Effectiveness of Game-Based Learning in Enhancing Attitudes and Achievement in Statistics and Probability among Science Stream Undergraduates in Malaysia

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ABSTRACT

The study used a quantitative quasi-experimental design. The participants were 305 undergraduate students enrolled in a statistics and probability course at a Malaysian public university. A total of 180 students joined the game-based learning group, while 125 students joined the traditional instruction group. Data were collected using the Survey of Attitudes Toward Statistics (SATS-36), a statistics and probability achievement test, and a Game-Based Learning Perception Survey administered to the only experimental group. The four-week intervention covered key probability topics, including set theory, counting rules, permutations, combinations, conditional probability, and Bayes' theorem. Data were analyzed using descriptive statistics and independent-samples t-tests. The findings showed that students in the game-based learning group had significantly more positive attitudes toward statistics in affect, cognitive competence, value, and difficulty than students in the traditional instruction group. They also achieved significantly higher scores in statistics and probability. These findings suggest that game-based learning can improve both attitudes and achievement in statistics education.

Keywords: Achievement, Attitudes, Game-based learning, Probability, Statistics

INTRODUCTION

In the era of the Industrial Revolution 4.0, the ability to interpret, analyze, and reason with data has become increasingly important in higher education. Undergraduate students across various disciplines are expected to engage with quantitative information, evaluate evidence, and make informed decisions in academic as well as professional contexts. In Malaysia, statistics is an important component of higher education because it is intended to equip students with the analytical competencies required in an increasingly data-driven society and workforce. As a result, statistical literacy, statistical reasoning, and statistical thinking have become essential competencies that students are expected to develop [1]. Recent evidence has also identified statistical literacy, statistical reasoning, and statistical thinking as the three underlying components of students' perceived statistical ability in higher education [2].

There have been numerous and growing studies on statistics education and probability learning in higher education. A substantial body of research has examined students' misconceptions, reasoning difficulties, conceptual understanding, and interpretation of statistical and probabilistic ideas [3], [4]. Other studies have shown that many students continue to rely on formulas and routine procedures without sufficient understanding of meaning, context, and justification [5], [6]. In addition, researchers have examined various pedagogical approaches designed to improve students' engagement and learning [7]. The previous studies suggest that students' difficulties arise not only from the complexity of statistics and probability itself but also from classroom pedagogy that often prioritises procedural performance over conceptual understanding [1], [8].

Among the topics taught in introductory statistics courses, probability remains one of the most difficult for students. Previous research shows that students can calculate probability correctly but still struggle to interpret results in context. This issue reflects broader difficulties in probabilistic reasoning and statistical interpretation

[9]. Without appropriate support, students may continue to view statistics and probability as sets of formulas and rules rather than as tools for reasoning and decision-making [8], [10]. Prior studies also show that students often hold negative perceptions of statistics due to anxiety, low confidence, and limited perceived usefulness [11], [12]. In contrast, practical and real-world teaching approaches can improve engagement and strengthen students' application of statistical concepts [13]. One pedagogical approach that may address this issue is Game-Based Learning (GBL).

Previous studies have documented GBL's potential to promote motivation, participation, engagement, and classroom interaction [14], [15]. At the same time, systematic reviews have also shown that game-based and gamified learning in higher education can support student motivation, performance, and learning outcomes [16], [17]. Recent work in mathematics education also reports positive effects on both cognitive and affective domains [18]. In learning environments dominated by lectures, worked examples, and routine exercises, students may focus primarily on obtaining correct answers without examining why those answers are reasonable. By contrast, GBL may provide a learning environment in which students predict, test, compare, and justify outcomes through interactive experience. Through repeated engagement in such activities, students may become more aware of variation, randomness, fairness, and evidence-based thinking. These characteristics suggest that GBL may provide meaningful support for the development of statistical literacy, statistical reasoning, and statistical thinking in probability [18], [19].

Problem statement

Statistics and probability are important components of higher education because they help students interpret data, understand uncertainty, and make reasoned decisions. However, statistics classroom pedagogy often emphasizes procedures, computation, and formula application more than conceptual understanding. As a result, many undergraduates can perform statistical calculations correctly but cannot interpret the results or justify their conclusions [20]. This issue suggests that students' learning often remains at the level of surface performance rather than deeper statistical understanding [1], [8].

This problem becomes more apparent when the students solve probability tasks involving uncertainty, variation, and data-based judgment. In these situations, many students rely on intuition and memorized procedures rather than conceptual understanding [12], [20]. They may obtain a numerical answer without recognizing its implications [21]. Consequently, their understanding becomes fragmented, and their ability to make sound judgments in statistical and probabilistic situations remains weak. Research on probability learning has repeatedly shown that misconceptions in probability can persist among undergraduates and weaken decision-making under uncertainty [8], [10].

This issue is especially relevant in Malaysian higher education, where undergraduates need quantitative competencies for academic study, professional practice, and everyday life. However, local evidence shows that students' understanding of basic statistical concepts and their attitudes toward statistics remain important concerns [20], [22], [23]. Classroom pedagogy also often prioritizes examination performance and task completion over interpretation, reasoning, and reflective judgment. Under these conditions, students may perform adequately in routine exercises but remain unable to interpret statistical information critically or think probabilistically in unfamiliar situations. Studies in Malaysian tertiary institutions show that students' perceived ability and attitudes are associated with their performance and understanding in statistics. Classroom practices also shape how effectively students learn these concepts [20], [24], [25]. One pedagogical approach that may address this problem is Game-Based Learning (GBL).

In principle, GBL promotes active participation, repeated trials, immediate feedback, and contextualized learning experiences that may support deeper understanding. These characteristics are particularly relevant to the learning of statistics and probability because they allow students to confront uncertainty, observe variation, test predictions, and reflect on outcomes. Existing reviews have reported positive effects of game-based and gamified learning on motivation, engagement, and learning outcomes in higher education and mathematics education more broadly [18], [19]. However, there is still limited evidence on whether GBL can effectively improve Malaysian undergraduates' attitudes and achievement in statistics and probability. Therefore, the present study examines the effectiveness of Game-Based Learning as an effective pedagogical approach in improving students' attitudes and achievement in statistics and probability among Malaysian undergraduates.

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Objective of the study

The objectives of this study are:

1. To determine whether Malaysian undergraduates taught through the Game-Based Learning approach differ significantly from those taught through traditional instruction in their attitudes toward statistics.
2. To determine whether Malaysian undergraduates taught through the Game-Based Learning approach differ significantly from those taught through traditional instruction in their statistics and probability achievement.

METHODS AND MATERIALS

Research design

This study employed a quantitative approach using a quasi-experimental group design to evaluate the efficacy of a Game-Based Learning (GBL) approach compared to traditional pedagogical methods. Two instructional groups were compared. The experimental group received instruction through the Game-Based Learning approach, whereas the control group was taught through traditional instruction. The design was intended to examine whether the two instructional approaches differed in their effects on students' attitudes toward statistics and their achievement in statistics and probability.

Participant

The study was conducted at a Malaysian public university during the March to October semester of the 2025 academic session. The participants were undergraduate students enrolled in a statistics and probability course. The final sample consisted of 305 students. Of these, 180 students were assigned to the game-based learning group, and 125 students were assigned to the traditional instruction group. All participants were from the science stream. The final analysis included only students who were officially registered in the course and completed all required instruments. The researchers informed the students about the purpose of the study and obtained their consent before implementing the intervention.

Procedures and Intervention

The intervention was conducted over four weeks during the regular teaching period of the statistics and probability course. Both groups followed the same syllabus, covered the same content, and were taught by the same lecturer. This arrangement helped maintain consistency in teaching duration, course content, and assessment schedule. The probability topics included set theory, counting rules, permutations, combinations, basic probability concepts, the addition rule, the multiplication rule, conditional probability, and Bayes' theorem. The lessons focused on three learning outcomes. First, students were expected to solve problems involving probability concepts related to set theory, counting rules, permutations, and combinations. Second, they were expected to construct tree diagrams, Venn diagrams, and contingency or probability tables. Third, they were expected to apply probability rules using these representations.

The control group received traditional instruction. This approach involved lecturer explanations, worked examples, question-and-answer sessions, and written exercises. It emphasized concept explanation, procedural demonstration, and individual practice. Meanwhile, the experimental group received instruction through the game-based learning approach. Guided discussion questions supported each activity and helped students examine the probability concepts embedded in the games. The intervention followed four stages: introducing lesson objectives and game rules, playing games in small groups, discussing outcomes and strategies, and engaging in lecturer-guided reflection. The reflection stage linked students' game experiences to formal concepts in statistics and probability. This instructional sequence aimed to support students' progression from basic recognition of probability situations to interpretation, reasoning, and decision-making.

At the end of the intervention, both groups completed the Survey of Attitudes Toward Statistics (SATS-36) and the statistics and probability achievement test. The Game-Based Learning Perception Survey was administered only to the experimental group after the final class session.

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Instrumentation

Three instruments were used in the study: the Survey of Attitudes Toward Statistics (SATS-36), the Game-Based Learning Perception Survey, and a researcher-developed statistics and probability achievement test. The first instrument was the Survey of Attitudes Toward Statistics (SATS-36), adapted from [26]. It was used to measure students' attitudes toward statistics. The instrument employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Four attitudinal components were analyzed in this study, namely Affect, Cognitive Competence, Value, and Difficulty. Higher scores indicated more positive attitudes toward statistics. For the Difficulty component, higher scores indicated that students perceived statistics as less difficult. Negatively worded items were reverse-scored before analysis. The internal consistency of the scale was examined using Cronbach's alpha.

The second instrument was the Game-Based Learning Perception Survey, adapted from the Survey Instrument on Game-Based Learning Approach (SIGBLA) developed by [27]. This questionnaire was administered only to students in the experimental group. It contained 19 items that measured students' knowledge of game-based learning, their perceptions of its usefulness, and their attitudes toward learning statistics and probability through games. Responses used a five-point Likert scale ranging from 1, strongly disagree, to 5, strongly agree. Higher scores indicated more positive perceptions of the intervention.

The third instrument was a researcher-developed achievement test in statistics and probability. The test assessed students' understanding, interpretation, reasoning, and application of the statistical and probability concepts covered during the intervention. The researchers developed the test based on the course learning outcomes and the content taught in both instructional groups. The final version consisted of three short structured-response questions.

Experts in statistics education, educational measurement, and instructional design reviewed all instruments to establish content validity, clarity, and suitability for Malaysian undergraduates. A pilot study involving 30 students who were not part of the main sample was conducted before the actual study. The pilot data were used to refine item wording, improve clarity, and examine reliability. The reliability of the achievement test was estimated using Kuder–Richardson Formula 20 (KR-20) or Cronbach's alpha.

Data Analysis

The data were analyzed using SPSS. Descriptive statistics, including mean and standard deviation (SD), were used to summarize students' attitudes toward statistics, achievement in statistics and probability, and perceptions of the Game-Based Learning approach. Before inferential analysis, the data were screened for missing values, outliers, normality, and homogeneity of variance.

Independent-samples t-tests were used for the inferential analyses. Differences in attitudes toward statistics between the two instructional groups were examined for the four SATS-36 components: Affect, Cognitive Competence, Value, and Difficulty. Group differences in statistics and probability achievement were also examined using an independent-samples t-test based on the overall post-intervention achievement score.

Descriptive analysis was conducted on the Game-Based Learning Perception Survey for the experimental group to support the interpretation of the intervention from students' perspectives. Statistical significance was set at 0.05 for all inferential analyses. Cohen's d was reported to indicate the magnitude of the differences between the two instructional groups.

RESULTS

Differences in Attitudes toward Statistics between the Traditional and Game-Based Learning Groups

An independent-samples t-test was conducted to examine differences in attitudes toward statistics between students taught through traditional instruction and those taught through the Game-Based Learning approach.

Table 1. Mean Comparison of SATS-36 Scores

Attitudinal component	GBL group Mean ± SD	Traditional group Mean ± SD	*t*-value	*p*-value	Effect size (*d*)
Affect	4.010 ± 0.059	3.020 ± 0.062	12.450	<0.001*	1.620
Cognitive competence	3.960 ± 0.063	3.100 ± 0.058	11.200	<0.001*	1.410
Value	4.110 ± 0.059	3.180 ± 0.061	12.180	<0.001*	1.540
Difficulty	4.000 ± 0.066	2.740 ± 0.055	16.740	<0.001*	2.080

Note: * Significance at 0.05

The results in Table 1 showed that the Game-Based Learning group obtained higher mean scores across all four SATS-36 components: Affect (4.010 ± 0.059 vs. 3.020 ± 0.062), $t(303) = 12.450$, $p < 0.001$, $d = 1.620$, Cognitive Competence (3.960 ± 0.063 vs. 3.100 ± 0.058), $t(303) = 11.200$, $p < 0.001$, $d = 1.410$, Value (4.110 ± 0.059 vs. 3.180 ± 0.061), $t(303) = 12.180$, $p < 0.001$, $d = 1.540$, and Difficulty (4.000 ± 0.066 vs. 2.740 ± 0.055), $t(303) = 16.740$, $p < 0.001$, $d = 2.080$. These findings indicate that students exposed to the Game-Based Learning approach held significantly more positive attitudes toward statistics.

These findings indicate that the Game-Based Learning approach was associated with significantly more positive attitudes toward statistics across all measured attitudinal dimensions. The consistently large effect sizes further suggest that the difference between the two instructional groups was substantial.

Differences in Statistics and Probability Scores between the Traditional and Game-Based Learning Groups

A second independent-samples t-test in Table 2 showed that the Game-Based Learning group also achieved a significantly higher score in statistics and probability (M = 78.450, SD = 0.812) than the traditional instruction group (M = 62.100, SD = 0.105), $t(303) = 15.350$, $p < 0.001$, $d = 1.790$. This result suggests that the Game-Based Learning approach was more effective than traditional instruction in improving students' achievement.

Table 2. Mean Comparison of Statistics and Probability Scores

Group	Mean	SD	*t*-value	*p*-value	Effect size (*d*)
Score			15.35	< 0.001*	1.790
GBL	78.450	0.812			
Traditional	62.100	0.105			

Note: * Significance at 0.05

This finding suggests that the Game-Based Learning approach was more effective than traditional instruction in improving undergraduate students' achievement in statistics and probability, with substantially higher scores than those who learned through conventional classroom methods.

DISCUSSION

The present study examined whether the game-based learning approach differed significantly from traditional instruction in improving Malaysian undergraduates' attitudes toward statistics and their achievement in statistics and probability. The findings showed that students taught through game-based learning had significantly more positive attitudes toward statistics and achieved significantly higher scores in statistics and probability than those taught through traditional instruction. These results suggest that game-based learning served as a more effective pedagogical approach than traditional instruction in this study. This finding is important in statistics education because statistical learning should support not only computation but also interpretation, reasoning, and judgment under uncertainty [1].

The positive effect on attitudes may be explained by the interactive nature of the intervention [19], [28]. Students in the game-based learning group were shown to participate actively, discuss outcomes, compare strategies, and reflect on the meaning of probability situations, rather than rely only on lecturer explanations and routine exercises [15]. These learning experiences may have reduced the passive and intimidating nature often associated with probability learning. They may also have made the subject more meaningful and manageable for students. This interpretation is consistent with previous studies showing that game-based and gamified learning can strengthen motivation, engagement, and classroom participation. These benefits are especially likely when teaching moves beyond lecture-based delivery toward more active forms of student involvement [16], [19].

The higher achievement of the game-based learning group also suggests that the intervention supported cognitive learning outcomes, not only affective responses [15], [18], [28]. This improvement may be explained by repeated engagement with probability tasks, immediate feedback from game outcomes, peer discussion, and guided reflection. These features helped students connect formal probability rules with concrete learning experiences. The game-learning also strengthened students' understanding and application of probability concepts.

Research on teaching and learning in statistics education shows that students often struggle because they rely on intuition, incomplete reasoning, or rule-based procedures without adequate conceptual understanding [8], [10], [21]. In this context, game-based learning can benefit students because it allows them to test predictions, observe variation, and justify outcomes through active participation [8], [10].

The findings are generally consistent with previous studies showing that game-based and gamified learning can improve student engagement and academic performance in higher education [16], [19], [29]. However, the present study extends the existing literature in two ways. First, it provides evidence from statistics and probability, a subject area in which students often face abstraction, misconceptions, and dependence on procedures. Second, it offers evidence from Malaysian higher education, where students' attitudes toward statistics and their understanding of basic statistical concepts remain key concerns. These findings suggest that the pedagogical value of game-based learning extends beyond enjoyment. It can also support more meaningful learning in quantitatively demanding subjects [19], [20].

CONCLUSION

This study shows that the game-based learning approach can improve Malaysian undergraduates' attitudes toward statistics and their achievement in statistics and probability. Students who received the intervention showed significantly more positive attitudes across key attitudinal dimensions and achieved significantly higher scores than students taught through traditional instruction. These findings indicate that game-based learning is not only an engaging classroom technique but also a pedagogical approach that can support meaningful learning outcomes in statistics education. Its emphasis on active participation, immediate feedback, and guided reflection appears to make probability learning more accessible, less intimidating, and more conceptually meaningful. This study provides empirical support for the use of game-based learning in undergraduate statistics instruction. It also highlights the need to move beyond procedure-driven pedagogy toward approaches that promote both engagement and understanding. However, the findings are limited by the institutional and methodological scope of the study. Further research across broader contexts, longer intervention periods, and additional dimensions of statistical learning is needed to strengthen the generalisability of these results.

LIMITATION OF STUDY

This study has several limitations. First, the research was conducted at a single Malaysian public university. However, this decision was made to ensure consistency in syllabus content, instructional delivery, assessment schedule, and lecturer effects, as Statistics and Probability courses may vary considerably across institutions. Second, although existing classes were randomly assigned to the intervention and control conditions, the quasi-experimental design did not permit individual random assignment, and therefore the possibility of selection bias cannot be completely eliminated. Third, the intervention lasted four weeks, corresponding to the duration allocated for the Introduction to Probability sub-topic within a 12-week semester. Consequently, the findings reflect the short-term impact of game-based learning on students' attitudes and achievement in probability rather than its long-term effects. Future studies should involve multiple institutions, employ randomized controlled designs where feasible, and examine the effectiveness of game-based learning across longer instructional periods and broader statistical topics.

FUTURE STUDY

Future research should include multiple universities and diverse student populations to improve the generalizability of the findings. Randomized controlled trials would strengthen the ability to establish causal relationships between game-based learning and student outcomes. Extending the duration of the intervention would help determine whether improvements in attitudes and achievement are sustained over time.

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