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Digital Game-Based Learning and its Impact on Junior Secondary School Students' Motivation in Basic Science in Gombe State, Nigeria

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Abstract

Digital technology has significantly broadened educational prospects in science, with gamification emerging as a vital instrument. However, its full potential in advancing science education remains predominantly unexamined. This study examines the influence of digital game-based learning on the motivation of junior secondary school students in fundamental science in Gombe State, Nigeria. The study utilises a quasi-experimental methodology including 140 people. The experimental group utilised a 3D instructional digital game through Cospaces Edu, specifically tailored for designated themes within the junior secondary II fundamental science curriculum. The control group engaged in a tabletop game encompassing identical principles. Participants were randomly allocated to the treatment and control groups. Eight fundamental science educators submitted comprehensive studies regarding their pupils' motivation to comprehend scientific concepts. The research employed the validated Basic Science Students' Motivation Questionnaire (BSSMQ, r = 0.91), which was administered following a six-week intervention period. Data were examined using descriptive analysis for research questions and the Mann-Whitney statistical test for hypotheses at a significance level of 0.05. Data from in-depth interviews were manually transcribed, analysed, and coded to discern patterns. The results indicated the superiority of the CoSpaces Edu application compared to conventional in-person activities. The main result is that incorporating digital games into fundamental science classes markedly increases students' motivation to comprehend scientific concepts compared to conventional tabletop games. This study emphasises the importance of technological integration in science education and stresses the need for varied instructional approaches.

Keywords: Digital game-based learning approach, Students' motivation, Science concepts, Basic science, Junior Secondary School.

Introduction

The significance of science education in personal and national development is substantial. The major objective is to enhance students' understanding of scientific concepts, procedures, and the fundamental nature of science. Globally, scientific

education has become a pivotal concern, garnering considerable attention from educators and various stakeholders (Kayan-Fadlelmula et al., 2022). It seeks to prepare new generations with vital twenty-first-century competencies, including computational, critical, and creative thinking (Wahono et al., 2020). Furthermore, fundamental science, an essential domain within scientific education, is vital in addressing real-world issues such as energy, environmental sustainability, and health (Struyf et al., 2019). As a result, numerous countries regard fundamental science as a strategic need for enhancing and transforming primary education (Dou, 2019).

UNESCO (2019) states that basic science and technology encompass a pedagogical approach that integrates scientific concepts and principles cohesively, reducing premature or excessive focus on the contrasts among different scientific disciplines. However, conventional teaching techniques frequently fail to enhance student motivation, leading to suboptimal learning outcomes and reduced interest in scientific disciplines (Winarno et al., 2020).

Motivation is an essential element in the educational process, requiring novel strategies to enhance it successfully. This is especially significant as the determinants of motivation are ever-changing and becoming obsolete. Ensuring continuity is crucial for preserving educational quality (Tisza et al., 2021). Motivation serves as the catalyst for learning, fostering engagement, which is essential for the learning process to take place. There exist two categories of motivation (Filgona et al., 2020). Internal motivation is an individual's inner drive, independent of external influences, and directly associated with their own wants and objectives. Conversely, extrinsic motivation pertains to the inclination to engage in an activity to attain favourable results, such as rewards (often manifested as positive assessments) or to evade unfavourable outcomes, such as penalties (commonly represented as negative assessments).

The phenomenon of learning motivation has been thoroughly examined throughout the disciplines of education, psychology, neuroscience, and sociology. The research encompasses various academic and practical disciplines to comprehend individuals' motivation for learning. The genesis of learning motivation study can be attributed to early behavioural theories, in which scholars examined the influence of external cues and reinforcement on motivation as reactions to rewards and punishments. Prominent scholars like Skinner (1938) investigated the influence of positive and negative stimuli on behaviour modification. Prior research has indicated a correlation between learning desire, academic success, and lifelong learning (Nadeem et al., 2023). Investigating learning motivation aids in comprehending the facilitation of personal development and welfare, as well as improving students' comprehension of scientific concepts. A multitude of plausible reasons has been found for the decline in enthusiasm

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for science, with numerous environmental influences and expectations imposed on children during their maturation being significant determinants.

Jansen et al. (2022) conducted a meta-analytic study of the K-12 population, indicating that both student characteristics (including achievement, socioemotional factors, and background) and instructional variables (such as teacher factors, interventions, and technology) are comparably associated with academic motivation. Significant correlations were identified between socioemotional and achievement characteristics for children, as well as instructional variables for teachers. This study seeks to assess the influence of instructional elements on students' motivation to comprehend scientific topics. Computer games are progressively becoming a fundamental component of children's lives and their domestic cultural contexts. Individuals globally, including youngsters in Nigeria, utilise technological devices on a regular basis. While Digital Games Learning (DGL) is largely utilised for enjoyment, educators acknowledge that digital games (DG) can serve as effective instruments for skill development. Advancements in science and technology significantly affect our lifestyle, influence our lives, and transform every facet, including pedagogical approaches (Çelik & Baturay, 2024). The increasing enthusiasm of children for electronic gaming has rendered the subject of games widely discussed. Sabirli and Coklar (2020) examined the influence of educational games on students' academic achievement and discovered that integrating digital educational games into lessons improves students' engagement with the topic, resulting in notable performance enhancements. Consequently, including DGL in classes may augment student growth by elevating their motivation to engage, comprehend scientific concepts, resolve issues, and derive greater benefits from the educational experience.

Anastasiadis et al. (2018) asserted that the Digital Game-Based Learning (DBL) methodology serves as an effective educational instrument that improves the learning experience by augmenting motivation and student involvement. Game-based learning in science has demonstrated superior learning outcomes relative to conventional instructional methods (Chen & Chang, 2024). Stoica and Wardat (2021) performed a comparative analysis of non-gamified and gamified digital lessons utilising live games. Their findings demonstrated that gamified digital lectures significantly enhanced students' motivation, enabling them to concentrate on exercises for extended durations and accurately finish a greater number of arithmetic assignments. In contrast, students in a non-gamified setting exhibited boredom and accomplished fewer tasks. Dayo et al. (2020) highlighted that Digital Game-Based Learning (DGL) enhances mathematical problem-solving skills, whereas Aloufi et al. (2021) determined that DGL has a beneficial effect on student performance. Mikrouli et al. (2024) performed a review of game-based learning (GBL) methodologies across different educational levels and discovered that GBL enhances learning results and engagement. It improves students' comprehension of

intricate ideas and fosters the practical application of learnt knowledge. The research highlights the benefits of game-based learning in primary and secondary education, enhancing comprehension, promoting critical thinking, and facilitating skill acquisition. Hu (2024) examined the efficacy of game-based learning in health sciences education and determined that it enhances learning outcomes by engaging students, fostering critical thinking, and improving the entire educational experience in health sciences. This study intends to utilise the CoSpaces Education game to assess students' motivation for learning scientific ideas. CoSpaces Education is an innovative solution that transforms student engagement with instructional material. It fosters creativity, critical thinking, and teamwork, rendering it an indispensable asset for contemporary education (Lo, Ng & Ng, 2024).

CoSpaces Education encompasses the following features: 3D Creation: Students may fabricate nearly any object in three dimensions utilising intuitive tools. This encompasses the creation of interactive narratives, virtual exhibitions, games, and simulations. The tool facilitates block-based coding and complex scripting, enabling students to incorporate interactions into their projects. This cultivates coding proficiency and promotes computational reasoning. Virtual and Augmented Reality: Students can investigate their works in Virtual Reality (VR) or Augmented Reality (AR), offering an immersive educational experience. Collaboration: CoSpaces Education facilitates student collaboration on projects, hence improving cooperation and communication abilities. Cross-Platform Compatibility: The application functions on multiple devices, including desktops, laptops, tablets, and smartphones. It is accessible via a web browser or mobile application, facilitating convenient use at any location and time. CoSpaces Education offers a range of tools, including teacher guides, lesson plans, and student checklists, to assist educators in incorporating the programme into their instruction. Numerous educators and academics endorse the establishment of an effective learning environment through the implementation of exploratory methodologies, such as the constructivist learning approach.

In this active learning approach (Abdallah & Wardat, 2021), learners actively generate knowledge instead of passively receiving information, hence shifting the teacher's role from lecturer to facilitator. Constructivism encompasses an educational approach in which students assimilate newly acquired material with their pre-existing knowledge. It also promotes autonomous learning, enabling pupils to develop their knowledge freely (Alarabi & Wardat, 2021). Researchers propose that Digital Game-Based Learning (DGBL) qualifies as constructivist instructional material because of its capacity to foster student-centred possibilities and establish an active learning environment (Adipat et al., 2021; Gui et al., 2023). Science educators and educational researchers consider genetics a fundamental concept in science; nonetheless, elementary pupils frequently encounter considerable difficulties in comprehending it (Michal & Anat,

2021). They assert that genetics should be taught in innovative and captivating methods, as students meet this subject throughout their educational journey and thereafter. Technology ascended to prominence with the worldwide technological expansion in the late 20th century, and the present generation has been raised with perpetual access to digital technology, underscoring its significance in their lives.

A further aspect affecting pupils' motivation to comprehend scientific topics is gender. Gender disparities in science education, particularly in digital game-based learning (DBG), exhibit intricate patterns that may influence the efficacy of this method. Research suggests that boys and girls may exhibit differing motivations in DBG environments, attributable to disparities in scientific conceptions, communication styles, engagement levels, self-efficacy, and problem-solving abilities (Wijnia et al., 2024).

Literature Review

Theoretical framework

Two fundamental theories underpin the game-based learning method model: problem-solving theory and self-determination theory. Theory of Problem-Solving: Problem-solving skills are crucial in the contemporary, ever-changing environment. Enhanced problem-solving abilities augment an individual's worth to employers, therefore conferring a competitive edge in the job market. Dostál (2015) asserts that the resolution of well-structured problems is a linear process consisting of two stages: 1) the generation of a problem space and 2) the formulation of a solution by navigating through the problematic space. Nonetheless, resolving issues in a well-organised environment is more manageable than addressing challenges that may arise in real life. Workplace issues are typically ambiguous and not easily resolved using conventional classroom methodologies. Consequently, fostering an environment that enables students to tackle unstructured difficulties can enhance their capacity to address real-world challenges once graduating and entering the workforce. Educational games aim to connect classroom issues with real-world obstacles. The game-based learning methodology enhances problem-solving skills by initially offering diverse strategies for solution discovery, subsequently evaluating students' problem-solving capabilities through the presentation of ambiguous challenges, and ultimately facilitating collaborative efforts among students to address these challenges.

Self-Determination Theory (SDT): Self-Determination Theory (Ryan & Deci, 2020) identifies three essential psychological needs: autonomy, competence, and relatedness, which are vital for motivation and learning. The role of game-based learning in the academic setting must align with these ideas. Self-Determination Theory posits that

enhanced fulfilment of the three fundamental needs—autonomy (sense of initiative and ownership), competence (feeling of mastery), and relatedness (sense of belonging and connections)—leads to improved results, such as student engagement (Ryan & Deci, 2020). Consequently, Self-Determination Theory (SDT) offers a theoretical framework for analysing the enhancement of student motivation within social contexts, such as teacher instruction and the CoSpaces Education gaming environment.

The conceptual framework for this study is based on theories of science education and the adoption of CoSpaces Education game learning, recognising the impact of elements such as perceived utility, ease of use, institutional support, and gender differences (Dostál, 2015). This study examines the intersection of these issues with the distinctive opportunities presented by CoSpaces Education game integration in science education in Nigeria. This section offers a summary of the current literature about the integration of Digital Game-Based Learning (DGBL) in education, specifically emphasising integrated science within science education. Principal themes encompass DGBL technology in science education, its influence on student motivation, and the instructors' role in providing CoSpaces Education game-based learning experiences. Numerous research studies have examined the influence of Digital Game-Based Learning (DGBL) on students' motivation to comprehend scientific concepts across diverse educational fields, yielding inconsistent outcomes.

Chen and Tu (2021) investigated the impact of learning motivation and performance inside a Digital Game-Based Learning (DGBL) environment, as well as the influence of competition. Their research employed Social Cognitive Theory, emphasising the reciprocal interactions of personal variables, contextual factors, and behaviour. The research encompassed data samples from over 600 junior high school pupils in Taiwan. The students were categorised into three groups: the Control Group (CG), which adhered to a traditional learning methodology; Experimental Group 1 (EG1), which engaged in learning via a digital game; and Experimental Group 2 (EG2), which utilised a digital game integrated with a competitive and entrepreneurial framework among peers. The results demonstrated that emotional state adversely affected learning motivation and self-efficacy. Nonetheless, self-efficacy acquired by DGBL favourably impacted learning motivation, while social support positively improved self-efficacy. Self-efficacy and learning motivation positively influenced learning performance.

Gui et al. (2023) conducted a study to examine (1) the overall impact of digital game-based STEM learning relative to traditional STEM learning and (2) the improvement effect of incorporating more game-design aspects compared to basic game versions in STEM education. The study encompassed two meta-analyses. The initial meta-analysis, encompassing 136 effect sizes from 86 studies, demonstrated a medium to substantial overall effect of digital game-based STEM learning on motivation to comprehend scientific

concepts in contrast to traditional STEM learning (g = 0.624, 95% CI [0.457, 0.790]). The efficacy of digital game-based STEM education differed according to various learning outcomes, game styles, and disciplines. The second meta-analysis examined 44 primary studies and 81 effect sizes, revealing a minor to medium enhancing effect of additional game-design aspects compared to base game versions (g = 0.301, 95% CI [0.163, 0.438]). The findings demonstrated that game-design elements incorporated for subject learning were more efficacious than those introduced for general gaming experience. Kuo et al. (2022) examined the effects of a hybrid digital-physical escape room on students' creative thinking, learning motivation, and academic performance in science. The research incorporated both digital and physical escape rooms into fifth-grade science curricula, including an experimental group of 22 participants and a control group of 21 participants. The Torrance Test of Creative Thinking (assessing fluency, flexibility, originality, and elaboration), the learning motivation scale (measuring value, expectancy, affect, and executive volition), and the scientific achievement assessment were employed to statistically evaluate students' learning efficacy. The findings demonstrated that the experimental group markedly surpassed the control group for innovative thinking and learning motivation. Nonetheless, there was no notable disparity in scientific academic performance between the two groups. The research validates that a hybrid digital-physical escape room is an effective and pragmatic method with the potential for widespread implementation in educational institutions to enrich students' learning experiences.

Ilić et al. (2024) performed a systematic review to investigate the impact of digital game-based learning (DGBL) in STEM education on student motivation. The research sought to detect emerging trends and evaluate the feasibility of integrating DGBL into STEM education. In accordance with PRISMA guidelines, the sample was chosen based on screening and eligibility criteria pertinent to the research purpose. The review encompassed twenty-eight pieces of research, indicating an increasing interest in DGBL within STEM education from 2018 to 2023. The majority of research concentrated on the K-12 education system and higher education institutions. The review selected educational games and simulation technology for digital learning as the most promising instruments in this research domain. The investigation investigated elements affecting the enhancement of student motivation in Digital Game-Based Learning for STEM education. The results indicated that previous gaming experience enhances students' motivation to engage in DGBL STEM education. Furthermore, students' pre-existing understanding of a STEM discipline augments engagement and motivation. The implementation of instructional computer games has demonstrated considerable engagement among students in STEM education. Research indicates that students more effectively retain knowledge acquired through game-based methods compared to alternative learning strategies; however, they may experience a lack of motivation in interdisciplinary subjects necessitating skills like critical thinking and interpersonal communication

(Kucher, 2021). Leaderboards are an essential element of game design and an effective mechanism for incentivising users via competition (Bai et al. 2020). Nevertheless, some research indicates that leaderboards may demotivate students in their learning (Ortiz-Rojas et al., 2019; Bai et al., 2021). Moreover, research indicates that game-based learning frequently necessitates specialised gear or software, which can be costly and labour-intensive to establish and sustain. Technical difficulties, like glitches or system failures, can disrupt learning and diminish students' motivation (Huang & Hew, 2018). Li et al. (2024) demonstrated that motivation diminished in distracting digital environments or when involvement failed to foster deeper learning in science.

Baker et al. (2024) examined the mediation of the association between gender and learning outcomes in a digital learning game through system gaming. They re-evaluated three retrospective datasets from studies conducted in various years, encompassing 213, 197, and 287 pupils acquiring decimal ideas in late elementary and middle school. The data sets were examined to discern gender disparities in system manipulation, a behavioural metric signifying disengagement during gameplay. The incidence of system manipulation was analysed between male and female students across the game's two primary instructional activities (problem-solving and self-explanation) and in both game and non-game conditions. The findings revealed that female students used the system far less than male students during the self-explanation phase in the gaming condition across all three trials. The disparity in gaming rates facilitated the connection between gender and learning outcomes, with female students generally achieving superior learning results compared to male students across all three investigations. Comprehending these gender-specific disparities in gaming behaviours can guide future game design to enhance learning results for all students. Nadeem et al. (2023) did a study to investigate the impact of Digital Game-Based Learning (DGBL) on student engagement and motivation, as well as gender disparities in online learning contexts. The research was conducted in two stages. It evaluated engagement and motivation levels across game-based and traditional online quizzing methods while also examining gender disparities. In the initial phase, 276 male and female college students were recruited from Sophomore Seminar classes, with 101 individuals engaging in the survey (83 males and 18 females). In the second phase, 126 participants were recruited, of whom 107 (63 females and 44 males) completed anonymous feedback surveys. The findings indicated that DGBL exerted a more favourable influence on student engagement and motivation than conventional online activities. The integration of a scoreboard as a gaming component substantially impacted the academic achievement of certain students; however, it may also dissuade others. Moreover, female students often indicated marginally greater enjoyment of the games than male students; however, they chose to refrain from comparisons with their peers to a lesser extent than their male counterparts.

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Statement of the Problem

In recent years, there has been an increasing interest in integrating digital game-based learning into educational environments to enhance student engagement and motivation. Notwithstanding the potential benefits, conventional teaching techniques in Nigerian junior secondary schools frequently fail to adequately engage students and foster a profound comprehension of fundamental science topics. The absence of involvement and drive may lead to subpar academic performance and diminished interest in scientific disciplines. The dilemma is further aggravated by the scarcity of empirical research that particularly examines the effect of digital game-based learning on the motivation of junior secondary school students in basic science within the Nigerian environment. As a result, educators and policymakers are devoid of the requisite evidence to make educated judgements on the implementation of novel teaching approaches. This study seeks to examine the efficacy of digital game-based learning in improving the motivation of junior secondary school students in fundamental science in Nigeria. This study aims to fill the research vacuum by offering useful insights on the capacity of digital games to enhance science teaching and elevate student performance.

1. The perception of students on students' motivation to learn science concepts who are exposed to CoSpaces digital game-based learning approach and their counterparts who are taught conventional tabletop method.
2. Significant difference of male and female students' motivation to learn science concepts in basic science

Research Questions

The following research questions guided the study:

1. What extent is the impact of DGBL on students' motivation to learn science concepts who are exposed to CoSpaces-based learning approach
2. What extent is the impact of conventional tabletop gaming learning on students' motivation to learn science concepts

Research hypotheses

Ho_1: There is no statistically significant difference between students' pre-test scores exposed to CoSpaces digital game-based learning and those in conventional tabletop game learning approach in their motivation to learn science concepts in basic science.

Ho_2: There is no statistically significant difference between students exposed to CoSpaces digital game-based learning and those in conventional tabletop game learning approach in their motivation to learn science concepts in basic science.

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Ho_3: There is no statistically significant difference between male and female students' motivation to learn science concepts in basic science.

Methodology

The research employed a pre-test, post-test non-equivalent quasi-experimental design in conjunction with a qualitative-interpretive methodology. This quasi-experimental approach was used to correspond with the primary objective of the study, which seeks to establish a causal relationship between variables (Mills & Gay, 2019). Qualitative study entailed the accumulation of vast narrative data (non-numeric) over time to derive insights into the discourse (Adriana et al., 2024). This study examined the effect of Digital Game-Based Learning (DGBL) on the motivation of junior secondary school pupils in Gombe State, Nigeria, to learn fundamental scientific topics. The study population comprised all JSS II basic science students in the Gombe Central Senatorial District. A random sample of 140 JSS II basic science students was obtained from four junior secondary schools in the Gombe Central Senatorial District. Each school was randomly allocated to either the treatment or control group, with two schools designated as the control group and two as the experimental group.

The control group comprised 73 pupils, whereas the experimental group included 67 kids. To ensure excellent data collection, eight basic science instructors (research assistants) from the selected schools were deliberately picked to furnish detailed reports, as the study concentrated on basic science ideas. Participants were designated pseudonyms "A" and "B" to safeguard their identities. The researchers created and utilised the Basic Science Students' Motivation Questionnaire (BSSMQ) for this investigation. The structured questionnaire employed a scoring scale of "Extremely", "Significantly", "Moderately", "Slightly", and "Not at all" to collect respondents' opinions. It consisted of ten items aimed at gathering information regarding students' enthusiasm to pursue scientific subjects. The instrument's validity was affirmed by peer experts from the Science Education Department at the Federal University of Kashere, Gombe State, and two JSS II basic science educators from Gombe State.

The instrument's reliability was evaluated using the Cronbach alpha statistic to determine internal consistency, with SPSS software utilised to compute the mean correlation across item pairs and the overall item count in the scale. Three aspects were examined: (a) item-total correlation, which assesses the correlation between each item and the aggregate of the remaining items; (b) squared multiple correlation for each item (R^2) when the item is incorporated into multiple regression as a criterion variable with other items as predictor variables; (c) the value of Cronbach's alpha for the scale upon the deletion of a specific item; and (d) the unidimensionality of the scale. The preliminary reliability analysis resulted in the removal or revision of items exhibiting significant

deviation from others. A subsequent reliability examination of the remaining items produced a coefficient of 0.91.

Experimental Procedure

The experimental group engaged in a 3D instructional digital game utilising the CoSpaces Edu application, specifically designed for JSS II and addressing genetics themes from the basic science curriculum. The control group participated in a tabletop game that covered the identical genetics subjects offered to the experimental group. Researchers created two distinct sets of instructional guides: one for the experimental cohort and another for the control cohort. Each guide was intended for a 40-minute instructional period, utilising sample learning aids for both the experimental and conventional tabletop gaming methods. Fundamental science educators served as research aides. Prior to initiating the investigation, the researchers acquired authorisation from the state ministry of education and the respective school administration to perform the experimental procedure. They also secured the collaboration of the involved fundamental science educators. Upon receiving authorisation, the researchers sent the validated instructions to the research assistants in both the treatment and control groups, although they did not participate directly in the implementation of the treatment programmes. They instead oversaw the process and functioned as supervisors. The study persisted for a duration of six weeks.

Treatment Phase

The study utilised two approaches: The Teachers' Instructional Guide for Digital Game-Based Learning Approach (TIGDGBLA) employing the CoSpaces Edu application and a traditional method. Students were organised into small groups consisting of 4 to 5 people. Educators registered using their email addresses or accessed the platform via Google, while students joined by entering the teacher's class code for a duration of five minutes. Students in the experimental group developed genetic characteristics in CoSpaces Edu via a straightforward drag-and-drop method, employing diverse creation tools such as 3D objects, building blocks, block-based coding, and additional resources for a duration of 20 minutes. They adhered to written directions, utilised game tips, solicited assistance from group members, documented observations, derived inferences from results, and reported actions independently. Game scores were documented, and victors were acknowledged. In the control group, students engaged in a tabletop game covering identical genetics subjects as the experimental group. Students were organised into small groups of 4-5 individuals and provided with tabletop game materials for a duration of 5 minutes. They employed conventional in-person techniques for 20 minutes. Educators offered additional elucidations on the principles presented via the tabletop game to enhance comprehension.

Table 1. Teaching Strategy in learning genetics in basic science with CoSpaces Education game learning

Teacher's task	Description	Autonomy	Structure	Involvement
Teacher explains the teaching objectives clearly	The Teacher explains to the students the objective of using CoSpaces Edu game learning in genetics concepts and how lesson is arranged chronologically for easier understanding.	X	X	
Present prior knowledge	The first lesson on the CoSpaces Edu learning platform gives a background on genetics and its importance as an area of study.	X	X	
Encouraging students to interact with AI-Based learning.	The teacher encourage student to interact with CoSpaces Edu learning platform to read, view diagrams and videos to generate more ideas about the genetics concepts and relate the ideas with their previous knowledge.		X	X
Provide help when needed	The teacher communicates with the students and provide useful information on CoSpaces Edu learning platform, solve technical problems and encourages students to perform their tasks.		X	X
Feedback	Teacher check students' performance and discuss areas of weakness, to support the students to improve.		X	X
Encourage self-assessment	Teacher encourages the students to take quiz at the end of each lesson and the general quiz at the end of all the lessons.		X	X

Note: X indicate that Teaching strategy falls in the corresponding of teacher instruction

We got ethical approval from our institution and consent forms from the participants.

After the treatment in both groups, the Basic Science Students' Motivation Questionnaire (BSSMQ) was administered to test participants' motivation for learning science concepts. Data collected were analyzed using frequency counts, simple percentages, and means, while hypotheses were tested using the Mann-Whitney statistical test at a 0.05 significance level.

In-depth interviews were conducted with the participating research assistants for qualitative data collection. The interviews were semi-structured and focused on recording students' motivation. Each interview lasted 20 minutes and was recorded on an Android mobile phone with participants' consent. The information collected was transcribed and returned to the interviewees for verification (member-check). Unnecessary information was deleted.

The transcribed data were manually annotated, and initial observations were made. Common themes were identified and coded. These coded themes were grouped, and excerpts were taken out of their original context and merged with related data to identify patterns.

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Results

Research Question 1: What extent is the impact of DGBL on students' motivation to learn science concepts who are exposed to CoSpaces-based learning approach

Table 2. Participants' Response of Impact of CoSpaces Edu on Students' Motivation to Science Learning Concepts

S/N	Item	EM (%)	SG (%)	MD (%)	SL (%)	NA (%)	Mean	Std.d
1	Interest: How extent is your interest in learning science concepts through digital games?	19(28.4)	38(56.7)	6(9.0)	4(6.0)	0(0)	4.07	.785
2	Enjoyment: How much do you enjoy learning science concepts through digital games?	15(22.4)	38(56,7)	9(13.4)	2(3.0)	3(4.5)	3.9	.940
3	Challenge: How challenging do you find the science concepts presented in the digital games?	0(0)	0(0)	4(6.0)	14(20.9)	49(73.1)	1.33	.587
4	Curiosity: How curious are you about exploring new science concepts through digital puzzle games?	22(32.8)	40(59.7)	2(3.0)	1(1.5)	2(3.0)	4.18	.815
5	Engagement: How much do you feel engaged while learning science concepts through digital games?	23(34.3)	37(55,2)	3(4.5)	4(6.0)	0(0)	4.18	.777
6	Relevance: To what extend do you find the science concepts relevant in the digital games to your everyday life?	25(37.3)	38(56.7)	2(3.0)	1(1.5)	1(1.5)	4.27	.730
7	Confidence: How confident do you feel in your ability to learn science concepts through digital games?	28(41.8)	33(49.3)	3(4.5)	2(3.0)	1(1.5)	4.27	.809
8	Persistence: How motivated are you to keep trying even when the science concepts in the digital games are difficult?	19(28.4)	35(52.2)	8(11.9)	3(4.5)	2(3.0)	3.09	.929
9	Satisfaction: How has game-based learning satisfied you with your learning experience of science concepts?	24(35.8)	34(50.7)	5(7.5)	2(3.0)	2(3.0)	4.13	,7903
10	Future use: To what extent will you use games to learn science concepts in the future?	18(26.9)	44(65.7)	3(4.5)	0(0)	2(3.0)	4.13	,757

Table 2 showcases the responses of students who experienced the CoSpaces-based learning approach regarding the impact of digital game learning on their motivation in basic science.

Items 1 and 2 indicate that 85.1% and 79.1% of respondents felt that the CoSpaces-based learning approach enhanced their interest and enjoyment, thereby boosting their motivation to learn science concepts.

74.4% of respondents noted that the science concepts presented in the CoSpaces games did not pose any learning challenges.

For items 4, 5, 6, 7, 8, 9, and 10, the percentages of respondents who claimed to be curious, engaged, able to relate science concepts to their daily lives, confident, persistent, satisfied, and inclined to use digital games for learning science concepts in the future were 92.2%, 89.5%, 94%, 91.1%, 80.6%, 86.5%, and 92.6%, respectively.

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Research Question 2. What extent is the impact of conventional gaming learning on students' motivation to learn science concepts who are exposed to tabletop game learning approach.

Table 3. Participants' Response of Impact of Tabletop Game on Students' Motivation to Science Learning Concepts

S/N	Item	EM (%)	SG (%)	MD (%)	SL (%)	NA (%)	Mean	Std.d
1	Interest: How extent is your interest in learning science concepts through tabletop games?	1(1.4)	1(1.4)	7(9.6)	52(71.2)	12(16.)	2.00	.667
2	Enjoyment: How much do you enjoy learning science concepts through tabletop games?	1(1.4)	2(2.7)	8(11.0)	51(69.9)	11(15.1)	2.05	.705
3	Challenge: How challenging do you find the science concepts presented in the tabletop games?	10(13.7)	51(69.9)	8(11.0)	2(2.7)	2(2,7)	3.89	.774
4	Curiosity: How curious are you about exploring new science concepts through tabletop games?	1(1.4)	7(9.6)	36(49.3)	29(39.7)	0(0)	2.73	.692
5	Engagement: How much do you feel engaged while learning science concepts through tabletop games?	2(2.7)	4(5.5)	46(63.0)	20(27.4)	1(1.4)	2.81	.680
6	Relevance: To what extend do you find the science concepts relevant in the tabletop games to your everyday life?	0(0)	2(2.7)	19(26.0)	46(63.0)	6(8.2)	2.23	.635
7	Confidence: How confident do you feel in your ability to learn science concepts tabletop games?	0(0)	2(2.7)	34(46.6)	35(47.9)	2(2.7)	2.43	.604
8	Persistence: How motivated are you to keep trying even when the science concepts proved challenging in the tabletop games?	0(0)	4(5.5)	41(56.2)	26(35.6)	2(2.7)	2.64	.632
9	Satisfaction: How has tabletop games satisfied you with your learning experience of science concepts?	0(0)	3(4.1)	16(21.9)	47(64.4)	7(9.6)	2.21	.666
10	Future use: To what extent will you use tabletop games to learn science concepts in the future?	1(1.4)	3(4.1)	16(21,9)	45(61.6)	8(11.0)	2.23	.775

Table 3 depicts the reactions of participants involved in tabletop game-based learning activities and their influence on students' interest in fundamental science. Items 1 and 2 suggest that 2.8% and 4.1% of respondents, respectively, reported that tabletop game-based learning activities favourably impacted their interest and enjoyment in learning scientific ideas. Simultaneously, 83.6% of players reported that the scientific concepts introduced in the tabletop games posed significant challenges to their comprehension. For items 4, 5, 6, 7, 8, 9, and 10, less than 11% of respondents asserted that the tabletop game positively stimulated their curiosity to learn, maintained their engagement, rendered science concepts pertinent to their daily lives, elevated their confidence in learning, fostered persistence, yielded high satisfaction, and inspired them

to utilise tabletop games for learning science concepts in the future. Ho1: There exists no statistically significant disparity between the pre-test scores of students engaged in CoSpaces digital game-based learning and those participating in traditional tabletop game learning regarding their motivation to comprehend basic science ideas.

Table 4. Mann-Whitney Pre-test Analysis of Impact of Digital Game-Based Learning on Students' Motivation in Basic Science According to Treatment

Treatment	N	Mean Rank	U	P value	Remark
Cospaces game-based learning	73	72.88	2271.50	.453	Not Significant
Tabletop game-based learning	67	67.90			

Significant at P<0.05

The Mann Whitney pretest analysis, presented in Table 4, compared the effects of CoSpaces game learning with traditional tabletop game-based learning on student motivation. The findings demonstrated that the disparity between the two methodologies was not statistically significant (U = 2271.50, N1 = 73, N2 = 63, P = .453, two-tailed). Therefore, Hypothesis 1 is accepted. Ho2: There exists no statistically significant disparity in the motivation to study science ideas in basic science between students engaged in CoSpaces digital game-based learning and those participating in a conventional tabletop game learning strategy.

Table 5. Mann-Whitney Post-test Analysis of Impact of Puzzle Game-Based Learning on Students' Motivation in Basic Science According to Treatment

Treatment	N	Mean Rank	U	P value	Remark
Cospaces	73	101.97	148.50	.000	Significant
Tabletop game	67	36.22			

Significant at P<0.05

The Mann Whitney post-test scores analysis, shown in Table 5 compared the difference in students' motivation to learn science concepts between those exposed to CoSpaces game learning and those exposed to conventional tabletop game learning. The results indicated that the difference in motivation between the two groups was statistically significant (U = 148.50, N1 = 73, N2 = 67, P = .000, two-tailed). Consequently, Hypothesis 2 is rejected.

Ho_3: There is no statistically significant difference between male and female students' motivation to learn science concepts in basic science.

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Table 6. Mann-Whitney Analysis of Impact of Puzzle Game-Based Learning on Students' Motivation in Basic Science cording to Gender

Treatment	N	Mean Rank	U	P value	Remark
Male	69	72.01	2345.50	.664	Not Significant
Female	71	69 .04			

Significant at P<0.05

The Mann Whitney post-test scores analysis, as indicated in Table 6, compared the motivation to learn science concepts between male and female students. The results showed that the difference in motivation between male and female students was not statistically significant (U = 2345.50, N1 = 69, N2 = 71, P = .664, two-tailed). Therefore, Hypothesis 2 is not rejected.

Results of Interview

This question aimed to identify the social characteristics and practices that implicitly promote students' motivation to learn science concepts. The characteristics found included: How students exposed to CoSpaces game-based learning developed their motivation to study basic science concepts. The extent to which CoSpaces game-based learning activities positively affected students' motivation. The motivational characteristics considered were interest, enjoyment, challenge, curiosity, engagement, relevance, and confidence, as well as persistence, satisfaction, and future use. Basic science teachers interviewed stated that CoSpaces game-based learning positively impacted students' motivation to learn science concepts in basic science in JSSS. Students showed high interest in learning science concepts, enjoyed the learning process, found the concepts in CoSpaces games less challenging, were curious about learning, engaged in learning activities, found the concepts relevant, and had self-confidence in their ability to learn science presented in CoSpaces games. Students were motivated to keep trying even when science concepts seemed challenging, were satisfied with their learning experience, and were willing to use CoSpaces game-based learning for future science concepts. In summary, students' motivation to learn science concepts was enhanced as they were interested in learning new concepts, felt happy and enjoyed playing CoSpaces games on various devices, contributing to their overall science development and growth. Interviewee "A" mentioned: "When students' interest is high, and they are actively engaged in the teaching and learning process, enjoy playing digital games, possess confidence in their ability to learn science concepts, and persist even when concepts presented in CoSpaces are challenging, their motivation to learn science concepts will be established and developed" (Transcript of interview 14/11/2024).

The responses indicate that CoSpaces game-based learning significantly enhances students' motivation and overall development in basic science and other science-related subjects in JS schools. This aligns with Adipat et al. (2021) findings that CoSpaces game-based learning, when used appropriately, improves students' motivation and general growth in science education. This question aimed to determine the extent to which tabletop game activities have positively influenced students' motivation to study science concepts in basic science for junior secondary schools (JSS). The motivation characteristics considered included interest, enjoyment, challenge, curiosity, engagement, relevance, confidence, persistence, satisfaction, and future use. Basic science teachers interviewed stated that tabletop games moderately changed students' motivation to learn science concepts. Students were not deeply interested in learning activities, did not significantly enjoy interacting with the game, and found the science concepts presented in tabletop games difficult due to the lack of adequate practice and repetition. Their satisfaction with the learning experiences was slight, and they were not very curious about learning new science concepts presented in tabletop games. They were not significantly motivated to learn new concepts when they seemed challenging, which consequently reduced their confidence in learning science concepts. Students' interest in science was moderately enhanced through confidence, self-efficacy, and increased persistence to some extent.

In summary, students' motivation to learn science concepts was moderately enhanced because they were not highly interested in new concepts, felt only mildly happy and satisfied while playing tabletop games, and lacked the engagement that might come from digital formats like those on android phones, tablets, and laptops. Interviewee "B" mentioned: "When students' interest is not high, their engagement in the teaching and learning process is moderate, and they enjoy playing tabletop games less, their confidence in their ability to learn science concepts decreases. This results in less persistence, especially when concepts presented in tabletop games are challenging. As a result, their motivation to learn science concepts will not develop significantly" (Transcript of interview 21/11/2024).

The responses indicate that tabletop game-based learning for teaching basic science and other related subjects in elementary schools plays a moderately significant role in enhancing students' motivation and overall development in science education. This aligns with the findings of Ilić et al. (2024), which show that the conventional tabletop game-based approach has not significantly enhanced students' motivation and general growth in basic science compared to Digital Game-Based Learning (DGBL).

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Discussion and Empirical Implications

The study demonstrated that CoSpaces game-based learning significantly enhanced students' motivation to learn science concepts compared to tabletop game-based learning in basic science education for junior secondary schools. This conclusion was derived from the performance of 140 students on a 10-item structured motivation questionnaire administered twice: as a pre-test before teaching and as a post-test after the intervention of the CoSpaces game. Results from the pre-test showed no significant difference between the two groups in terms of their motivation to learn science concepts, indicating that both groups had comparable motivation levels before the experiment and were homogenous in this regard. The possible reason for this finding could be that CoSpaces game-based learning enabled and motivated students in the experimental group to practice and play with customized science concepts through digital games on their android phones, computers, etc. CoSpaces motivated the students to practice more by playing more games, thereby increasing their motivation to learn science concepts more effectively than tabletop game-based learning. The enjoyment derived from playing the games could have also contributed to the enhanced motivation of the students in the experimental group, as the enjoyment likely resulted in increased interest in learning science concepts.

The study supports the findings of Chen and Tu (2021), which revealed that self-efficacy gained through DGBL positively affected learning motivation compared to conventional STEM learning. Additionally, it corroborates Kuo et al. (2022), which indicated that DGBL significantly enhanced creative thinking and learning motivation compared to the control group. Stohlmann's (2019) findings align with this study, showing that DGBL engaged students in mathematical thinking and enhanced their motivation, understanding of knowledge concepts, and problem-solving abilities. The finding of this study negates the finding of Li et al, 2024; Kucher, 2021) that motivation dropped when digital environments were distracting or when engagement did not translate into deeper learning in science and may be demotivated in interdisciplinary topics that require skills such as critical thinking and interpersonal communication.

However, the findings contradict those of Baker et al. (2024), which revealed that female students benefited significantly less than male students in the self-explanation step in the game condition. Similarly, the findings differ from Nadeem et al. (2023), which affirmed that female students generally showed a slightly higher level of enjoyment toward the games compared to male students, thereby promoting female motivation to learn science. Female students tend to engage more in discussions and show higher levels of cooperation, whereas male students often take on more leadership roles and focus on task completion. This suggests that while game-based learning activities can enhance

motivation for both genders, group dynamics can influence the effectiveness of these activities.

Theatrical contributions

First, the empirical implications of this study contribute to SDT-based research by examining the relationship between perceived teacher support, needs satisfaction, and four dimensions of student engagement in a new technology-support context (CoSpaces Edu learning). Our findings echo the SDT founders' call about enriching SDT research in a technological environment (Ryan & Deci, 2020). In addition, this study specially specified how needs satisfaction affected student engagement and mediated the relationship between teacher support and student engagement in CoSpaces Edu genetic learning. Needs satisfaction and enhanced motivation in the CoSpaces Edu context was less understood (Stoica & Wardat, 2021) and SDT-based research on science education was limited (Kuo et al., 2022). Therefore, this study provided more evidence on how needs satisfaction and students' motivation was enhanced under the CoSpaces Edu context within the genetic concepts in basic science in junior secondary schools.

Second, this study enriches technological pedagogical content knowledge (TPACK) research by providing teaching strategies in the CoSpaces Edu learning environment. Teachers in this study acted as knowledge presenters, designers, facilitators, assessors, and resource providers. They provided both technology and content knowledge to students and incorporated genetic concepts learning materials as CoSpaces Edu app in the teaching process to support the pedagogy, which could contribute to TPACK (Rosenberg & Koehler, 2015).

Conclusion

The study's findings demonstrate that students benefit most from the digital game-based learning approach (CoSpaces Edu). This approach encourages and motivates students to be actively engaged in the learning process, solve problems, be proactive and creative, work together, have fun while learning, and ultimately enhance their motivation to learn. As a result, this leads to improved overall growth and development in science education. CoSpaces Edu is deemed suitable for educating students as it provides an enabling learning environment for 21st-century learners, where the use of technology is rapidly advancing in all aspects of life. Furthermore, the findings indicate that significant differences do not exist between male and female participants exposed to CoSpaces Edu learning environment and the conventional traditional lecture method. This suggest that

pedagogical practices should carefully take care of gender issues and properly attend to them irrespective of teacher's instructions.

Limitation of the Study

Further exploration and implementation of digital games are necessary because the study focused on JSS II students in a specific local government area, which may limit the generalizability of its results. It is also recommended to investigate the effectiveness of training teachers to use CoSpaces Edu game learning on student motivation. This further investigation will determine if teachers are confident in using and integrating the technology (CoSpaces), assigning suitable games for each lesson, and how this could impact students' motivation during the teaching and learning process.

Recommendations

Based on the finding of this study, recommendations were made as following:

i. Basic science teachers should adopt the use of digital game-based learning approach (cospaces Edu) in teaching basic science and by extension science education generally.

ii. Governments, educational planners and junior secondary schools/elementary school's management should organize seminars, workshops and conferences for basic science teachers on how to use digital game-based learning approach for teaching. T

iii. Teacher education programs should be modified to reflect current and contemporary teaching practices and students should be encouraged to be proficient in computer literacy skills.

iv. Students should be encouraged to possess a mini-laptop computer to himself/herself Equal opportunities should be given to all category of learners to learn science concepts irrespective of their sex and background.

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Data availability: The datasets used for the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval This study got ethical clearance from the participated school's authority.

Conflicts of interest There is no conflict of interests between the author and participants

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Contributions

SA designed the research, 3D educational digital game, interpreted the data and drafted the work; JA participated in the acquisition, 3D educational digital game designing, analysis and interpretation of data and drafted the work; VO gave an important advice and revised the conclusion and MI took part in the acquisition and analysis of data. All authors read and approved the final manuscript.