplatform combination—integrating game-based quizzes with interactive

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→ Tambahkan pembahasan yang lebih reflektif, misalnya:
- Mengapa media digital efektif dalam konteks peluang?
- Faktor apa yang paling memengaruhi peningkatan motivasi?

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worksheets—provides a more holistic learning environment that supports practice, exploration, and reflection.

Overall, the qualitative and quantitative results suggest that the most influential factors behind the increase in motivation were:

1. interactive feedback,
2. gamification elements,
3. ease of access using familiar devices, and
4. varied digital activities that prevented monotony.

These findings indicate that integrating digital-based learning media not only fosters a more interactive classroom environment but also supports students' conceptual understanding and motivation more effectively than traditional approaches.

Analysis: The Use of Digital-Based Learning Media to Improve Conceptual Understanding of Probability

Drawing on the pre-test and post-test data, the analysis aimed to evaluate whether the use of digital-based learning media contributed to meaningful improvements in students' conceptual understanding of probability. As an initial step, the effectiveness of the intervention was examined using the N-Gain score calculated via SPSS.

Table 12. Descriptive Statistics of N-Gain

	N	Minimum	Maximum	Mean	Std. Deviation
Ngain_Score	33	-0.43	0.69	0.2497	0.21429
Ngain_persen	33	-42.86	68.75	24.9737	21.42864
Valid N (listwise)	33				

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→ Revisi interpretasi hasil berdasarkan kategori Hake (low/medium/high).
→ Tambahkan *effect size* (Cohen's d atau r) untuk memperkuat kesimpulan.
→ Jelaskan mengapa ada beberapa *negative gain* dan bagaimana peneliti menanganinya.

The N-Gain mean of **0.25** falls into the **"low" category** based on Hake's (1998) classification ($g < 0.3$). This indicates that the digital media, in its current form, did not produce substantial conceptual gains across the group. Several factors contributed to this outcome, including technical issues, varying student readiness, and uneven engagement levels.

Furthermore, **negative N-Gain values** were found for several students, indicating a post-test score lower than the pre-test score. These cases were not removed from analysis, as excluding them would distort the real learning condition; instead, they were interpreted as indicators of difficulties in accessing or interacting with the media, as confirmed during student interviews.

To determine whether the digital-based media still produced a statistically detectable improvement for at least a subset of students, inferential testing was conducted. Since the research employed a

single-group pretest–posttest design, normality and homogeneity tests were performed to determine the appropriate statistical procedure.

Table 14. Results of the Normality Test

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
pretes pemahaman	0.128	33	0.184	0.938	33	0.061
postes pemahaman	0.194	33	0.003	0.908	33	0.008

According to the normality test results presented above, the Shapiro–Wilk test was applied because the sample size was fewer than 100 participants. The findings revealed that one of the posttest understanding scores had a significance level (sig) below 0.05, indicating a non-normal data distribution. Consequently, the parametric t-test was deemed unsuitable, and a nonparametric approach—the Wilcoxon test—was performed instead. The outcomes from IBM SPSS are presented as follows:

Table 15. Results of the Statistical Test

		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
postes pemahaman – pretes pemahaman	Negative Ranks	1a	14.5	14.5	-4.587b	0
	Positive Ranks	30b	16.05	481.5		
	Ties	2c				
	Total	33				

The test results showed a **significant difference** ($p < 0.05$), indicating measurable improvement for most students even though the overall N-Gain remained low.

An **effect size** for the Wilcoxon test was calculated using $\boldsymbol{r = Z / \sqrt{N}}$, resulting in:

r = –4.587 / √33 ≈ –0.80,
which represents a **large effect**.

This suggests that while the *average* gain was low, the *magnitude of change among students who improved* was substantial.

Interview data from five randomly selected participants clarified this discrepancy. Students reported that the digital media helped them visualize probability concepts but also expressed difficulty navigating certain features, especially during initial use. As one student noted: *"The*

digital media helped me understand, but I needed time to learn how to use it." These qualitative findings help explain the mixed statistical outcomes: high variation, some strong individual progress, and several negative gains linked to technical barriers.

These results are consistent with previous studies (Kristanti, 2019; Sastro et al., 2023), which highlight that digital media can enhance conceptual understanding but require adequate scaffolding and user readiness. Other findings (Hidayat et al., Inarto) show that tools such as Quizizz and LiveWorksheet increase engagement, which can support learning outcomes when used effectively.

Analysis of the Use of Digital-Based Learning Media to Improve Learning Motivation

Pretest and posttest questionnaires assessing learning motivation were distributed via Google Forms to examine whether the application of digital-based learning media led to a significant improvement. The analysis utilized a paired-sample t-test in SPSS, appropriate for the one-group pretest–posttest design applied in this research. Before conducting this parametric analysis, normality and homogeneity tests were performed as preliminary requirements. The outcomes of the normality assessment for learning motivation scores in both pretest and posttest stages are presented below:

Table 16. Results of the Normality Test for Learning Motivation

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest motivasi	0.096	33	.200*	0.982	33	0.856
posttest motivasi	0.125	33	.200*	0.97	33	0.475

Both distributions were normal ($p > 0.05$), supporting the use of a parametric paired-sample t-test. The statistical results are shown below.

Table 17. Results of the Paired Sample t-Test

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	pretest motivasi - posttest motivasi	-3.63636	4.74222	0.82551	-5.31788	-1.95485	-4.405	32	0

The significance value of **p < 0.05** indicates that digital-based learning media produced a statistically significant improvement in students' motivation.

To strengthen the interpretation, **Cohen's d** was calculated:

$$d = \frac{t}{\sqrt{n}} = \frac{-4.405}{\sqrt{33}} \approx -0.77$$

This represents a **medium-to-large effect**, suggesting that the intervention meaningfully enhanced students' motivation, even if conceptual gains were modest.

Interview data corroborated this result: students described the learning process as "more enjoyable," emphasizing that interactive platforms increased engagement. Prior studies (Nurhadi, 2023; Prasetyo & Dewi, in Inarto) similarly reported that digital media improve learning motivation by making activities more interactive and learner-centered.

CONCLUSION

Based on the results of this classroom action research, it can be concluded that the use of digital-based learning media led to measurable improvements in students' conceptual understanding and learning motivation on the topic of probability in Grade XII at SMAN 1 Parakansalak. The average score increased from 74.76 in the pre-test to 82.67 in the post-test, indicating a 10.5% improvement. However, when examined through the N-Gain score, which was 0.25 and categorized as *low* according to Hake's criteria, the learning gains were relatively modest. This suggests that although the intervention produced statistically significant improvements—as supported by the Wilcoxon test and the medium-to-large effect size—the overall effectiveness of the digital learning media remained limited and varied across students. Several students showed substantial improvement, while others experienced minimal or even negative gain, likely due to technical challenges and differences in digital literacy.

These outcomes were supported by observations indicating increased student engagement, with activity levels reaching 82.5% during Cycle 4, as well as interview findings where students reported that digital media enhanced their enjoyment and helped them visualize probability concepts more effectively. Nonetheless, the study faced several limitations that must be considered in interpreting these results. Technical issues such as inconsistent internet access, device problems, and students' unfamiliarity with the digital tools constrained the consistency of learning experiences, especially during the early stages of the intervention. The short duration of the research cycles and the focus on a single class also limit the extent to which the findings can be generalized. Variations in students' digital readiness may have further contributed to the inconsistency in learning gains.

Considering these limitations, future research should explore the long-term impact of digital-based learning media on conceptual understanding and motivation by conducting studies with extended implementation periods. Further investigations are also recommended to compare different forms of digital media to determine which features most effectively support deep conceptual learning in

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→ Ubah menjadi kesimpulan berbasis data (mis. *"Peningkatan berada pada kategori rendah, menunjukkan potensi media digital tetapi masih memerlukan pendampingan reflektif."*)
→ Tambahkan bagian *limitations* dan *future research directions*.

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→ Disarankan menjalani penyuntingan bahasa akademik (English proofreading atau editing Bahasa Indonesia formal).

mathematics. Additionally, studies involving more diverse school contexts and student populations would improve generalizability and offer deeper insights into how digital tools function across varying technological infrastructures. More comprehensive qualitative analyses, such as thematic coding of student reflections, could also provide richer explanations of how digital learning environments influence cognitive and motivational processes. Together, these directions will help refine the design, implementation, and evaluation of digital learning media to maximize their potential in enhancing mathematics education.

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