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The Framework of DOUBLE-LOGGY Board Game: A Game-Based Learning Model to Support Repetition and Memory in Biology Learning

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ABSTRACT

Biology is an elective subject in the Malaysian KSSM upper secondary curriculum that encompasses conceptually complex topics such as human physiology, genetics, and molecular biology. Students frequently struggle to master these topics due to extensive scientific terminology and the abstract nature of biological processes that are not directly observable. Therefore, this study aims to propose the framework of the DOUBLE-LOGGY board game as a game-based learning model to enhance repetition and memory retention in selected Form 4 Biology topics, namely *Transport in Humans and Animals* and *Support and Movement in Humans and Animals*. A design-based research approach was employed, consisting of needs analysis, content selection, game design, expert validation, and framework development. For each selected chapter, twenty-four (24) curriculum-aligned questions were developed and validated by subject-matter experts to ensure content accuracy and alignment with the KSSM syllabus. The board game integrates structured matching mechanics, strategic gameplay, memory-based reinforcement, and collaborative problem-solving elements. The resulting framework provides a structured model that systematically integrates curriculum content with repetitive exposure to key biological terms through gameplay. The development process demonstrates that the DOUBLE-LOGGY framework is pedagogically aligned with student-centred and active learning principles, offering a structured approach to support conceptual recall and collaborative engagement. This framework contributes to the development of innovative instructional strategies in Biology education and provides a scalable model adaptable to other topics.

1. Introduction

The world has experienced three major industrial revolutions and is currently undergoing the fourth, known as Industry 4.0. This era is characterised by the integration of digital technologies, artificial intelligence, and automation into everyday life. In response to these changes, the education sector has evolved into what is known as Education 4.0. In this new paradigm, students are

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encouraged to take ownership of their learning, while teachers act as facilitators and guides, as highlighted in the previous discussion of Education 4.0 transformation [1]. Education 4.0 represents a significant departure from traditional classroom methods. It emphasises the development of logical and computational thinking skills, often cultivated through subjects such as computer science, robotics, and coding. Beyond technical abilities, Education 4.0 aims to foster students' emotional intelligence, ethical decision-making, and adaptability, as discussed in previous research [2]. Furthermore, Education 4.0 emphasises collaborative learning, lifelong skill development, and the acquisition of digital competencies essential to success in the modern workforce [3]. By nurturing these qualities, Education 4.0 prepares students to navigate the challenges and opportunities presented by rapid technological change.

The 21st century is marked by rapid technological advancement, and technology is now globally accessible. In this context, gamification offers significant benefits across sectors, particularly in education, and aligns with the objectives of the Industrial Revolution 4.0 by enhancing interactive learning features. Specifically, game-based learning enhances interactivity through features such as representation, enjoyment, play, goal-setting, feedback, win states, competition, challenge, problem-solving, tasks, and narrative [4]. When used well, games can increase motivation to learn by providing diverse and engaging experiences [5]. Moreover, commercial games also support educational outcomes by improving motivation, increasing subject interest, fostering openness to information, and enhancing student autonomy through peer collaboration [6].

Although gamification and game-based learning approaches are increasingly implemented in STEM education, few studies have introduced a structured, curriculum-aligned board game framework specifically tailored to support systematic repetition and memory reinforcement in upper secondary Biology within the Malaysian KSSM context. Most existing research emphasises digital applications or general motivational outcomes, with limited attention to pedagogically structured physical board games that incorporate validated curriculum content and memory-based strategies for abstract biological concepts. This study proposes the Framework of the DOUBLE-LOGGY board game as a structured game-based learning model intended to enhance repetition and conceptual recall in selected Form 4 Biology topics. The output of this study contributes to Biology education by providing a pedagogically grounded, curriculum-aligned, and scalable instructional framework that supports active learning and collaborative engagement. The proposed framework offers educators a practical, adaptable model that can be extended to other Biology topics.

2. Literature Review

2.1 Education 4.0

Education 4.0 is widely recognised for enhancing learning outcomes and student engagement in higher education through active learning approaches, such as project-based and challenge-based learning, which bridge the gap between theoretical knowledge and real-world application [7]. In language learning, the implementation of Education 4.0 in Hyderabad, India, has significantly improved English proficiency among engineering students, highlighting its potential to address the limitations of traditional teacher-centred instruction [8]. However, challenges persist, including inadequate digital infrastructure, limited access to technology, insufficient teacher training, and resistance to change among educators and administrators, which can impede the effective adoption of Education 4.0 in educational institutions [9]. Table 1 summarises the comparative analysis from Education 1.0 until projection to Education 6.0 [10].

Table 1
Comparative analysis education 1.0 until education 6.0

Dimension	Education 1.0	Education 2.0	Education 3.0	Education 4.0	Education 5.0	Education 6.0
Primary Driver	Industrial	Digital	Connectivity	AI	Values	Human-AI
Student Role	Passive	Collaborator	Self-Directed	Adaptive	Purpose Seeker	Co-Creator
Teacher Role	Authority	Coordinator	Facilitator	Architect	Mentor	Designer
Knowledge Source	Textbooks	Web	Networks	AI Systems	Community	Collective
Assessment	Tests	Projects	Portfolio	Analytics	Holistic	Badges
Location	Classroom	Class + Online	Anywhere	Platforms	Project Sites	Borderless
Key Skills	Facts	Collaboration	Agility	Adaptability	Emotional	Wisdom
Technology Role	Minimal	Interactive	Enabler	Personalizer	Supporter	Partner

Student-centred and personalised learning are foundational principles of Education 4.0, as both prioritise integrating digital technologies and flexible learning models to customise education to individual student needs, interests, and abilities. This approach promotes active participation, autonomy, and lifelong learning skills as emphasised in prior analyses of personalised learning frameworks [11]. Within the Education 4.0 paradigm, methods such as student-centred learning (SCL) emphasise active learning from students and autonomy in knowledge construction [12], while blended learning integrates physical and online approaches to provide flexibility in learning [13]. In addition, guided personalised learning and adaptive learning technologies leverage a data-driven approach to deliver instruction according to learners' preferences and progress [14]. As a result, these approaches empower learners to assume greater responsibility for their educational experiences through experiential, collaborative, and technology-supported activities.

2.2 Gamification and Game-Based Learning

Gamification and Game-Based Learning (GBL) are both prevalent in the Education 4.0 framework to enhance learner engagement and motivation. These approaches differ in both methodology and practical implications. Gamification incorporates specific game elements, such as points, badges, and leaderboards, into traditional learning environments. In contrast, GBL uses complete games as structured instructional tools to deliver content through immersive and interactive formats. Previous research has shown that GBL can enhance learner engagement and contextual understanding through experiential gameplay mechanics [15], while other studies emphasise its role in supporting self-regulated learning and deeper cognitive processing when aligned with clear pedagogical objectives [16]. Empirical research demonstrates that both strategies positively affect learning achievement and motivation. However, gamification frequently yields more consistent and measurable outcomes, with learners often achieving higher academic performance and motivation compared to traditional methods and, in some cases, GBL [17]. Critically, gamification is generally easier to implement and maintain, as it can be integrated into existing digital platforms without significant technical resources, thereby increasing accessibility for educators. Nevertheless, poorly designed gamification systems may result in superficial engagement or an overemphasis on extrinsic rewards [16]. Conversely, GBL offers substantial potential for deep learning and skill application, particularly in vocational and professional contexts. Its effectiveness, however, is contingent upon the quality of game design, alignment with learning objectives, and resource availability, which may constrain scalability [18]. In summary, while both methods support the objectives of Education 4.0,

gamification offers greater practicality and scalability, whereas GBL delivers richer learning experiences but requires strategic planning and institutional support to ensure effective pedagogical alignment and scalability. This distinction underscores the need for further research on the long-term impact of these approaches and the development of transferable skills [16,19].

2.3 STEM Subject in Malaysia's Perspective

STEM education in Malaysia receives substantial support through national policy frameworks, including the Malaysia Education Blueprint (2013–2025), which prioritises innovation-driven learning and workforce readiness. At the programme level, the Young Innovators Challenge Programme has been shown to enhance students' interest in STEM-related careers by offering competitive and project-based experiences [20]. Mentor–mentee outreach initiatives have also produced positive outcomes, including strengthening university and school collaboration and increasing STEM participation, particularly in rural areas [21]. Broader policy analyses indicate that these national and institutional efforts are designed to align STEM education with evolving technological and workforce requirements [22].

However, a critical analysis reveals that while these initiatives demonstrate promising outcomes at the pilot or programme level, their overall impact remains limited due to systemic challenges, such as declining student interest [23], uneven implementation, and gaps in teacher readiness, particularly in integrating interdisciplinary and technology-driven pedagogies [24]. Furthermore, although teacher training programmes exist, teachers' behavioural and affective readiness to adopt interdisciplinary and technology-driven STEM pedagogies remains insufficient, resulting in a continued reliance on traditional, exam-oriented teaching methods [25]. Overall, this suggests that Malaysia's STEM agenda, though well-articulated at the policy level, requires deeper pedagogical reform, equitable resource distribution, and sustained professional development to translate innovation into meaningful and inclusive learning outcomes.

3. Methodology

This study employed a design-based research approach to develop and evaluate an educational board game for selected Biology topics in the Malaysian KSSM syllabus. The methodology consisted of four main phases: needs analysis, game design and development, validation, and evaluation. Figure 1 illustrates the two main phases applied in this study to develop the educational board game framework.

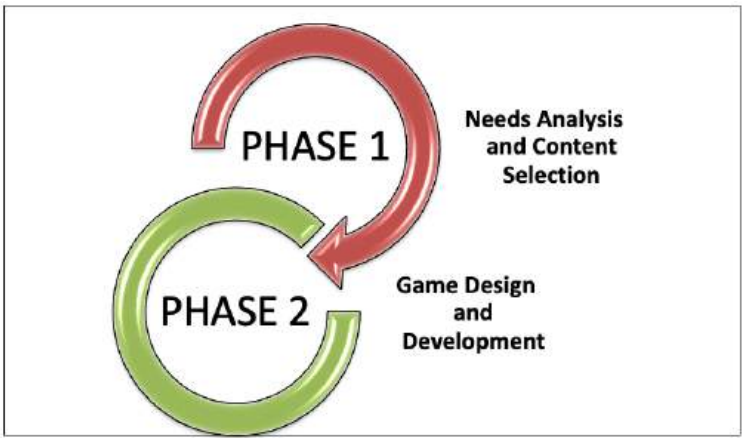

Fig. 1. Phases in methodology

Phase 1: Needs Analysis and Content Selection

During the initial phase, a needs analysis identified Biology topics that secondary school students frequently perceive as challenging. Two Form 4 chapters from the KSSM Biology syllabus, Transport in Humans and Animals and Support and Movement in Humans and Animals, were selected for their conceptual complexity and for the need to visualise biological processes that are not directly observable. Relevant learning outcomes and key biological terms were extracted from the official syllabus to ensure alignment with curriculum standards.

Phase 2: Game Design and Development

In the second phase, the educational board game was designed using the selected content. For each chapter, twenty four (24) questions were developed, emphasising complex biological terms and concepts. Biology subject matter experts currently teaching the selected chapters reviewed and verified all content to ensure validity and scientific accuracy. The board game was adapted from the Secret Door Board Game and modified for educational purposes. The original game mechanisms were redesigned to incorporate instructional elements. The game's physical components, including the board, question cards, answer cards, and an answer booklet, were subsequently designed. The board featured designated spaces for each team to place their matched answers. The game aimed to foster strategic thinking, memory retention, and collaborative problem-solving among players.

4. Results and Discussion

This study has successfully developed an educational innovation, the DOUBLE-LOGGY Board Game, by integrating elements of gamification into Biology learning. The innovation was adapted from the *Secret Door Board Game* and pedagogically modified to support teaching and learning objectives. Specifically, the game incorporates selected content from Chapter 10 (Transport in Humans and Animals) and Chapter 14 (Support and Movement in Humans and Animals) of the KSSM Form 4 Biology syllabus.

DOUBLE-LOGGY is a matching and investigative board game that requires players to apply both strategy and memory skills to achieve successful matches between biological terms and their corresponding explanations. The game structure encourages active engagement, as students must recall prior knowledge, discuss possible answers within their team, and justify their choices before submitting a final match. The game reinforces students' understanding of key biological terms and concepts previously taught in class. By repeatedly engaging with essential concepts through gameplay, students can strengthen knowledge retention and deepen their conceptual understanding of biological processes that cannot be directly observed. The collaborative nature of the game also promotes peer learning, communication skills, and cooperative problem-solving.

DOUBLE-LOGGY transforms conventional rote learning into an interactive experience, enabling students to learn through exploration and discovery. Rather than passively receiving information, students actively construct knowledge by engaging with the game mechanics and content. This approach supports student-centred learning and aligns with 21st century educational practices that emphasise engagement, critical thinking, and meaningful learning. Figure 2 illustrates the overall framework of the DOUBLE-LOGGY Board Game, including its design flow, gameplay mechanics, and integration with learning objectives.

Fig. 2. The framework of Double-Loggy Board Game

5. Conclusions

The DOUBLE-LOGGY Board Game is an educational innovation designed to increase student engagement and interaction in secondary school Biology education. By integrating gamification principles with curriculum-aligned content, the game fosters an engaging, supportive environment that promotes active participation, collaboration, and meaningful learning experiences among students. The implementation of DOUBLE-LOGGY has the potential to complement traditional instructional methods and serve as an alternative interactive learning tool. Strategic gameplay and teamwork enable students to reinforce their understanding of key biological concepts while developing essential skills, including communication, problem-solving, and critical thinking. These competencies are crucial for academic achievement and are also valuable for future educational pursuits and potential careers in STEM-related fields.

Additionally, this innovation offers practical advantages for educators, particularly Biology teachers, by providing an alternative instructional approach that can be readily incorporated into classroom activities. DOUBLE-LOGGY supports student-centred learning and aligns with 21st century educational objectives by fostering engagement, motivation, and knowledge retention. Although the findings indicate positive potential, further improvements and extended studies are recommended. Future research may involve larger sample sizes, longer implementation periods, and the inclusion of quantitative learning-outcome measures to strengthen the game's effectiveness and applicability.

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References

[1] Moraes, Eduardo Baldo, Liane Mahlmann Kipper, Ana Clara Hackenhaar Kellermann, Leonardo Austria, Pedro Leivas, Jorge André Ribas Moraes, and Marcus Witczak. "Integration of Industry 4.0 technologies with Education 4.0: advantages for improvements in learning." *Interactive Technology and Smart Education* 20, no. 2 (2023): 271-287. https://doi.org/10.1108/ITSE-11-2021-0201.

[2] González-Pérez, Laura Icela, and María Soledad Ramírez-Montoya. "Components of Education 4.0 in 21st century skills frameworks: systematic review." *Sustainability* 14, no. 3 (2022): 1493. https://doi.org/10.3390/su14031493.

[3] Joshi, Kapil, Rajesh Kumar, Salil Bharany, Dilip Kumar Jang Bahadur Saini, Rajiv Kumar, Ashraf Osman Ibrahim, Abdelzahir Abdelmaboud, Wamda Nagmeldin, and Mohammad Awad Medani. "Exploring the connectivity between education 4.0 and classroom 4.0: Technologies, student perspectives, and engagement in the digital era." *IEEE Access* 12 (2024): 24179-24204. https://doi.org/10.1109/ACCESS.2024.3357786.

[4] Cheng, Ching-Hsue, and Chung-Ho Su. "A Game-based learning system for improving student's learning effectiveness in system analysis course." *Procedia-Social and Behavioral Sciences* 31 (2012): 669-675. https://doi.org/10.1016/j.sbspro.2011.12.122.

[5] Hartt, Maxwell, Hadi Hosseini, and Mehrnaz Mostafapour. "Game on: Exploring the effectiveness of game-based learning." *Planning Practice & Research* 35, no. 5 (2020): 589-604. https://doi.org/10.1080/02697459.2020.1778859.

[6] Bourgonjon, Jeroen, Frederik De Grove, Cindy De Smet, Jan Van Looy, Ronald Soetaert, and Martin Valcke. "Acceptance of game-based learning by secondary school teachers." *Computers & education* 67 (2013): 21-35. https://doi.org/10.1016/j.compedu.2013.02.010.

[7] Keprate, Arvind, Sam Woodford, and Rafael Borrajo. "From Theory to Practice: Leveraging Project Based Learning to Cultivate Student Engagement in Mechanical Engineering Education." In *2023 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pp. 0143-0147. IEEE, 2023. https://doi.org/10.1109/IEEM58616.2023.10406362.

[8] Srivani, V., A. Hariharasudan, Nishad Nawaz, and Sabina Ratajczak. "Impact of Education 4.0 among engineering students for learning English language." *PLoS One* 17, no. 2 (2022): e0261717. https://doi.org/10.1371/journal.pone.0261717.

[9] Singh, Kiran Deep, Prabhdeep Singh, Gaganpreet Kaur, Vikas Khullar, Rishu Chhabra, and Vikas Tripathi. "Education 4.0: Exploring the potential of disruptive technologies in transforming learning." In *2023 international conference on computational intelligence and sustainable engineering solutions (CISES)*, pp. 586-591. IEEE, 2023. https://doi.org/10.1109/CISES58720.2023.10183547.

[10] Hasnain, Mohd, and M. Vanaja. "The Evolution of Education: From Education 1.0 to Education 6.0 A Comprehensive Study on the Transformation of Learning Systems in the 21st Century." *JOURNAL OF ADVANCE AND FUTURE RESEARCH* 3, no. 12 (2025): 734-742. https://doi.org/10.56975/jaafr.v3i12.502354.

[11] LeGeros, Life. "Critical reflections on Genius Hour as personalized learning at the middle level." In *Dialogues in Middle Level Education Research Volume 3*, pp. 109-120. Routledge, 2024. https://doi.org/10.4324/9781003457831.

[12] Salendab, Fahad A., and Kendatu L. Tago. "Innovative Approaches to Revolutionize Student-Centered Learning in the 21st Century." In *Emerging Trends, Global Perspectives, and Systemic Transformation in AI*, pp. 33-62. IGI Global Scientific Publishing, 2026. https://doi.org/10.4018/979-8-3373-5102-5.ch002.

[13] Vasylechko, M. M., I. S. Lisetska, and O. I. Kocherzhat. 2023. "Student-Centred Orientation in the Medical Educational Space of Ukraine on the Example of Ivano-Frankivsk National Medical University." Ukrainian Journal of Perinatology and Pediatrics 96 (4): 151–56. https://doi.org/10.15574/pp.2023.96.151.

[14] Shashanka, P., Goparapu Srishanth, G. Anitha, Gajengi Harsha Vardhan, and Getteboina Murali Krishna. "Smart Tutoring and Adaptive Learning-Leveraging AI to Personalize Education in Real-Time: A Model for Engaging, Individualized, and Effective Learning Experiences." In *2025 8th International Conference on Circuit, Power & Computing Technologies (ICCPCT)*, pp. 630-635. IEEE, 2025. https://doi.org/10.1109/ICCPCT65132.2025.11176528.

[15] Nietfeld, John L., Rayne A. Sperling, and Taylor M. Young. "More than just fun and games: The role of games in postsecondary education to support self-regulated learning." *New Directions for Teaching and Learning* 2023, no. 174 (2023): 41-47. https://doi.org/10.1002/tl.20547.

[16] Ahma, Greta, and Arbana Kadriu. "Exploring the Impact of Gamification Strategies on Student Engagement and Learning Outcomes in Education." In *2025 20th Annual System of Systems Engineering Conference (SoSE)*, pp. 1-6. IEEE, 2025. https://doi.org/10.1109/SoSE66311.2025.11083792.

[17] Kučak, Danijel, Đani Pašić, and Leo Mršić. "An empirical study of long-term effects of applying gamification principles to an introductory programming courses on a university level." In *International Conference on Intelligent Computing & Optimization*, pp. 469-477. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-031-19958-5_44.

[18] Lantzouni, Marina, Vassilis Poulopoulos, and Manolis Wallace. "Gaming for the education of biology in high schools." *Encyclopedia* 4, no. 2 (2024): 672-681. https://doi.org/10.3390/encyclopedia4020041.

[19] Božić, Ana Vrcelj, Nataša Hoić-Božić, Martina Holenko Dlab, Kristian Stančin, and Tomislav Jagušt. "Analysis of the gamification aspects of digital educational tools using gamification classification." In *2024 International Conference*

on Software, Telecommunications and Computer Networks (SoftCOM), pp. 1-6. IEEE, 2024. https://doi.org/10.23919/SoftCOM62040.2024.10721650.

[20] Ali, Marlina, Corrienna Abdul Talib, Johari Surif, Nor Hasniza Ibrahim, and Abdul Halim Abdullah. "Effect of STEM competition on STEM career interest." In *2018 IEEE 10th International Conference on Engineering Education (ICEED)*, pp. 111-116. IEEE, 2018. https://doi.org/10.1109/ICEED.2018.8626904.

[21] Siew, Nyet Moi. "Mentor–Mentee Outreach Programme: Promoting University and School Partnerships to Revitalize STEM Education in Rural Secondary Schools in Malaysia." In *Concepts and practices of STEM education in Asia*, pp. 175-197. Singapore: Springer Nature Singapore, 2022. https://doi.org/10.1007/978-981-19-2596-2_10.

[22] Halim, Lilia, Lay Ah Nam, and Edy Hafizan Mohd Shahali. "STEM education in Malaysia: Policies to implementation." In *STEM education from Asia*, pp. 33-48. Routledge, 2021. https://doi.org/10.4324/9781003099888.

[23] Jamaluddin, Fadhilah, Ahmad Zabidi Abdul Razak, and Suzieleez Syrene Abdul Rahim. "Exploring self-leadership strategies and the successful transition of STEM students to higher education in Malaysia: Academic anxiety as a bridge." *STEM Education* 5, no. 4 (2025): 643-685. https://doi.org/10.3934/steme.2025030.

[24] Woo, Pei Syan, Zakiah Mohamad Ashari, Zaleha Binti Ismail, and Nurul Farhana Jumaat. "Relationship between teachers' self-efficacy and instructional strategies applied among secondary school teachers in implementing STEM education." In *2018 IEEE international conference on teaching, assessment, and learning for engineering (TALE)*, pp. 454-461. IEEE, 2018. https://doi.org/10.1109/TALE.2018.8615432.

[25] Abdullah, Abdul Halim, Mohd Hilmi Hamzah, Raja Haffizah Soffia Raja Hussin, Umar Haiyat Abdul Kohar, Sharifah Nurarfah S. Abd Rahman, and Juhazren Junaidi. "Teachers' readiness in implementing science, technology, engineering and mathematics (STEM) education from the cognitive, affective and behavioural aspects." In *2017 IEEE 6th international conference on teaching, assessment, and learning for Engineering (TALE)*, pp. 6-12. IEEE, 2017. https://doi.org/10.1109/TALE.2017.8252295.