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Boosting Year 4 Science Education: A Dynamic Blend of Paper-Based and Computerized Board Games

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ABSTRACT

This study examines using Paper-Based and Computerised Board Games with collaborative learning to enhance science learning involving 48 Year 4 participants from National-Type Chinese Primary Schools (24 Male and 24 Female). The study utilises a mixed-methods approach combining quantitative (pre-tests, post-tests, questionnaires) and qualitative (classroom observations, interviews) data to investigate the unique strengths of these pedagogical approaches. Paper-based Board Games with Collaborative Learning (CL) showed the most substantial impact on academic performance, motivation, and social interaction compared to Computerised Board Games with collaborative learning. The research suggests that paper-based board games might be a more effective tool for educators using CL to create engaging learning experiences in science for young students. Additionally, no significant difference between genders was observed in the learning scores. Further research with more extensive and diverse samples, longitudinal studies, and exploration in different contexts are recommended to broaden the understanding of these methods' effectiveness across various settings and learning goals.

Keywords: pedagogy, paper-based board games, computerised board games, collaborative learning, academic performance, learning motivation, social interaction, national-type Chinese primary schools

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1 INTRODUCTION

Despite the Malaysian government's laudable efforts to foster science and technology (STEM) education through various national initiatives, including the National Education Policy, the 3rd Core of the Eleventh Malaysia Plan, the Malaysia Education Blueprint 2013-2025 (Abdullah, 2021), science curriculum revisions from Year 1 to Year 6 (Sulaiman et al., 2017) and STEM education policy (Jamel et al., 2019), international assessments paint a concerning picture of declining science performance (Aliyu, 2020; Suhaili et al., 2020). While the National STEM Centre advocates for adopting inquiry-based learning approaches (Ong et al., 2021), a reliance on traditional, exam-oriented teaching methods persists (Shah et al., 2017; Abdullah et al., 2017). This emphasis on rote memorisation often hinders students' genuine comprehension and engagement with scientific concepts, creating challenges in developing higher order thinking skills (HOTS) (Phang et al., 2020; Mat & Yusoff, 2019). Additionally, students' motivation in learning science tends to be driven by exam results rather than a genuine desire to understand (Phang et al., 2020), further contributing to a superficial grasp of scientific knowledge. Moreover, the persistent perception of science as a dull and challenging subject remains challenging, potentially hindering students' grasp of science concepts and impeding effective teaching techniques (Teppo et al., 2021; Virata et al., 2019).

This research addresses these challenges by exploring the potential of gamification by using board games as a supplementary tool to enhance science learning among primary school students in Malaysia. Board games leverage gamification's inherent motivational and collaborative benefits (Zakaria et al., 2022; Le et al., 2018), fostering engagement and positive learning experiences. This study investigates two forms of board games: Paper-Based Board Games (PBBG) and Computerized Board Games (CBG). PBBG offer readily accessible and cost-effective solutions, fostering social interaction and communication among players. Conversely, CBG provides opportunities for increased engagement, interactivity, and multimedia integration (Aditya et al., 2021; Liu & Lu, 2021).

Social Interaction as the Cornerstone of Collaborative Learning: Cultivating Growth in Science Education

Collaborative Learning (CL) is characterised by intentional group work, where students work in small groups towards a shared learning goal. This necessitates co-labouring, requiring them to actively engage with each other, exchange ideas, and contribute collectively to achieve the task (Major, 2020). CL strategies like peer-based learning activities and social collaboration projects (Urrea et al., 2022) create an environment where students can leverage their strengths and diverse perspectives to deepen their collective understanding of scientific concepts. Positive social interaction within CL offers many benefits for students. For example, students solidify their understanding of scientific principles by engaging in discussions, explaining concepts to peers, and receiving feedback (Tocaimaza-Hatch & Santo, 2020). Furthermore, social interaction stimulates critical thinking and problem-solving skills as students collaboratively analyse information and reach shared conclusions (Hult, 2019). CL fosters effective communication as students learn to articulate their thoughts clearly, listen actively to their peers, and present information persuasively. Working within groups helps students develop teamwork, conflict resolution, and leadership skills, which are essential for success in both academic and professional settings (Valiente et al., 2020).

Technological advancements are transforming the way CL is implemented in classrooms. Integrating electronic devices and wireless communication allows students to collaborate seamlessly, share learning materials, and engage in interactive activities (Zhang & Zou, 2022).

Motivation in Science Learning

A student's attitude towards science is pivotal to academic success (Toma & Greca, 2018), and teachers are pivotal in captivating students' interest and encouraging self-driven explorations in Science Education (Gerard et al., 2022). As Gonzalez-Gomez et al. (2022) aptly explain, attitude reflects a student's emotional response and overall disposition towards the subject. However, motivation goes beyond mere liking; the internal drive fuels the pursuit of knowledge and propels students to overcome challenges (Makransky et al., 2019).

Stark (2019) highlights the profound impact of motivation on science learning. Students with high motivation demonstrate more remarkable perseverance and goal-oriented behaviour, leading to improved academic performance and a deeper grasp of scientific concepts. Jurado and Garcia (2018) emphasise the intricate interplay between attitude and motivation. Fostering high motivation in students is essential for facilitating knowledge acquisition, developing critical thinking skills, and refining scientific process skills in the classroom.

The Science of Gamification: The Role of Board Games and Gender

Gamification strategically incorporates game mechanics and design elements into non-game contexts, like education (Lim et al., 2021). This innovative approach holds immense promise for boosting student engagement and motivation in science learning. However, understanding the potential influence of gender differences on the use and impact of these games is crucial for educators and game designers alike.

PBBGs (Paper Based Board Games) have been a cornerstone of entertainment and education for decades, offering an interactive and engaging learning experience (Lim et al., 2021). While research by Eriksson et al. (2021) acknowledges the importance of understanding gender differences in the context of PBBGs, the overall body of research presents a mixed picture. Several studies, like those by Lin & Hou (2016) and Al-Tarawneh (2016), found no significant gender differences in the use or effectiveness of PBBGs. However, others suggest potential gender disparities in learning preferences and engagement levels (Salta et al., 2022; Yu, 2021). These disparities might stem from individual learning styles, as Al Rosjidi and Mohfuroh (2023) and Temiran (2022) highlighted.

Furthermore, social interaction during PBBG sessions can reveal gender-specific communication and collaboration patterns (Terlouw et al., 2021). Understanding these dynamics, as explored by Kuo and Hsu (2020), can inform the design of PBBGs that promote inclusive and collaborative learning environments. Additionally, Alt (2023) suggests the need to consider intrinsic and extrinsic motivation when designing PBBGs, as these factors can influence student engagement and learning outcomes.

CBGs (Computer Based Board Games) have emerged as a powerful tool for engaging students in the learning process (Wang et al., 2022). Integrating CBGs into science education is a recent development, offering a unique way for students to interact with learning materials (Boghian et al., 2019). Like PBBGs, research on CBGs presents congruent findings, such as Wang et al. (2022) and Hou and Keng (2021) indicate potential gender differences in academic performance when using CBGs. These differences may be linked to the design of the games themselves, as highlighted by Johnson and Elliott (2020), who advocate for incorporating elements of competition and collaboration to cater to diverse learning styles and preferences.

Theoretical Framework

This research proposes a theoretical framework that integrates Activity Theory (AT) (Engeström, 1987) and Social Constructivism Theory (SCT) (Vygotsky, 1978) to understand how CL gamified with PBBG and CBG influences science learning outcomes (academic performance, social interaction, and motivation) among Year 4 students. Engeström's (1987) expanded model of AT provides a lens to examine the interaction between individuals (students), tools (PBBG, CBG), rules (game mechanics, communication norms), community (peers and teacher), and division of labour within the science learning activity. This framework highlights how these elements can create internal conflicts that initially hinder learning (e.g., initial frustration with technology) but drive positive transformations in students' science approaches. On the other hand, SCT emphasises the social and cultural context of learning (Vygotsky, 1978). This framework posits that knowledge is constructed through social interactions and collaboration. In this study, the classroom environment serves as a social setting where CL strategies are implemented to foster collaborative learning, communication, and knowledge sharing. The proposed framework integrates AT and SCT to highlight how PBBG and CBG, used within a CL approach, impact science learning outcomes.

1. Social Interaction: CL strategies facilitate the classroom environment, encouraging cooperative learning, individual roles within groups, and effective communication. As SCT emphasises, this fosters student social interaction, a crucial element for knowledge construction.
2. Learning Motivation: The gamified elements of PBBG and CBG, such as points, rewards, and competition, are expected to motivate students and increase their intrinsic engagement with science content.
3. Academic Performance: Through collaborative problem-solving, knowledge sharing, and active engagement facilitated by the CL-gamified approach, students are expected to achieve a deeper understanding of scientific concepts, leading to improved academic performance.

This research investigates how PBBG and CBG, integrated with well-developed CL strategies, impact students' academic performance, social interaction, and intrinsic motivation in learning science. By examining the effectiveness of these two CLG approaches, this study aims to:

1. Contribute valuable insights to the ongoing discourse of enhancing science education in Malaysia.
2. Inform the development of innovative instructional approaches that foster deep understanding, active engagement, and a love for learning science among young learners.
3. Bridge the gap between current, exam-oriented practices and a more comprehensive approach that cultivates students' scientific curiosity and problem-solving skills.

This research can provide crucial evidence for the efficacy of board games in the Malaysian science education context, potentially influencing future curriculum development and instructional practices designed to cultivate a generation of scientifically literate and inquisitive young minds.

Research Questions

This study investigated the following research questions:

1. Are there any gender differences in science learning outcomes between PBBG and CBG for Year 4 participants?
2. How do pre-test and post-test scores in science learning differ between PBBG and CBG groups for Year 4 participants?
3. How does social interaction differ between PBBG and CBG settings for Year 4 participants learning science?
4. How does learning motivation differ between PBBG and CBG settings for Year 4 participants learning science?

The following sections delve into the literature review and the theoretical foundation of this study, followed by the methods section. We then present our results, analyse, and discuss them in the discussion section, and provide the study's implications in the conclusion section.

2 METHODOLOGY

Research Design

This research employed a true experimental design (two-group pretest-post-test design). Two teaching methods, paper-based board games (PBBG) and computerised board games (CBG), were tested. Each method lasted one week and was implemented after regular school hours, with 48 participants (24 male, 24 female) taking a pre-test before establishing a baseline.

Participants

Purposive sampling was used to select Year 4 students from Chinese primary schools in Sibu who had prior exposure to science and familiarity with electronic devices. An interview assessed their positive attitudes towards technology and school. The diverse group comprised students from Chinese, Malay, and Iban backgrounds, all learning science in Mandarin. Twenty-four students were in the PBBG group, and another 24 used electronic devices for CBG. The number of participants in each group is equal in gender distribution.

Research Procedure

Two separate groups received PBBG with CL and CBG with CL instruction. Specific steps were followed to ensure data accuracy. First, permission was obtained from the Damai Tuition Centre in Sibu, and consent letters were distributed to year students from various Chinese primary schools. Subsequently, all students took a pre-test to measure their initial knowledge before instruction. Lessons focusing on Year 4 science topics were conducted during school holidays. A post-test followed the PBBG sessions for the first group. The second group took a pre-test, followed by CBG sessions and a post-test. This study received ethical review clearance from Universiti Malaysia Sarawak to ensure adherence to ethical considerations. Participants were assured privacy, and parents were informed about using a hidden camera.

Research Instruments and Materials

Two identical board games were developed by researchers focusing on the science subtopic “Light Moves in a Straight Line". These board games were developed based on the Millionaire Monopoly Game. Various game elements were integrated, such as scores, leaderboards, and rewards. Additionally, these board games were play tested with science teachers and participants to ensure their reliability in this study. The questionnaire was adapted from Pintrich et al. (1991) and Sousa et al. (2017) for the Learning Motivation section, while the Social Interaction section was adapted from Högberg et al. (2019). The observation protocol was adapted from Swaran Singh et al. (2017).

Data Collection Methods

Data collection methods involved various qualitative and quantitative approaches. For the observations both groups were observed throughout the research using hidden cameras. An additional teacher was also present as an observer. These discussions aimed to enhance data accuracy. Questionnaires were administered to both groups to collect and analyse their feedback. We also conducted semi-structured interviews with participants after the PBBG and CBG sessions for later analysis. Furthermore, these pre-test and post-test scores, questionnaire responses, interview transcripts, observational notes, and video recordings were reviewed thoroughly. During the sessions, a questionnaire focused on "Light Moves in a Straight Line" was used, and its responses were analysed alongside observational notes. Additional interview questions aided in refining the collected data analysis for improved accuracy.

Data Analysis

Each data from various methods was analysed using appropriate methods. For the pre-test and post-test: Due to non-normal data distribution in PBBG and CBG groups, the Mann-Whitney U test was used to compare score changes between groups (focusing on the subtopic "Light Travels in a Straight Line"). The results indicated a significant difference in how pre-test and post-test scores changed, suggesting the PBBG group differed significantly from the CBG group.

The data from the study's questionnaire regarding social interaction and learning motivation revealed non-normality in both groups. Therefore, the Mann-Whitney U test was utilised for comparison. While no significant differences in social interaction were found between the PBBG and CBG groups, learning motivation scores displayed a clear discrepancy. The Independent Samples of the Mann-Whitney U Post Hoc Test confirmed this significant difference in learning motivation between the PBBG and CBG groups.

Classroom observations were conducted to gain insights into participants' learning motivation and social interactions, including the researcher's interactions. Video recordings and non-participant observer feedback supplemented these observations. The data collected through these methods was analysed to assess its influence on participants' learning motivation and social interaction.

Moreover, the researcher recorded interview feedback and employed manual thematic analysis to ensure accurate data coding. This approach involved verbatim transcription of the interviews and systematic application of codes to capture participants' thoughts related to the research questions. Braun & Clark's (2006) thematic analysis protocol was followed. The interviews were transcribed immediately after each session, serving as a preliminary data analysis stage.

3 RESULTS

RQ1: Are there any gender differences in science learning outcomes between PBBG and CBG for Year 4 participants?

Analysis of Gender Differences in Learning Outcomes

This section examines potential gender differences in science learning outcomes following the implementation of PBBG and CBG interventions. Before conducting further analyses, the normality of the outcome measures (change scores, social interaction, learning motivation) was assessed for both males and females using the Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 1). The results suggest that change scores and social interaction scores for both interventions met the criteria for normality (all p-values > .05). However, learning motivation scores for the PBBG intervention showed a borderline significant deviation from normality according to the Shapiro-Wilk test (p = .071).

PBBG Intervention

Levene's test confirmed the assumption of equal variances between genders for change scores (F (1, 22) = 2.198, p = .152) (Table 2). An independent-sample t-test revealed no significant difference in change scores between males and females after implementing PBBG (t (22) = .718, *p* = .480). The mean difference between the groups was 0.9167, indicating a slight advantage for one group, but this difference was not statistically significant (p = .480). The results for social interaction (U = 67.000, *p* = .736) and learning motivation scores (U = 59.000, *p* = .437) were analysed using the Mann-Whitney test, indicating no significant difference between male and female Year 4 participants after the implementation of the PBBG.

CBG Intervention

Like the PBBG intervention, Levene's test confirmed equal variances for change scores between genders following CBG implementation (F (1, 22) = 0.008, *p* = .928) (Table 3). An independent-sample t-test revealed no significant difference in change scores (t (22) = .477, *p* = .638). The mean difference favoured the female group slightly (M = -.83333), but this difference was not statistically significant (p = .638). The results for social interaction and learning motivation scores were analysed using t-tests due to meeting the normality criteria (Table 1). No significant gender differences were found in social interaction (t (22) = .477, *p* = .638) or learning motivation (t (22) = .420, *p* = .678).

Table 1. Tests of normality for outcome measures after interventions.

Aspect	Intervention	Gender	Kolmogorov-Smirnov Statistic (df, Sig.)	Shapiro-Wilk Statistic (df, Sig.)
Change Scores	PBBG	Male	.209 (12, .153)	.918 (12, .270)
		Female	.203 (12, .186)	.924 (12, .323)
	CBG	Male	.184 (12, .200)	.919 (12, .280)
		Female	.225 (12, .096)	.945 (12, .568)
Social Interaction	PBBG	Male	.446 (12, .000)	.592 (12, .000)
		Female	.279 (12, .011)	.784 (12, .006)
	CBG	Male	.167 (12, .200)	.947 (12, .598)
		Female	.284 (12, .008)	.970 (12, .065)
Learning Motivation	PBBG	Male	.201 (12, .197)	**.873 (12, .071)**
		Female	.302 (12, .003)	.901 (12, .164)
	CBG	Male	.228 (12, .084)	.868 (12, .062)
		Female	.244 (12, .047)	.868 (12, .061)

Table 2. Results of statistical tests for outcome measures after implementing PBBG.

Aspect	Levene's Test for Equality Variances Sig.)	of t-Test (t, (F, df, Sig.)	Mean Difference (M)	Std. Error Difference (SD)	95% Confidence Interval of the Difference

Change Scores	2.198, .152	.718, 22, .480	0.9167	1.27599	-1.72958, 3.56291

Table 3. Results of Mann-Whitney U test for social interaction scores after implementing PBBG among Year 4 participants.

Aspect	Gender	N	Mean Rank	Sum of Ranks	U-Statistic	Asymp. Sig. (2-tailed)
Social Interaction	Male	12	12.08	145.00	67.000	.736
	Female	12	12.92	155.00		

Table 4. Results of Mann-Whitney U test for learning motivation scores after implementing PBBG among Year 4 participants.

Aspect	Gender	N	Mean Rank	Sum of Ranks	U-Statistic	Asymp. Sig. (2-tailed)
Learning Motivation	Male	12	13.58	163.00	59.000	.437
	Female	12	11.42	137.00		

Table 5. Results of statistical tests for outcome measures after implementing CBG.

Aspect	Levene's Test for Equality of Variances (F, df, Sig.)	t-Test (t, Sig.)	Mean Difference (M)	Std. Error Difference (SD)	95% Confidence Interval of the Difference
Change Scores	0.008, .928	.477, 22, .638	-.83333	.54818	-1.97020, .30353
Social Interaction	1.786, .195	.477, 22, .638	.02750	.05764	-.09205, .14705
Learning Motivation	1.426, .245	.420, 22, .678	.01000	.02380	-.03936, .05936

Overall, the analyses based on Tables 1, 2, 3, 4 and 5 revealed no statistically significant gender differences in science learning outcomes (change scores, social interaction, learning motivation) for either the PBBG or CBG interventions.

RQ2: How do pre-test and post-test scores in science learning differ between PBBG and CBG groups for Year 4 participants?

We examine the differences in pre-test and post-test scores between the PBBG and CBG groups in learning science among Year 4 participants, focusing on "Light Travels in a Straight Line. "Table 6 presents the results of normality tests conducted on pre-test and post-test scores for the PBBG and CBG groups. The findings suggest that the data distribution is not normal for both groups at both pre-test and post-test stages (Sig. < .05).

Table 6. Normality tests for the pre-test and post-test after implementing PBBG and CBG among the Year 4 participants for the "Subtopic Light Travels in a Straight Line".

Groups	**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
PBBG (Pre-test)	.232	24	.002	.868	24	.005
PBBG (Post-test)	.146	24	.200	.904	24	.027
CBG (Pre-test)	.211	24	.007	.851	24	.002
CBG (Post-test)	.179	24	.045	.900	24	.022

A Wilcoxon Signed Ranks test (Table 7) revealed a significant difference in the change scores (pre-test and post-test) between the PBBG and CBG groups for the subtopic "Light Travels in a Straight Line" (W = 298.5 for PBBG, W = 300 for CBG, $p = .000$) (see Table 7). These W values represent only positive ranks. Due to the non-parametric nature of the test, the direction of the difference (which group improved more) cannot be determined.

Table 7. Results of Wilcoxon Signed Ranks test for subtopic "Light Travels in a Straight Line" towards pre-test and post-test scores between PBBG and CBG groups.

Aspect	**Groups**	**N**	**Mean Rank**	**Sum of Ranks**	**Asymp. Sig. (2-tailed)**
Change Scores (Pre-test and Post-test)	PBBG	24	12.98	298.50	.000
	CBG	24	12.50	300.00	.000

RQ3: How does social interaction differ between PBBG and CBG settings for Year 4 participants learning science?

This section explores the social interaction aspects of using PBBG and CBG in science learning among Year 4 participants, drawing on data from questionnaires, classroom observations, and interviews. Table 8 summarises the average scores for social interaction when using PBBG and CBG. Both groups received high average scores, with PBBG scoring slightly higher (4.82) than CBG (4.76). This suggests that both methods fostered high social interaction among participants.

Table 8. Mean score interpretation for social interaction in learning science using PBBG and CBG among Year 4 participants.

Aspect	Groups	Average Mean Score	SD	Interpretation
Social Interaction	PBBG	4.82	.333	Very high
	CBG	4.76	.396	Very high

The data distribution for social interaction scores in both PBBG and CBG groups was found to be non-normal based on normality tests (Table 9).

Table 9. Tests of normality for social interaction after implementing PBBG and CBG among the Year 4 participants.

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PBBG	.366	24	.000	.770	24	.000
CBG	.214	24	.006	.907	24	.031

A Wilcoxon Signed Ranks test revealed a significant difference in the mean social interaction scores between the PBBG and CBG groups, W = 300.00, p = .000 (two-tailed) (see Table 10). However, due to the non-parametric nature of the test, the direction of the difference (which group scored higher) cannot be determined.

Table 10. Results of Wilcoxon Signed Ranks test for the mean scores of social interactions between PBBG and CBG groups.

Aspect	Groups	N	Mean Rank	Sum of Ranks	Asymp. Sig. (2-tailed)
Mean Score (social interaction)	PBBG	24	12.50	300.00	.000
	CBG	24	12.50	300.00	.000

Data from the qualitative method were analysed using an appropriate method. Data from classroom observations unveiled two factors: interaction with the researcher. The participants actively engaged with the researcher and displayed excitement while learning with PBBG and CBG. They had many opportunities to interact with the games in their groups and reflect individually before starting—secondly, the interaction among participants. Participants actively participated in classroom activities, engaging in frequent discussions while playing PBBG and CBG. They collaborated and explained game rules to each other, ensuring everyone had a chance to learn. They also discussed answers and kept track of points during gameplay. The co-observer noted an elevated level of involvement and collaboration among participants.

We analysed the interview data using Braun and Clarke's (2020) six-phase thematic analysis approach. The researcher identified themes related to social interaction. The themes revealed that participants valued collaboration and enjoyment while using PBBG and CBG. Discussing science concepts and interacting with peers during gameplay were highlighted as critical aspects of social interaction. Most participants reported experiencing high social interaction while using both game types.

Overall, the findings from the questionnaires, classroom observations, and interviews consistently suggest that both PBBG and CBG fostered positive social interaction among Year 4 participants during science learning activities.

RQ4: How does learning motivation differ between PBBG and CBG settings for Year 4 participants learning science?

This section uses data from questionnaires, classroom observations, and interviews to explore the differences in learning motivation between PBBG and CBG in science learning among Year 4 participants. Table 11 shows that both PBBG and CBG groups received very high average scores for learning motivation, indicating a strong level of motivation in both groups.

Table 11. Mean score interpretation for learning motivation in learning science using PBBG and CBG among Year 4 participants.

Aspect	Groups	Average Mean Score	SD	Interpretation
Learning Motivation	PBBG	4.80	.342	Very high
	CBG	4.76	.367	Very high

Based on normality tests, the data distribution for learning motivation scores in PBBG and CBG groups was found to be non-normal (Table 12).

Table 12. Tests of normality for learning motivation after implementing PBBG and CBG among Year 4 participants.

Groups	**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
PBBG	.242	24	.001	.903	24	.024
CBG	.195	24	.019	.893	24	.015

The Wilcoxon Signed Ranks test revealed a significant difference in learning motivation scores between the PBBG and CBG groups, W = 300, $p = .000$ (two-tailed). However, due to the nature of the non-parametric test, the direction of the difference (which group scored higher) cannot be determined from this analysis (see Table 13).

Table 13. Results of the Wilcoxon Signed Ranks test for the mean scores of learning motivation in the PBBG and CBG groups.

Aspect	**Groups**	**N**	**Mean Rank**	**Sum of Ranks**	**Asymp. Sig. (2-tailed)**
	PBBG	24	12.50	300.00	.000
Mean Score (learning motivation)	CBG	24	12.50	300.00	.000

Data from the qualitative method were analysed for classroom observation and interviews. The classroom observation data unveiled two factors. First, the lesson structure. The lessons followed a consistent structure, with clear explanations, game distribution, supervised gameplay, and concluding discussions. Secondly, the use of technology/devices/resources: PowerPoint presentations explained game instructions and a projector displayed timers. While technology was utilised, some participants unfamiliar with laptops and board games faced challenges. The researcher provided extra help, and peers assisted struggling group members. Data from the interviews were analysed using Braun & Clarke's (2020) six-phase thematic analysis approach. We identified themes related to learning motivation, and the analysis revealed that PBBG and CBG increased participants' engagement and motivation in science learning. The games were perceived as exciting and facilitated collaboration and learning. Participants reported a preference for using these games, believing they enhanced their understanding and performance in science. Overall, the findings from all three data sources suggest that while PBBG and CBG fostered high learning motivation, the PBBG group exhibited significantly higher motivation levels than the CBG group.

4 DISCUSSIONS

Gender Differences

This research investigated potential gender differences in the learning outcomes of Year 4 participants using PBBG and CBG for science education. The findings revealed no significant impact of gender on learning performance in PBBG or CBG groups. These results align with previous studies that found no significant gender disparities in learning through game-based educational approaches. For example, studies investigating the use of board games with junior high school students (Lin & Hou, 2016), science instruction for first graders (Al-Tarawneh, 2016), and digital games for learning road rules (Li, 2015) and energy conservation (Dorji et al., 2015) all reported no significant differences in learning outcomes based on gender.

These findings suggest that gender may not significantly influence learning effectiveness in game-based science education for Year 4 participants. Further research is necessary to explore and confirm these findings in diverse contexts and with larger sample sizes.

Academic Performance: Pre-test and Post-test Scores

This study revealed a significant positive impact of PBBG with Collaborative Learning (CL) on student grades in science compared to conventional teaching and CBG. Students in the PBBG with CL group consistently achieved higher scores, demonstrating improved learning outcomes. Several studies support the benefits of board games in enhancing learning across various subjects (Parks, 2023; Alejandria et al., 2023; Miculob et al., 2022; Soewono et al., 2022; Aliyu et al., 2021). This research confirms the effectiveness of PBBG and CBG with CL in enhancing student grades, fostering group interaction, and boosting motivation in science learning for Year 4. These findings provide further evidence for the broader educational benefits of board games across different subjects and age groups.

Social Interaction

Literature shows the growing body of research on the benefits of game-based learning, which has demonstrated positive impacts on problem-solving skills and social interaction (Assapun&Thummaphan, 2023; Murray et al., 2022; Cardinot& Fairfield, 2022; Botes, 2022). Studies by Parekh et al. (2021) and Pinhatti et al. (2019) further emphasise board games' collaborative and learning-enhancing nature. Similarly, Triboni and Weber (2018), Barton et al. (2018), and numerous other researchers have documented the positive influence of board games on fostering interaction and learning. Kuo & Hsu (2020), Chen et al. (2021), and Fjællingsdaland and Klöckner (2020) extend these findings by demonstrating the ability of board games to promote teamwork and creative problem-solving in educational settings. However, this research found a significant difference between PBBG and CBG for social interaction among Year 4 participants in science classes with CL. However, we could not tell which group had more interaction. This research and existing studies suggest the positive influence of board games on promoting social interaction and collaboration among students, thereby enhancing the learning environment. However, the specific impact of PBBG vs. CBG on social interaction remains unclear. This study adds to this body of knowledge by highlighting the need for further investigation into the specific social interaction patterns within PBBG and CBG settings.

Learning Motivation

This research examined the impact of PBBG and CBG with Collaborative Learning (CL) on learning motivation in science among Year 4 participants. Questionnaire and test results revealed (1) Significant increase in learning motivation: PBBG and CBG with CL led to heightened interest in science compared to traditional teaching approaches; (2) Greater impact of PBBG: PBBG demonstrated a more substantial positive influence on learning motivation compared to CBG, as evidenced by higher scores in a test. These scores suggest that participants found PBBG enjoyable and beneficial for learning science. These findings imply that PBBG can enhance learning by making science more engaging and fostering positive learning attitudes. Implementing PBBG as a teaching tool allows teachers to incorporate game elements and create a more stimulating learning environment.

The study's results align with existing research on the effectiveness of board games in boosting student motivation and enjoyment during learning. Similar findings were reported in studies involving a board game about minerals in Portugal (Teixeira & Lima, 2023), a nutrition board game in Beijing (Chiang et al., 2022), a game on fruits and vegetables (Sangwanna et al., 2022).

These, along with numerous other studies (e.g., Lin & Cheng, 2022; Stanley, 2022), highlight the broader potential of board games in making learning more enjoyable and motivating across different subjects and age groups. This research, alongside existing evidence, strongly suggests that incorporating board games like PBBG into the curriculum can significantly enhance student motivation and create a more engaging learning environment, particularly in science education.

5 CONCLUSIONS AND RECOMMENDATIONS

This research investigated the effectiveness of various instructional methods in promoting academic performance, social interaction, and learning motivation among Year 4 participants learning science. The findings can be summarised in terms of their main components. First, academic Performance. The PBBG with Collaborative Learning (CL) emerged as the most effective method, significantly influencing participants' understanding and mastery of science knowledge and skills. Second, social interaction. All methods, PBBG and CBG with CL, stimulated positive social interaction within the science classroom, indicating participants' awareness of the different teaching approaches. Thirdly, the learning motivation: PBBG and CBG with CL significantly fostered higher learning motivation than traditional teaching methods. This highlights their potential to create a more engaging and stimulating learning environment.

Building upon these findings, future research can explore the potential impact of PBBG and CBG with CL through (1) Increased Sample Size: Enrolling participants from various schools in

Sarawak to investigate the generalizability of these findings to a more extensive and more diverse population; (2) Longitudinal Studies: Implementing longitudinal studies to assess the long-term influence of these methods on learning outcomes and student engagement; (3) Exploration of Diverse Settings: Applying these methods in different educational contexts (e.g., different geographical locations, age groups, and subject areas) to broaden the understanding of their efficacy across various settings and learning goals and (4) Group comparison: Comparing these PBBG and CBG with traditional teaching methods to gauge understanding of the effectiveness of each method.

By expanding the scope of research in these directions, we can gain a deeper understanding of the effectiveness of PBBG and CBG with CL in empowering students to excel academically, foster positive social interactions, and build intrinsic motivation for learning within the classroom environment.

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