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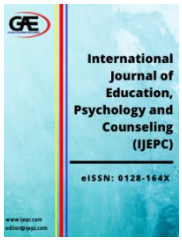

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ENHANCING BACTERIAL PHYSIOLOGY EDUCATION: A MIXED-METHODS STUDY ON THE IMPACT OF GAMIFICATION AND YOUTUBE-BASED INSTRUCTION

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Abstract:

Bacterial physiology is a crucial component of microbiology education, but its abstract and complex content often leads to student disengagement and poor academic performance. Traditional lecture-based methods frequently fail to promote active participation or conceptual clarity. This study investigates the impact of combining gamification and YouTube-assisted teaching strategies on student engagement, understanding, and academic achievement in a bacterial physiology course. Using a mixed-methods design, data were collected from 136 undergraduate microbiology students through structured questionnaires and open-ended responses. Quantitative findings revealed strong student support for both gamified and video-enhanced learning approaches, with high agreement on improvements in motivation, engagement, conceptual understanding, and exam preparedness. Qualitative responses highlighted the benefits of visual content, including its motivational effect, interactivity, and immediate feedback, although some challenges, such as internet access and time constraints, were also noted. The integration of gamification and YouTube was found to align well with contemporary educational theories that emphasize active and multimedia learning. These methods enhanced both cognitive outcomes and emotional engagement, fostering deeper understanding and learner autonomy. Overall, the study supports the value of incorporating gamified and multimedia strategies into microbiology education to better meet diverse learning needs and improve academic success.

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Keywords:

Bacterial Physiology, Gamification, YouTube-Embedded Teaching Methods, Mixed-Methods Design, Structured Questionnaires, Open-Ended Responses.

Introduction

Bacterial physiology is a fundamental part of microbiology education, providing key insights into microbial metabolism, cellular structure, and functional pathways that support important applications in antibiotic development, biotechnology, and clinical diagnostics. Despite its essential role, undergraduate students often find the conceptual complexity of bacterial physiology challenging due to its abstract nature and the need for interdisciplinary knowledge in biochemistry, molecular biology, and genetics (Coil, Wenderoth, & Freeman, 2010). Traditional lecture-based teaching, although common, often fails to cater to different learning styles and to foster active, meaningful engagement with the material (Freeman et al., 2014). This teaching gap can result in reduced motivation, poor academic results, and difficulty in applying theoretical concepts to practical laboratory skills or clinical settings.

The cognitive challenges linked to bacterial physiology, such as understanding metabolic regulation, signal transduction, and membrane transport, often lead to student cognitive overload, especially when instruction lacks practical application or interactivity (Michael, 2006; Paas, Renkl, & Sweller, 2003). Traditional passive learning environments are inadequate for fostering the deep conceptual understanding needed for proficiency in microbiology (Prince, 2004). In response to these pedagogical limitations, there is increasing interest in adopting active learning strategies that incorporate educational technologies to enhance comprehension, engagement, and retention. Among these, gamification and YouTube-based instruction have become innovative tools to refresh science education.

Gamification, defined as the use of game design elements in non-game contexts, has been widely applied in education to enhance motivation and learning outcomes (Deterding et al., 2011). By integrating points, leaderboards, challenges, and rewards into educational content, gamified instruction transforms traditional classroom dynamics, making learning more engaging and interactive (Hamari et al., 2014). Studies indicate that gamification can improve classroom participation, cognitive engagement, and knowledge retention, particularly in science-based courses (Domínguez et al., 2013; Subhash & Cudney, 2018). Furthermore, gamification encourages autonomy and self-regulated learning by allowing students to progress through content at their own pace and set personal learning goals.

In parallel, YouTube has become a powerful platform for delivering educational content, particularly in higher education. Its ability to convey dynamic visual content including animations, laboratory demonstrations, and expert explanations supports the cognitive processes involved in understanding complex biological mechanisms (Kay, 2012; Jaffar, 2012). Grounded in Mayer's Cognitive Theory of Multimedia Learning, YouTube videos that combine words and visuals facilitate deeper conceptual understanding and support the construction of robust mental models (Mayer, 2009). Additionally, YouTube enables self-paced learning, which is especially valuable for students with varied academic backgrounds and learning preferences. The use of educational videos has also been shown to enhance student motivation, enable repetition for reinforcement, and support flipped classroom models that shift

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passive content delivery outside the classroom to make room for active learning during face-to-face sessions (Bishop & Verleger, 2013; Guo, Kim, & Rubin, 2014).

In bacterial physiology, abstract and complex content often leads to cognitive overload among undergraduates, and traditional lecture-based teaching has not adequately addressed this issue, resulting in low engagement and poor retention. In addition to that, conventional didactic methods fail to cater to diverse learning styles, especially visual and interactive learners, which limits students' ability to grasp and apply bacterial physiology concepts in laboratory and clinical contexts. There is also limited empirical research on the synergistic integration of gamification and YouTube-based instruction in microbiology education, despite increasing calls for innovative pedagogical tools that align with digital-native learners' preferences. Given these pedagogical advancements and problem statements, this study aims to evaluate the combined effect of gamification and YouTube-based instruction on student learning in a bacterial physiology course. Specifically, the study investigates how these tools influence student engagement, conceptual understanding, motivation, and academic performance. Understanding the impact of such blended instructional strategies is essential for refining teaching approaches in microbiology and addressing persistent challenges in science education.

Literature Review

Challenges in Teaching and Learning Bacterial Physiology and the Need for Innovative Pedagogical Approaches

The study of bacterial physiology is a fundamental part of microbiology education because it offers essential insights into microbial metabolism, growth, and cellular structures that support applied fields like antibiotic development, biotechnology, and clinical diagnostics. However, undergraduate students often find it challenging to fully grasp the complex biochemical and molecular mechanisms behind bacterial processes due to the abstract nature and wide scope of the material (Coil, Wenderoth, & Freeman, 2010). Despite its significance, student engagement and understanding in bacterial physiology remain less than ideal. This issue is partly due to traditional didactic teaching methods that may not effectively cater to diverse learning styles or promote active learning (Freeman et al., 2014). Without a clear conceptual understanding, students struggle to apply theoretical knowledge to laboratory experiments and real-world microbiological issues, leading to poor academic performance and decreased motivation.

Several challenges have been identified in bacterial physiology education, including abstract and complex content, limited practical application, cognitive overload, and a lack of active learning techniques. For example, concepts such as metabolic regulation, signal transduction, and membrane transport are abstract and require a solid foundation in biochemistry and molecular biology, which many students may lack (Michael, 2006). Moreover, traditional lecture-based formats often fail to link theoretical knowledge with practical microbiological techniques, reducing student interest and retention (Prince, 2004). The large volume of detailed information and the need to integrate knowledge across multiple domains (such as genetics, cell biology, and biochemistry) can overwhelm students, leading to cognitive overload (Paas, Renkl, & Sweller, 2003). Passive instructional strategies restrict student engagement. Evidence indicates that active learning approaches, such as problem-based learning and gamification, significantly enhance student outcomes in science education (Freeman et al., 2014). As educators seek ways to improve student engagement and learning results in science education, the use of innovative pedagogical tools has gained considerable interest. Among these,

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gamification and YouTube-embedded teaching methods have become promising strategies to foster deeper understanding and active participation in the classroom.

Gamification in Education

Gamification refers to the application of game-design elements and principles in non-game contexts, such as education, to enhance user engagement, motivation, and learning outcomes (Deterding et al., 2011). In teaching, gamification involves incorporating game mechanics such as points, badges, leaderboards, and challenges into the instructional process to foster student participation and improve knowledge retention. Gamification, which involves the incorporation of game elements such as points, quizzes, leaderboards, and rewards into educational activities, has been shown to enhance student motivation, foster engagement, and support knowledge retention (Deterding et al., 2011; Hamari et al., 2014). The core advantage of gamification in education lies in its ability to increase student motivation. By creating a more interactive and enjoyable learning environment, gamified instruction can transform passive learners into active participants (Hamari et al., 2014). It also encourages goal-setting and self-directed learning, as students often strive to achieve higher scores or progress through levels, promoting perseverance and sustained engagement (Domínguez et al., 2013).

Furthermore, gamification has been shown to enhance cognitive and emotional involvement in learning activities. Studies report improvements in learning performance, attendance, and classroom dynamics when game elements are strategically integrated into lesson plans (Subhash & Cudney, 2018). In digital learning environments, gamification also supports immediate feedback and personalized learning paths, making the educational experience more adaptive and responsive. Hence, gamification represents a valuable pedagogical approach that can revitalize traditional teaching methods. When applied effectively, it not only boosts motivation and engagement but also improves learning outcomes and student satisfaction. When applied to microbiology instruction, gamification can transform passive content delivery into an interactive learning experience, encouraging students to actively participate and compete constructively.

YouTube in Higher Learning

Similarly, YouTube-based instruction provides a powerful platform for visual learning. YouTube is a widely used online video-sharing platform that allows users to upload, view, share, and comment on videos across diverse content categories, including education. Since its launch in 2005, YouTube has become an influential tool in digital education, offering access to a vast library of multimedia learning materials (Snelson, 2011). With the ability to deliver dynamic animations, real-life laboratory demonstrations, and step-by-step explanations, YouTube videos can simplify the understanding of microbiological mechanisms and allow students to review material at their own pace (Kay, 2012; Jaffar, 2012). These visual aids are particularly beneficial for visual learners and can improve students' grasp of cellular processes and physiological interactions. Several advantages of YouTube have been reported in learning methods, including enhancing engagement and Motivation, supporting multimedia and Active Learning, promoting self-paced and flexible learning, encouraging repetitive and reinforcement learning, facilitating flipped classroom approaches and widening access to educational resources. YouTube videos use visual storytelling, animations, and real-life examples to capture students' attention and sustain interest in learning. Research shows that multimedia content increases learner engagement and supports better knowledge retention compared to traditional text-based methods (Guo, Kim, & Rubin, 2014).

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According to Mayer's Cognitive Theory of Multimedia Learning, combining words and images facilitates deeper understanding. YouTube videos cater to this by integrating audio-visual elements, which help learners build mental models and apply concepts more effectively (Mayer, 2009). YouTube allows students to pause, replay, and review videos, enabling personalized and self-directed learning. This flexibility supports diverse learning paces and styles (Kay, 2012), making it especially beneficial for complex subjects like microbiology or physiology. Students can revisit videos multiple times for revision and exam preparation. Repetition is a proven strategy for reinforcing learning and improving long-term retention (Brame, 2016). YouTube is commonly used in flipped classrooms, where students watch instructional videos before class, allowing in-class time to be devoted to discussion and problem-solving. This model improves conceptual understanding and learner autonomy (Bishop & Verleger, 2013). Being freely accessible and available globally, YouTube reduces barriers to learning by providing equal access to quality educational content regardless of location or institutional resources (Snelson, 2011). Hence, this study aims to assess the impact of combining gamification and YouTube-assisted teaching methods on students enrolled in a bacterial physiology course. Specifically, it explores how these methods influence engagement, conceptual understanding, motivation, and overall academic performance. Understanding the effectiveness of such innovative approaches is essential for the advancement of teaching strategies in microbiology and other science-based disciplines.

Methodology

A quantitative research design was employed to determine students' perceptions of the integration of gamification and YouTube-embedded teaching methods in the Bacterial Physiology course. This research design was supplemented by qualitative open-ended responses to allow deeper insights into student experiences. This mixed-methods approach provided both measurable trends and descriptive feedback (Creswell & Plano Clark, 2018).

Survey Instrument

A modified structured questionnaire was developed based on previous studies exploring technology-enhanced and gamified learning environments (Dichev & Dicheva, 2017; Kay, Leung, & Tang, 2018). The questionnaire comprised five (5) sections:

Section A: Demographic Information – Collected background data including age, gender, and academic standing.

Section B: Experience with Gamification in Learning – Assessed students' engagement and motivation derived from gamified tools like quizzes, badges, and competitions.

Section C: Experience with YouTube-Embedded Teaching – Measured the impact of video content on understanding complex microbiological concepts.

Section D: Combined Impact on Learning and Performance – Analyzed the synergistic effect of combining gamification and YouTube videos on learning outcomes.

Section E: Open-Ended Questions – Offered qualitative insight through questions such as:

a) What challenges do you face when using these methods?
b) What aspect of gamification or YouTube-assisted teaching helped you the most?
c) Do you have suggestions to improve the use of gamification and video content in teaching?

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Each item in the questionnaire presented a statement regarding the effectiveness and impact of gamified tools (such as quizzes, badges, and competitions) and YouTube videos (including animations, visual demonstrations, and real-world applications) on various aspects of learning.

Likert Scale Measurement

The application of Likert-scale methodology in this context enabled the quantification of subjective perceptions, making it a suitable tool for evaluating instructional strategies in higher education settings (Boone & Boone, 2012). Closed-ended items in Sections B to D were measured using a 5-point Likert scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, and 5 – Strongly Agree. The numerical values chosen by respondents reflected their level of agreement with each statement and represented their preferences for integrating these methods into the bacterial physiology curriculum. This scaling method is well-regarded for capturing attitudes and opinions in educational research and enables robust statistical analysis of subjective responses (Joshi et al., 2015).

Sampling and Data Collection

This study employed a purposive sampling technique, targeting students enrolled in the Bacterial Physiology course at the Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. A total of 136 undergraduate students participated in the study. These students were selected based on their direct exposure to the integration of gamification and YouTube-embedded teaching methods within the course, making them ideal respondents for the research objectives. Purposive sampling was appropriate in this context, as it enables researchers to focus on participants who have specific knowledge or experience relevant to the study (Etikan, Musa, & Alkassim, 2016). Data was collected using a modified structured questionnaire, administered during the final weeks of the semester to ensure participants had sufficient exposure to the teaching methods being evaluated. The survey was distributed online via a secure Google Form link, providing ease of access and ensuring anonymity. This digital approach facilitated broad participation and minimized disruption to the academic schedule (Wright, 2005). The questionnaire consisted of both quantitative and qualitative items, including Likert-scale statements and open-ended questions designed to capture students' perceptions, motivation, engagement, and learning outcomes related to the use of gamification and YouTube videos in teaching. Prior to data collection, participants were informed of the study's purpose, and informed consent was obtained in line with ethical research standards. Participation was voluntary, and no identifying information was collected to ensure confidentiality. This sampling and data collection approach ensured the reliability and relevance of the data for evaluating the pedagogical impact of gamified and video-assisted teaching strategies in microbiology education.

Data Analysis

Quantitative data were analyzed using descriptive statistics to identify frequencies, means, and standard deviations for each Likert-scale item. A higher mean indicates stronger agreement or satisfaction, and a lower mean suggests disagreement or dissatisfaction. A low SD (e.g., < 1.0) implies responses are clustered, indicating consensus among respondents. Meanwhile, a high SD (e.g., > 1.0) shows divergence in views, pointing to disagreement or heterogeneity in opinion. Open-ended responses from Section E were analyzed through thematic analysis to identify recurring themes and insights (Braun & Clarke, 2006).

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This comprehensive methodology enabled an in-depth understanding of how gamification and video-assisted learning influence engagement, understanding, and motivation in bacterial physiology education.

Results and discussion

Section A: Demographic Information

The study titled "Impact of Gamification and YouTube-Embedded Teaching Methods on Bacterial Physiology Students" involved a total of 136 undergraduate participants. The gender distribution revealed a predominance of female respondents, with 109 females (80.1%) and 27 males (19.9%) (Table 1). In terms of age, the majority of participants fell within the traditional undergraduate age range. Specifically, 2 respondents (1.5%) were aged 20, 45 respondents (33.1%) were aged 21, 59 respondents (43.4%) were aged 22, and 27 respondents (19.9%) were aged 23 (Figure 1). Additionally, a small number of older students were represented: one respondent (0.7%) each at ages 24, 25, and 27. Understanding the demographic composition of study participants is crucial in educational research, as factors such as age and gender may influence students' engagement levels, learning preferences, and responsiveness to specific teaching methods (Jaggars & Xu, 2016). The gender imbalance and the clustering of ages around early adulthood reflect typical enrolment patterns in science-based undergraduate programs, particularly within health and microbiological sciences.

Table 1: Gender Distribution of Respondents

Sex	Total	Percentage (%)
Female	109	80.1
Male	27	19.9

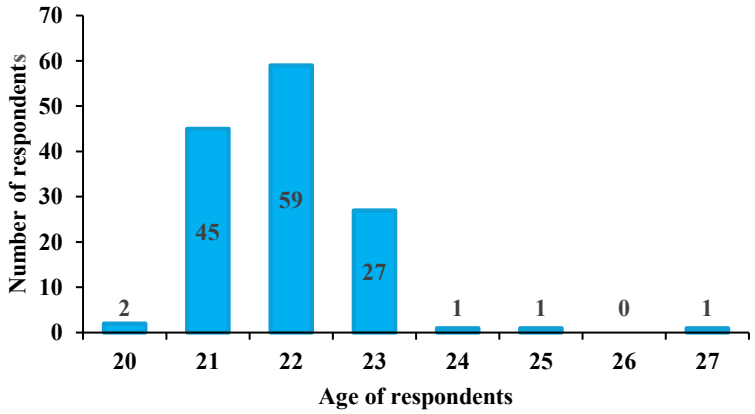

Figure 1: Age Distribution of Respondents

Section B: Experience with Gamification in Learning

Table 2 shows the responses of respondents regarding their experience with gamification in learning bacterial physiology. The response to the statement "*Gamified activities (e.g., quizzes, badges, competitions) made the class more engaging*" reflects a strong consensus among students regarding the positive impact of gamification on classroom engagement (Table 2 – item a). Out of 136 respondents, 104 students (76.5%) strongly agreed, and 28 students (20.6%) agreed, making a combined 97.1% who found gamified elements beneficial for engagement.

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Only 4 students (2.9%) remained neutral, and no respondents disagreed. These findings underscore the effectiveness of gamification in fostering an interactive and stimulating learning environment. The high level of agreement suggests that students were not only more involved in the learning process but also more motivated to participate, likely due to the rewarding and competitive nature of activities like quizzes, badges, and point systems. This is consistent with previous studies, such as those by Deterding et al. (2011) and Subhash & Cudney (2018), which highlight how gamification enhances learner engagement, motivation, and satisfaction by incorporating game-like dynamics into educational settings. By transforming passive learning into an active and immersive experience, gamification helps sustain attention and reinforce understanding. Therefore, the data strongly support the integration of gamified activities into teaching strategies, particularly in courses that require active student participation and conceptual clarity.

In response to the statement "*Gamification helped me to understand complex bacterial physiology concepts better*", the findings indicated a strong positive perception among students regarding the educational value of gamified learning (Table 2 – item b). Out of 136 students, 80 (58.8%) strongly agreed, 50 (36.8%) agreed, and 6 (4.4%) remained neutral. Notably, none disagreed, showing unanimous acceptance or neutrality toward the use of gamification in understanding microbiological content. These findings suggest that gamification is not only an engaging tool but also an effective pedagogical strategy for simplifying abstract or intricate scientific topics such as those found in microbiology. Gamified activities such as quizzes, competitive games, and reward systems likely helped students break down and retain complex information more efficiently. This aligns with findings from Alhammad and Moreno (2022), who emphasized that gamification supports deeper cognitive processing by fostering active learning, especially in science, technology, engineering, and mathematics (STEM) disciplines. Similarly, Subhash and Cudney (2018) noted that gamification can lead to improved comprehension and academic performance when integrated with well-structured educational content. The use of gamification in bacterial physiology, therefore, appears to enhance conceptual clarity, encourage student motivation, and promote meaningful learning through repeated exposure and immediate feedback mechanisms, factors critical to mastering complex biological systems and mechanisms.

Table 2: Experience with Gamification in Learning

	Item	Scale					Mean	SD
		1	2	3	4	5		
a)	Gamified activities (e.g., quizzes, badges, competitions) made the class more engaging	0	0	4 (2.9%)	28 (20.6%)	104 (76.5%)	**4.74**	**0.50**
b)	Gamification helped me to understand complex bacterial physiology concepts better	0	0	6 (4.4%)	50 (36.8%)	80 (58.8%)	**4.54**	**0.58**
c)	I felt more motivated to study when learning activities included games	0	1 (0.7%)	4 (2.9%)	38 (27.9%)	93 (68.4%)	**4.64**	**0.58**
d)	Gamification improved my class participation	0	0	1 (0.7%)	42 (30.9%)	93 (68.4%)	**4.68**	**0.48**

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e)	I retained more information through gamified teaching methods	0	1 (0.7%)	6 (4.4%)	51 (37.5%)	78 (57.4%)	**4.51**	**0.62**
f)	Gamification encouraged teamwork and interaction with classmates	0	0	8 (5.9%)	40 (29.4%)	88 (64.7%)	**4.59**	**0.60**

The statement "*I felt more motivated to study when learning activities included games*" received overwhelmingly positive responses from students (Table 2 – item c). Out of 136 respondents, 93 students (68.4%) strongly agreed, 38 students (27.9%) agreed, 4 students (2.9%) were neutral, and only 1 student (0.7%) disagreed. This indicates that 96.3% of students felt some level of increased motivation when gamification was part of their learning experience. These results clearly show that gamified learning strategies such as interactive games, quizzes, and point-based systems serve as powerful motivational tools in the classroom. By introducing elements of fun and challenge, gamification stimulates intrinsic and extrinsic motivation, encouraging students to engage more deeply with course material. In microbiology and other content-heavy fields, this motivational boost can significantly improve study habits and academic performance. Deterding et al. (2011) highlight that gamification promotes motivation by incorporating game elements such as rewards, feedback, and competition into non-game contexts. Additionally, Domínguez et al. (2013) found that students in gamified environments demonstrated higher engagement and spent more time interacting with course materials compared to traditional learning settings. Hence, integrating gamified elements into academic instruction not only enriches the learning experience but also significantly enhances students' willingness and enthusiasm to study, especially in challenging disciplines like bacterial physiology.

In response to the statement "*Gamification improved my class participation*", a substantial majority of students expressed strong agreement (Table 2 – item d). Out of 136 respondents, 93 students (68.4%) strongly agreed, 42 students (30.9%) agreed, and only 1 student (0.7%) was neutral. Notably, no students disagreed, indicating a near-universal perception that gamified learning methods enhanced their classroom engagement. These findings underscore the positive impact of gamification on student participation. Gamified learning incorporates game-like elements such as points, challenges, competitions, and real-time feedback, which create a more stimulating and interactive environment. This encourages students to be more active participants rather than passive recipients of information. This aligns with academic research indicating that gamification enhances classroom dynamics. Hamari et al. (2014) found that gamification positively affects engagement and participation, particularly when learners feel that game elements align with their educational goals. Moreover, Kapp (2012) emphasizes that gamified learning environments foster a sense of progress and achievement, which can lead to increased motivation and class participation. In fields like bacterial physiology, where conceptual content can be dense and abstract, gamified strategies such as quizzes, leaderboards, and interactive challenges offer alternative pathways to participation and understanding. These tools not only make learning more enjoyable but also promote sustained attention and collaborative learning behaviours.

In response to the statement "*I retained more information through gamified teaching methods*", the majority of students reported a positive experience (Table 2 – item e). Out of 136 respondents, 78 students (57.4%) strongly agreed, 51 students (37.5%) agreed, 6 students (4.4%) were neutral, and only 1 student (0.7%) disagreed. This distribution reflects that 94.9%

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of students perceived gamification as beneficial for long-term information retention. These results suggest that gamified teaching methods such as quizzes, puzzles, and interactive competitions can significantly enhance memory retention among students. The interactive and engaging nature of gamification activates deeper cognitive processing, making information more memorable and easier to recall. It moves beyond passive learning by requiring students to apply knowledge in a dynamic context. This is consistent with findings from Plass, Homer, and Kinzer (2015), who argue that game-based learning supports long-term retention by encouraging learners to actively retrieve and apply concepts in multiple formats. Similarly, de-Marcos et al. (2016) found that gamification promotes repeated engagement with content, which reinforces learning through spaced repetition and instant feedback. In bacterial physiology education, where memorization of complex processes, terminologies, and mechanisms is essential, gamified learning helps break down abstract concepts into manageable and repeatable tasks. This approach improves not only immediate understanding but also longer-term knowledge retention.

In response to the statement "*Gamification encouraged teamwork and interaction with classmates*", a significant majority of students responded positively (Table 1 – item f). Out of 136 total respondents, 88 students (64.7%) strongly agreed, 40 students (29.4%) agreed, and 8 students (5.9%) remained neutral. Notably, 94.1% of students recognized that gamified elements in class fostered collaborative behaviour and peer interaction. This high level of agreement indicates that gamification effectively promotes social learning, an essential component of an engaging educational experience. Gamified activities such as group quizzes, team competitions, or collaborative challenges naturally require students to communicate, cooperate, and solve problems together. These interactions not only enhance academic understanding but also help build interpersonal skills, peer trust, and a sense of classroom community. This aligns with research by Capdeferro and Romero (2012), who note that gamified learning environments create shared goals and foster peer collaboration, improving group cohesion and interaction. Similarly, Kuo and Chuang (2016) found that gamification significantly increased student collaboration and social presence, especially in blended or active learning environments. In bacterial physiology or other applied science courses, where problem-solving and critical thinking are key, fostering teamwork through gamification creates a more supportive and active learning atmosphere, encouraging students to learn from one another.

Section C: Experience with YouTube-Embedded Teaching

Table 3 exhibits the responses of respondents regarding their experience with the YouTube-embedded teaching method. The survey (Table 3 – item a) asked students to respond to the statement "*YouTube videos embedded in lectures helped me visualize bacterial physiology concepts*." Out of 136 respondents, a significant majority of 86 students (63.2%) strongly agreed, and 45 students (33.1%) agreed with the statement. Only 5 students (3.7%) remained neutral, and no respondents disagreed. These findings indicate a high level of student approval and perceived effectiveness of using YouTube videos as visual learning tools in bacterial physiology lectures. This aligns with previous research suggesting that multimedia content, particularly educational videos, enhances comprehension of complex biological processes by providing dynamic, visual representations (Kay, 2012). In courses like bacterial physiology, where abstract concepts such as metabolic pathways, cell signaling, and structural components can be challenging to grasp, YouTube videos serve as valuable supplements to traditional instruction. They support dual coding theory by engaging both visual and verbal channels, thus

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improving memory retention and conceptual understanding (Mayer, 2009). The overwhelmingly positive response underscores the value of integrating YouTube-based multimedia into microbiology curricula to support visual learners and enhance overall engagement and comprehension.

In response to the statement "*The videos made learning more interesting and interactive*", a substantial majority of students expressed positive perceptions (Table 3 – item b). Specifically, 92 students (67.6%) strongly agreed, 39 students (28.7%) agreed, and only 5 students (3.7%) remained neutral. No participants disagreed with the statement, indicating unanimous support for the use of video content in enhancing student engagement. These results suggest that integrating videos into the teaching of bacterial physiology significantly increased students' interest and interaction with the course material. This finding aligns with educational research showing that multimedia elements, particularly videos, can increase motivation and engagement by making learning experiences more dynamic and student-centred (Guo, Kim, & Rubin, 2014). Video content fosters active learning by providing visual context, real-life applications, and step-by-step demonstrations, which help bridge the gap between theoretical concepts and practical understanding (Zhang et al., 2006). Furthermore, interactive video-based learning environments have been associated with improved learner satisfaction and participation, especially in science and health education domains. The overwhelmingly positive student response confirms the pedagogical value of using videos as a tool to promote interactive learning, capture attention, and enhance the overall educational experience in microbiology courses.

Table 3: Experience with YouTube-Embedded Teaching

	Item	Scale					Mean	SD
		1	2	3	4	5		
a)	YouTube videos embedded in lectures helped me visualize bacterial physiology concepts	0	0	5 (3.7%)	45 (33.1%)	86 (63.2%)	**4.60**	**0.56**
b)	The videos made learning more interesting and interactive	0	0	5 (3.7%)	39 (28.7%)	92 (67.6%)	**4.64**	**0.55**
c)	I found it easier to understand practical applications through video demonstrations	0	0	6 (4.4%)	35 (25.7%)	95 (69.9%)	**4.65**	**0.56**
d)	YouTube content enhanced my understanding beyond textbook material	0	2 (1.5%)	5 (3.7%)	39 (28.7%)	90 (66.2%)	**4.60**	**0.63**
e)	I rewatched YouTube videos to revise for quizzes or exams	0	5 (3.7%)	12 (8.8%)	44 (32.4%)	75 (55.1%)	**4.40**	**0.80**
f)	Video explanations were more effective than traditional lectures	0	4 (2.9%)	11 (8.1%)	48 (35.3%)	72 (52.9%)	**4.39**	**0.76**

When asked whether "*I found it easier to understand practical applications through video demonstrations*", a large proportion of students responded favourably (Table 3 – item c). Specifically, 95 students (69.9%) strongly agreed, 35 students (25.7%) agreed, and 6 students (4.4%) were neutral. No students disagreed with the statement, indicating a strong consensus on the usefulness of video demonstrations for learning practical content in bacterial physiology.

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This high level of agreement highlights the pedagogical effectiveness of video-based demonstrations in bridging the gap between theory and practice. In microbiology and other laboratory-intensive disciplines, abstract concepts can often be difficult to translate into real-world applications without direct visual examples. Research has shown that video demonstrations enhance procedural understanding, promote visualization of techniques, and improve students' ability to replicate and apply learned skills (Sadik, 2008). They provide repeated access to complex procedures, allowing students to learn at their own pace and revisit demonstrations as needed, which supports the development of procedural fluency and confidence (Kay, 2012). Furthermore, video demonstrations have been found to increase learner autonomy and reduce cognitive load by breaking down complex tasks into manageable visual steps (Mayer, 2009). In bacterial physiology, where understanding techniques such as Gram staining, metabolic assays, or bacterial growth kinetics is essential, such demonstrations can significantly enhance comprehension and retention.

In response to the statement "*YouTube content enhanced my understanding beyond textbook material*", a strong majority of students agreed (Table 3 – item d). Specifically, 90 students (66.2%) strongly agreed, 39 students (28.7%) agreed, 5 students (3.7%) were neutral, and only 2 students (1.5%) disagreed. These results indicate that most students found YouTube content to be a valuable supplement that extended their comprehension beyond what was provided in traditional textbooks. This aligns with findings in educational research, which emphasize the limitations of static textbook content in conveying complex scientific concepts, especially in visually rich fields such as microbiology and bacterial physiology. YouTube videos often present dynamic, visual, and context-rich explanations that cater to diverse learning styles and allow for self-paced review, making them particularly effective in supporting deeper learning (Burke & Snyder, 2008). Videos can contextualize textbook information with real-life examples, animations, laboratory demonstrations, and expert commentary, thereby reinforcing understanding and promoting application of knowledge (Kay, 2012). Moreover, the use of YouTube in higher education has been associated with increased learner satisfaction, improved academic performance, and a higher level of engagement compared to text-only learning resources (Tan & Pearce, 2012). The fact that only a small minority disagreed suggests broad acceptance and appreciation of YouTube as an educational tool that complements and enhances traditional resources.

In response to the statement "*I rewatched YouTube videos to revise for quizzes or exams*", the majority of students acknowledged using YouTube as a revision tool (Table 3 – item e). Specifically, 75 students (55.1%) strongly agreed, 44 students (32.4%) agreed, 12 students (8.8%) were neutral, and 5 students (3.7%) disagreed. This suggests that over 87% of students relied on rewatching video content as part of their exam or quiz preparation strategy. This finding supports existing literature that emphasizes the value of video-based learning for review and reinforcement of academic material. YouTube videos, which are typically short, accessible, and repeatable, offer a flexible and student-centered resource that allows learners to revisit complex concepts at their own pace (Kay, 2012). This is particularly useful in content-heavy courses, such as bacterial physiology, where visual explanations of cellular processes, metabolic pathways, or laboratory techniques can be difficult to absorb in a single viewing. Rewatching videos also aligns with the principles of spaced repetition and retrieval practice, which are proven to enhance long-term memory and exam performance (Roediger & Butler, 2011). The ability to pause, rewind, and rewatch fosters self-regulated learning and reduces cognitive overload, particularly when students are preparing for assessments (Mayer, 2009).

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The relatively low percentage of disagreement further affirms the broad utility of YouTube as a revision tool among microbiology students.

In response to the statement "*Video explanations were more effective than traditional lectures*", a notable majority of students expressed a positive view (Table 3 – item f). Specifically, 72 students (52.9%) strongly agreed, 48 students (35.3%) agreed, 11 students (8.1%) were neutral, and only 4 students (2.9%) disagreed. These results indicate that approximately 88% of students perceived video-based instruction as more effective than conventional face-to-face lectures in helping them understand the content. This strong preference for video explanations is consistent with current educational research highlighting the benefits of multimedia learning. Videos combine visual, auditory, and textual information, making them especially useful in communicating complex scientific content, such as that found in bacterial physiology. According to Mayer's Cognitive Theory of Multimedia Learning (2009), when properly designed, multimedia formats reduce cognitive load and promote deeper understanding by engaging both verbal and visual processing channels. Moreover, videos offer students flexibility and control over their learning pace. They can pause, rewind, and review explanations, which supports individualized learning and improves information retention (Guo, Kim, & Rubin, 2014). Compared to traditional lectures, which are typically linear and time-bound, videos allow for self-directed and repeated exposure to challenging concepts, qualities that students often value, particularly when revisiting material for exams or assignments. While traditional lectures offer opportunities for real-time interaction, the overwhelming agreement in this study suggests that many students find the structured, visual, and repeatable nature of video content more conducive to learning, especially in complex subjects like microbiology.

Section D: Combined Impact on Learning and Performance

Table 4 shows the responses of respondents regarding the combined impact of gamification and YouTube on learning and student performance. In response to the statement "*The combination of gamification and YouTube videos increased my interest in bacterial physiology*", the majority of students reported a positive experience (Table 4 – item a). Specifically, 91 students (66.9%) strongly agreed, 39 students (28.7%) agreed, 5 students (3.7%) were neutral, and only 1 student (0.7%) disagreed. This overwhelming consensus suggests that integrating gamified elements with YouTube-based content significantly enhances student interest in learning bacterial physiology. This finding aligns with educational literature emphasizing the motivational impact of combining multimedia learning and gamification. Gamification through mechanisms such as quizzes, badges, point systems, and interactive challenges has been shown to improve learner engagement, participation, and enjoyment in scientific subjects (Subhash & Cudney, 2018). When paired with YouTube videos, which provide dynamic visual explanations and real-world context, students are more likely to remain interested and invested in the content (Kay, 2012). The synergistic use of both strategies supports multiple learning modalities and fosters a more interactive and stimulating learning environment. According to Deci and Ryan's Self-Determination Theory (2000), learners are more motivated when instructional design meets their needs for autonomy, competence, and relatedness goals, which are well-served through gamified, video-enhanced instruction. In microbiology education, where topics like bacterial metabolism or cellular mechanisms can be difficult to visualize and comprehend, this approach provides both clarity and engagement. The nearly unanimous positive response in this study reinforces the pedagogical value of integrating gamification and YouTube content to improve student interest and learning outcomes in complex scientific disciplines.

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In response to the statement "*My academic performance improved due to these teaching methods*", as shown in Table 4 – item b, a strong majority of students affirmed the positive impact of the combined teaching approaches. Specifically, 75 students (55.1%) strongly agreed, 51 students (37.5%) agreed, 7 students (5.1%) were neutral, and only 3 students (2.2%) disagreed. Altogether, over 92% of respondents indicated that the use of gamification and YouTube-embedded instruction contributed to their improved academic performance in the bacterial physiology course. These findings are supported by existing literature that highlights the role of innovative teaching methods—particularly those incorporating multimedia and gamification—in enhancing student learning outcomes. According to Mayer's (2009) Cognitive Theory of Multimedia Learning, students learn more effectively when instructional materials engage both visual and auditory channels, promoting better information retention and deeper conceptual understanding. Similarly, gamification has been shown to increase motivation and focus, both of which are closely linked to academic success (Domínguez et al., 2013). Research also indicates that students are more likely to perform better when they are actively engaged in their learning process through interactive and varied instructional methods (Freeman et al., 2014). In the context of microbiology education, where content is often complex and abstract, video demonstrations and gamified assessments offer concrete, repeated exposure to critical concepts, leading to better performance in quizzes, assignments, and exams. The data from this study, therefore, provide strong evidence that combining gamification and YouTube videos in the classroom positively influences academic achievement, validating the effectiveness of these student-centred teaching strategies.

Table 4: Combined Impact on Learning and Performance

	Item	Scale					Mean	SD
		1	2	3	4	5		
a)	The combination of gamification and YouTube videos increased my interest in bacterial physiology	0	1 (0.7%)	5 (3.7%)	39 (28.7%)	91 (66.9%)	**4.62**	**0.59**
b)	My academic performance improved due to these teaching methods	0	3 (2.2%)	7 (5.1%)	51 (37.5%)	75 (55.1%)	**4.46**	**0.70**
c)	These approaches (a combination of YouTube and gamification) helped reduce my anxiety during lessons or exams	0	2 (1.5%)	12 (8.8%)	50 (36.8%)	70 (51.5%)	**4.40**	**0.71**
d)	I would prefer future courses to include gamification and video content	0	1 (0.7%)	7 (5.1%)	44 (32.4%)	84 (61.8%)	**4.55**	**0.63**
e)	I rewatched YouTube videos to revise for quizzes or exams	0	5 (3.7%)	12 (8.8%)	44 (32.4%)	75 (55.1%)	**4.39**	**0.8**
f)	I recommend these methods (combining YouTube and gamification) to be applied across other science subjects	0	1 (0.7%)	3 (2.2%)	45 (33.1%)	87 (63.9%)	**4.60**	**0.57**

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In response to the statement "These approaches (a combination of YouTube and gamification) helped reduce my anxiety during lessons or exams" (Table 4 – item c), a clear majority of students reported a positive impact. Specifically, 70 students (51.5%) strongly agreed, 50 students (36.8%) agreed, 12 students (8.8%) were neutral, and only 2 students (1.5%) disagreed. Overall, 88.3% of students felt that integrating YouTube videos and gamified elements helped alleviate stress associated with learning and assessments in the bacterial physiology course. This result is consistent with educational research demonstrating that student-centred, technology-enhanced teaching strategies can contribute to reduced academic anxiety. YouTube videos, by allowing repeated access to content at a self-regulated pace, reduce performance pressure and promote mastery learning, which are both known to decrease anxiety levels (Kay, 2012; Mayer, 2009). Students who can revisit complex concepts multiple times feel more prepared and confident, especially in high-stakes assessment environments. Gamification also plays a critical role in lowering anxiety by transforming the learning environment into a more engaging, low-stress experience. According to Dichev and Dicheva (2017), gamified activities such as quizzes, badges, and interactive challenges increase motivation and participation while reducing fear of failure. These elements promote a sense of achievement and control, which has been linked to improved emotional well-being and reduced test-related anxiety. Together, these findings suggest that the combined use of YouTube-based content and gamification not only enhances academic engagement but also creates a psychologically supportive learning environment that reduces anxiety during lessons and examinations.

In response to the statement "I would prefer future courses to include gamification and video content" (Table 4 – item d), an overwhelming majority of students expressed a positive preference. Specifically, 84 students (61.8%) strongly agreed, 44 students (32.4%) agreed, 7 students (5.1%) were neutral, and only 1 student (0.7%) disagreed. In total, 94.2% of students supported the inclusion of gamification and video content in future learning experiences. This strong endorsement highlights a clear student demand for more interactive, multimedia-based teaching strategies. Research consistently shows that combining gamification and video resources enhances learner engagement, motivation, and satisfaction are factors that contribute to more effective learning environments (Subhash & Cudney, 2018; Kay, 2012). Gamification promotes active participation and motivation by incorporating game-like elements such as rewards, points, and challenges, which transform traditional learning into an enjoyable and goal-driven process (Deterding et al., 2011). Likewise, video content, especially when integrated into lesson delivery, has been shown to improve comprehension and retention by making complex topics more accessible and easier to visualize (Mayer, 2009). In science and health education, where abstract concepts can be difficult to grasp through text alone, videos provide concrete visual explanations that support deeper understanding. The overwhelmingly favourable response suggests that students not only benefit from these strategies academically and emotionally but also view them as essential components of effective and modern teaching. Incorporating such methods into future courses can help meet student expectations and foster more engaging and personalized learning experiences.

In response to the statement "I recommend these methods (combining YouTube and gamification) to be applied across other science subjects", the vast majority of students expressed strong support (Table 4 – item e). A total of 87 students (63.9%) strongly agreed, 45 students (33.1%) agreed, 3 students (2.2%) were neutral, and only 1 student (0.7%) disagreed. This shows that 97% of respondents recommend expanding these methods beyond bacterial

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physiology to other areas of science education. This finding underscores the perceived effectiveness and transferability of combining gamification and YouTube-based instruction across various scientific disciplines. Educational research supports the cross-disciplinary value of these approaches. Gamification has been shown to enhance motivation, engagement, and problem-solving skills in a variety of STEM fields by making learning more interactive and rewarding (Subhash & Cudney, 2018). At the same time, YouTube videos provide visual, real-world context and foster deeper understanding by allowing students to repeatedly access and internalize complex information (Kay, 2012; Mayer, 2009). Students' recommendations for broader implementation are consistent with the concept of universal design for learning (UDL), which promotes flexible teaching methods to accommodate diverse learning preferences and increase accessibility (CAST, 2018). These strategies are especially beneficial in science subjects that require visualization of processes, experimentation, and conceptual integration, areas where traditional lectures may fall short. The strong consensus in favour of wider adoption indicates that students view these methods not just as effective for bacterial physiology but as broadly applicable tools for improving learning outcomes across science education.

Section E: Open-Ended Questions

In response to the question "What challenges did you face when using these methods?", A thematic analysis of students' responses highlights several recurring challenges experienced during the implementation of gamified learning and YouTube-assisted teaching. These challenges are Internet connectivity issues, time pressure and fast-paced activities, content relevance and language barriers, and instructional and technical limitations. The most prominent and frequently cited issue was unstable or poor internet connection, mentioned in various forms (e.g., lag, disconnection, slow streaming, or complete inaccessibility). This challenge significantly disrupted the learning flow, particularly during live gamified sessions or while streaming YouTube videos. Students reported missing parts of lessons, difficulty joining quizzes, and unsaved progress due to intermittent connectivity. Poor internet infrastructure has been identified as a major barrier to online learning, especially in developing contexts (Adedoyin & Soykan, 2020). Reliable connectivity is crucial for the smooth delivery of multimedia-rich content and real-time interactive tools such as gamification platforms. A substantial number of students expressed difficulty coping with time-constrained gamified quizzes. They reported feeling anxious, rushed, and unable to process questions properly, especially when faced with countdown timers or fast-paced question delivery. While gamification enhances engagement, it can also induce performance anxiety and cognitive overload when activities are overly competitive or time-sensitive (Koivisto & Hamari, 2019). Students also noted that using smartphones or digital tools sometimes led to distractions from social media notifications or multitasking. Additionally, maintaining focus during lengthy or monotonous YouTube videos, or when the content lacked animations and visuals, was challenging for several learners. Digital distractions are a well-documented downside of mobile-based and self-directed learning environments (Chen et al., 2020). The passive nature of some video content also contributes to reduced attention spans. There were reports of discouragement among students who received low scores in gamified quizzes despite understanding the content. Peer competition sometimes exacerbated these feelings, leading to reduced motivation. A few also expressed hesitance in participating due to fear of failure or embarrassment. Although gamification aims to boost motivation, it can inadvertently create stress or reduce self-efficacy in certain learners if not properly scaffolded (Dichev & Dicheva, 2017). Some students struggled to find relevant or localized YouTube content, noting that

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videos often came from different educational systems or were narrated with unfamiliar accents. This created difficulty in comprehension and alignment with the syllabus. Content appropriateness and linguistic accessibility are vital to effective video-based learning. Learners may disengage if the instructional material lacks clarity or cultural alignment (Kay, 2012). Students mentioned unclear quiz instructions, a lack of subtitles in videos, or a mismatch between quiz content and the lecture scope. These technical and pedagogical mismatches further contributed to learning barriers. While gamification and YouTube-assisted teaching methods hold significant potential to enhance student engagement and understanding, these benefits are often undermined by infrastructural, cognitive, and emotional barriers. Addressing internet reliability, refining quiz pacing, ensuring content relevance, and supporting learner confidence are crucial to optimize the effectiveness of these methods.

Student feedback revealed a broad range of constructive suggestions for enhancing the effectiveness of gamification and YouTube-assisted learning. A primary theme was the importance of interactivity and engagement, with many recommending the use of shorter, visually rich videos that incorporate animations, simple language, and subtitles to accommodate diverse learning styles and maintain focus. According to Ibrahim and Callaway (2014), videos that are short and visually engaging significantly enhance learners' comprehension and retention, especially when they align with students' cognitive capacities. Several students emphasized that gamified activities should be more varied, incorporating tools beyond Quizizz, such as Kahoot, Wordwall, or simulation games, to cater to different learning preferences. Gamification elements like leaderboards, prizes, or points-based incentives were seen as motivating, but students also requested explanations for quiz answers to reinforce learning. These strategies align with the findings of Deterding et al. (2011), who argue that meaningful feedback and appropriate game mechanics are critical for successful educational gamification. A significant number of students suggested integrating quizzes directly into videos using tools like EdPuzzle or H5P, allowing learners to engage actively while watching. This approach encourages active learning, a practice supported by Mayer (2005), who found that multimedia instruction is most effective when learners are required to process information deeply through interactivity. Other notable suggestions include allowing repeated quiz attempts to support mastery-based learning, combining video and gamification in a sequence—e.g., watch a video then complete a related game or quiz, personalizing content based on student learning styles, making content relatable to real-life situations and curriculum needs and ensuring clear instructions for all activities and reducing cognitive overload by focusing each video on one key topic. A few students mentioned the need for improved internet access, especially in institutions like UiTM, to ensure uninterrupted engagement, and this concern is supported by Khalid et al. (2021), who highlight infrastructure as a key determinant of success in online and blended learning environments. Hence, students appreciate gamification and video integration in teaching but call for more diverse tools, interactive features, and content that is concise, visually engaging, and accessible. These improvements are likely to enhance learning outcomes, motivation, and long-term retention.

Student responses revealed that visualization, interactivity, and motivation through competition were the most valued aspects of gamification and YouTube-assisted teaching. A dominant theme was the benefit of visual representation, particularly through YouTube. Students found animations, illustrations, and diagrams highly effective in understanding complex biological mechanisms and abstract processes. Visual content, especially when paired with audio narration, helped in improving concept retention and recall. Research supports this,

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as Mayer's (2009) Cognitive Theory of Multimedia Learning emphasizes that people learn better from words and pictures together than from words alone. The dual coding of visual and auditory input enhances comprehension, especially in science education (Fiorella & Mayer, 2015). Gamification elements such as quizzes, puzzles, Kahoot, and Quizizz were praised for making learning more engaging and enjoyable. Students appreciated the shift from passive to active learning, where they could test their knowledge, receive immediate feedback, and track their progress. According to Domínguez et al. (2013), gamified learning environments increase student engagement and improve knowledge retention, especially when game elements like points, challenges, and leaderboards are implemented. Several students noted that competition for top scores or weekly achievements inspired them to study earlier and revise more often. Reward systems in games provided both extrinsic and intrinsic motivation, especially for those who were driven by goal setting and progress tracking. This is aligned with the Self-Determination Theory (Deci & Ryan, 2000), which states that reward-based systems can boost motivation when they support autonomy and competence. YouTube's pause-rewind-playback functionality allowed learners to control their pace, rewatch difficult sections, and reinforce understanding through repetition. This was particularly beneficial for learners who needed extra time to grasp new or dense material. As Kay (2012) found in his meta-analysis, educational videos are effective because they cater to individual learning speeds and styles, allowing students to review materials as needed. Gamification helped students memorize facts and terminology, especially when quizzes were aligned with specific learning objectives or class topics. The trial-and-error nature of quiz games also helped students learn from mistakes, a method often linked to deeper cognitive processing. Studies by Plass et al. (2015) suggest that game-based learning environments enhance memory by increasing cognitive engagement and promoting immediate feedback loops. Both gamification and YouTube-assisted teaching play complementary roles in enhancing student learning. The visual nature of YouTube videos aids comprehension and retention, while the interactive and competitive elements of gamification promote engagement and active learning. When integrated effectively, these strategies support diverse learning preferences and can significantly improve academic performance in science-based subjects.

Conclusion

The collective responses affirm the strong positive impact of gamification on students' learning experiences in the bacterial physiology course. With consistently high percentages of agreement across all statements, ranging from increased engagement, improved understanding, greater motivation, and enhanced retention to better class participation and peer collaboration, students overwhelmingly endorsed the use of gamified teaching strategies. Importantly, the positive student responses suggest that gamification transcends mere novelty and functions as a strategic instructional tool capable of transforming traditional science education into an interactive, student-centred experience. This is especially valuable in content-heavy subjects like bacterial physiology, where student engagement and conceptual mastery are often hindered by the complexity of the material. The finding also underscores a clear preference for multimedia-rich instruction, with YouTube videos emerging as a powerful pedagogical tool that supports comprehension, fosters engagement, and facilitates academic success. These outcomes are well-supported by existing literature and advocate for the intentional integration of video content across science curricula to meet the diverse needs and expectations of 21st-century learners. The results strongly validate the pedagogical value of combining gamification and YouTube-enhanced content in bacterial physiology education. This hybrid approach not only improves cognitive and academic outcomes but also supports students emotionally and

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motivationally. Given their proven effectiveness and scalability, these strategies should be considered essential components of modern science education and thoughtfully integrated into broader curricular design. The open-ended feedback confirms that while gamification and YouTube integration offer substantial pedagogical value, their success depends on careful design, equitable access, and responsiveness to student diversity. Tailoring content to learners' needs, enhancing interactivity, and reducing technical or cognitive friction will maximize the impact of these tools. When thoughtfully implemented, these approaches not only enhance comprehension and retention but also promote enjoyment, autonomy, and long-term academic growth in science education.

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