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ADVANCING LIFELONG LEARNING FOR EMPOWERED WORLD

## INFECTICODE: THE MOLECULAR LOCKDOWN - UNLOCKING MOLECULAR MYSTERIES THROUGH AN EDUCATIONAL ESCAPE ROOM

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### ABSTRACT

*Systematic bacteriology is often seen as difficult and complex, leading to low student engagement and limited conceptual understanding. InfectiCode: The Molecular Lockdown was developed as an innovative escape room-style educational game using the Genial.ly platform. The game is set in a hospital outbreak scenario, in which participants assume the role of a clinical investigation team responsible for identifying the pathogen causing neonatal sepsis in a newborn. Clues are gathered through a series of guided tasks incorporating phenotyping and genotyping principles, to unlock a briefcase containing a reward. A pre-test and post-test using similar questions were given to evaluate the students' understanding, and a satisfaction survey form was administered to capture perceptions related to engagement and the learning experience. The Wilcoxon signed-rank test was performed to determine statistical differences in scores obtained before and after the game was conducted ( $p$ -value  $< 0.05$ ). The results indicated significant improvements in understanding and high satisfaction levels regarding the game design and delivery. This game-based approach provided an effective alternative to conventional teaching methods by promoting deeper conceptual learning, collaboration, and learner motivation. Importantly, the simulation also fosters anticipatory thinking, one of the core competencies of Education for Sustainable Development, by encouraging learners to envision future public health scenarios and reflect on the long-term societal impacts of clinical microbiological decisions through systematic bacteriology. The outcomes suggest that game-based learning can help students learn complex scientific content more enjoyably and effectively.*

**Keywords:** *Escape room, Game-based learning, Active learning, Student engagement*

## INTRODUCTION

Systematic bacteriology is the branch of microbiology on the classification, identification and naming (taxonomy) of bacteria based on phenotypic (observable traits) and genotypic (DNA-based). Systematic bacteriology is a subject that is known to be included as part of the curriculum for students pursuing an undergraduate course in Microbiology. This bacterial identification is important for clinical diagnosis, effective treatment and public health to track outbreaks and emerging resistant strains. Systematic bacteriology is also crucial for agriculture and soil health, such as the detection of plant pathogens or support development of biofertilizers and biocontrol agents for sustainable farming. Besides, this contributes to the discovery of new bacterial species that may have environmental, industrial microbiology and biotechnology importance. This systematic bacteriology combines morphology, biochemical tests, molecular genetics and clinical relevance. The volume of information, combined with its complexity, can overwhelm learners and make the learners feel disconnected and reduced motivation (Walker et al, 2022). Traditional lecture-based methods tend to result in low engagement with limited conceptual understanding and difficult to relate to real-world applications, especially in a clinical context (Pineros et al, 2023). Therefore, there is a need to explore interactive, interactive and fun learning tools such as escape room-style educational games that connect learning to real-world microbiological applications and also promote deeper conceptual learning, fostering collaboration and increasing learner motivation (Alsawaier, 2018).

This study aims to design and implement an interactive escape room-style educational game titled '*InfectiCode: The Molecular Lockdown*', to improve student comprehension of complex topics in systematic bacteriology. By incorporating real-world clinical scenarios and guided problem-solving tasks, the innovation seeks to foster deeper conceptual understanding through active learning (Nieto-Escamez & Roldan-Tapia, 2021). To evaluate its effectiveness, pre- and post-tests were administered to measure students' gains in knowledge. Additionally, a structured feedback survey was used to assess student perceptions, focusing on their satisfaction with the game's design, delivery, and overall learning experience. Together, these objectives support the development of an engaging and flexible-learning tool that enhances both understanding and learner engagement in microbiology education. Notably, the simulation encourages anticipatory thinking, one of the core competencies of Education for Sustainable Development by guiding students to imagine future public health scenarios and consider the long-term societal implications of microbiological decisions in systematic bacteriology. The results indicate that game-based learning can make complex scientific content more accessible, engaging, and effective for students.

## METHODS

### Game Design and Development

*InfectiCode*: The Molecular Lockdown was conceptualized as an educational escape room-style game to enhance students' understanding of systematic bacteriology subjects related to phenotyping and genotyping. The game was developed using the Genial.ly platform, a web-based interactive tool embedded in a simulated hospital outbreak. Participants were placed in the role of a clinical investigation team assigned to identify the causative agent of neonatal sepsis in a newborn.

The game storyline was constructed through a series of sequential tasks designed to enhance the decision-making process in students related to knowledge in the related topics. These tasks incorporated phenotyping (Gram staining, cell morphology, biochemical tests) and genotyping (Polymerase Chain Reaction (PCR) amplification, sequencing, BLAST analysis, Multi Locus Sequences Typing (MLST)) approaches. Each task delivered clues essential to progress through the game and ultimately unlocking a virtual briefcase containing a "reward" representing successful pathogen identification.

The activities were designed to encourage students to think critically and solve problems. Game mechanics included clue discovery and password-protected interactive puzzles to simulate the pressure and complexity of real-world microbiological investigations. The game duration was approximately 15–20 minutes and was conducted in a single session in a classroom.

### Participants and Setting

The study recruited 96 undergraduate students (diploma level) in semester 4 enrolled in a microbiology course at UiTM. Participation in the study was voluntary and conducted during scheduled class sessions. Students participated in the game individually to allow for independent decision-making, self-paced problem-solving, and to ensure the measurement of individual learning outcomes.

### Pre- and Post-Assessment

To evaluate the impact of the game on students' conceptual understanding, a set of fifteen multiple-choice questions (MCQs) covering key concepts in systematic bacteriology was administered before the game (pre-test) and immediately after (post-test) the game session. The test items were designed to assess both knowledge recall and application of phenotypic and genotypic identification strategies. The same questions were used for both pre- and post-assessments to enable paired comparison of individual learning gains.

### Student Feedback and Engagement Survey

A post-activity survey assessed students' perceptions based on the MEEGA+ (Model for the Evaluation of Educational Games for Computing Education) (Petri et al., 2018) was used to assess students' enjoyment, focus of attention, motivation, perceived learning, user experience and social interaction of the game. The instrument consisted of a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) and open-ended suggestions for feedback purposes.

## Statistical Analysis

Survey responses were analysed, and mean scores and standard deviations were calculated for each item. Qualitative feedback was used to evaluate the learning experience, perceived benefits, and suggestions for improvement. The pre-test and post-test data were analysed using Wilcoxon Signed-rank test to evaluate the students' performance before and after the game-based intervention. A  $p < 0.05$  was considered significant. All statistical analyses were performed using SPSS Version 26.0.

## RESULTS AND DISCUSSION

### Conceptual Understanding of Pre and Post-Test Findings

The effect of the escape room-style educational game on the students' understanding was conducted. The assumption of normality was first tested using Kolmogorov-Smirnov and Shapiro-Wilk tests. The results showed that significant deviation from normality ( $W = 0.951$ ,  $p = 0.002$ ) based on the Shapiro-Wilk test indicated that the data were not normally distributed. Thus, a nonparametric Wilcoxon test was used for further analysis.

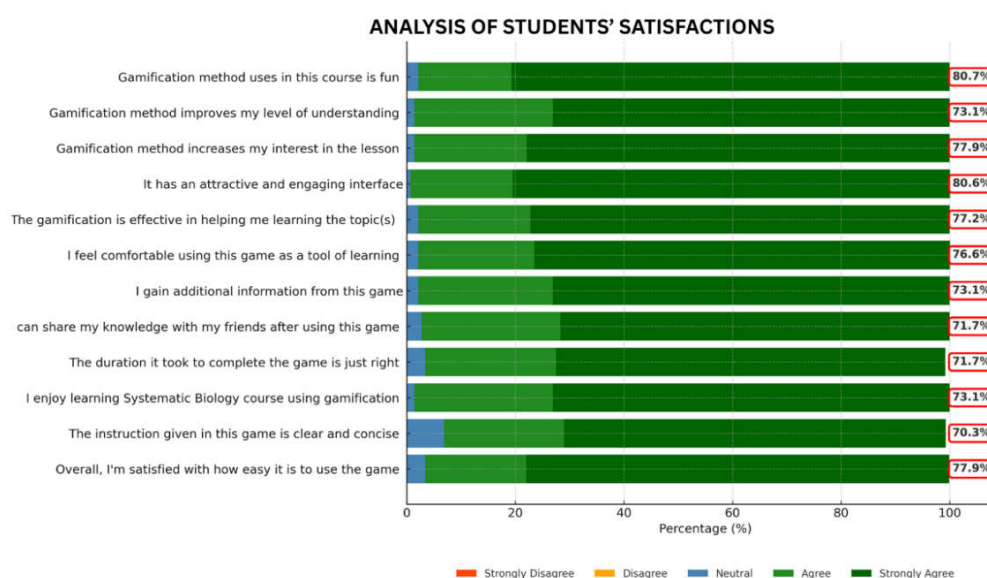
The Wilcoxon test revealed a statistically significant increase in scores from pre-test to post-test with the results of  $Z = -7.087$ ,  $p < 0.001$ . Out of 93 participants, 70 students showed an improved score (positive rank), five showed a decrease (negative ranks) and 18 students showed no change. The mean rank among positive ranks was 39.95 compared to negative rank 19.10 provides strong evidence that the game conducted has meaningful impact. These findings indicate that the game significantly enhances student comprehension of the complex microbiological concepts and thus fulfilling the objective of the study, which was to evaluate the effectiveness of the innovation in improving conceptual understanding. This improvement also aligns with the element confidence in MEEGA+ model where learners gain assurance in their understanding through gamified engagement.

### Student Satisfaction and Feedback of the Educational Game

Students' satisfaction and feedback on the game's design and learning experience were captured by the post-game session's survey. The satisfaction survey was conducted with 145 participants based on 5-point Likert scale. The responses obtained showed positive feedback from multiple perspectives as shown in Figure 1. Majority of the students strongly agreed (80.7%) that the gamification method used in the course was fun and had an attractive and engaging interface (80.6%). Furthermore, 77.9% of students reported that the game increased their interest in the lesson, while an equal number of percentages expressed an overall satisfaction with the ease of using the game. Additionally, high levels of strong agreement among students regarding the effectiveness of the game in helping students learn the topic (77.2%), improving understanding (73.1%), and increase the comfort in learning (76.6%). The clarity of the game instructions showed 70.3% scores and the ability to gain additional information and share knowledge with peers (71.7%) further underscore the educational value and usability of the innovation. These results are in align with the several aspects in MEEGA+ models particularly in the



elements of fun, satisfaction, interaction and feedback. The strong rating ( $> 70\%$  strongly agree) suggests that the educational game succeeded not only in delivering content effectively but also in fostering an enjoyable and intuitive learning environment.



**Figure 1.:** Analysis of students’ satisfaction post-game

### Relevance to ESD and Flexible Learning Pathways

Apart from achieving the study objectives, this educational game also aligns with Education for Sustainable Development (ESD) and Flexible Learning Pathways. In ESD context, this game enhances anticipatory thinking which is reflected in one of the core competencies in ESD. Additionally, this game also supports the principle of flexible learning pathways by offering a self-paced, student-centred and adaptive learning experience while engaging with the game. These aspects resonate strongly with the national higher education agenda for more flexible and personalized learning models, particularly in STEM-related courses.

## NOVELTY

The novelty of this game lies in its integration of escape room within a microbiological learning context, providing alternative to conventional learning. Using a clinical outbreak scenario, the game encourages students to apply bacteriological principles to solve the puzzles and unbreak the mystery which promotes the flexible and self-directed learning pathways. Moreover, the design aligns with the MEEGA+ model by embedding elements such as narrative-driven tasks, feedback loops, an intuitive interface, and motivational features like achievement tracking and challenge progression. These elements collectively boost student confidence, interest, and satisfaction, as demonstrated by strong post-intervention learning gains and positive perception ratings. Additionally, innovation contributes to Education for Sustainable Development (ESD) by fostering anticipatory thinking and decision-making enabling students to envision real-world implications of clinical diagnostics. Through its interdisciplinary design and evidence-based outcomes, this game-based learning tool represents a novel, scalable approach to enhancing microbiology education in line with 21st-century learning demands.

## CONCLUSION

This study demonstrates that the gamified escape room-style educational game, *InfectiCode: The Molecular Lockdown*, significantly enhanced students' conceptual understanding of complex systematic bacteriology content. The statistically significant improvement in post-test scores, reflects the game's effectiveness in deeper understanding of phenotypic and genotypic classification principles. Furthermore, student satisfaction data indicate high levels of engagement, enjoyment, and perceived learning value. These outcomes affirm the potential of gamification as an impactful tool for microbiology education, especially in difficult topics into immersive and learner-centered experiences. We concluded the innovation in gamification for systematic bacteriology course would engage learners and improved cognitive comprehension demonstrated through improved scores. Such interactive approaches can play a key role in advancing education for sustainable development through deeper learning and anticipatory thinking in scientific fields.

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