

## Revolutionary Health Education: The Impact of GERMiE on Student Knowledge and Attitudes

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**Abstract:** Antibiotics, which were developed in the early 20th century, are extensively used to cure infections in both humans and animals. However, new antibiotic development has stopped, resulting in an alarming surge in antimicrobial resistance (AMR). This study investigates the effectiveness of the GERMiE (Germs Eradication Mission for Education) application in improving knowledge and attitudes about personal hygiene, specifically infection prevention and antibiotic use. A quantitative research methodology using a survey was implemented in this study, employing a one-group pretest-posttest design. This study involved 44 students from pre-university colleges in northern Malaysia. Data were analyzed descriptively (mean and frequency) and inferentially using paired samples t-tests. The results indicated significant improvements in both knowledge and attitudes towards personal hygiene care post-intervention. Specifically, the paired samples t-test revealed a significant increase in mean scores for knowledge ( $t=-2.34$ ,  $p=.02$ ) and attitudes ( $t=-2.03$ ,  $p=.04$ ). These findings suggest that the GERMiE application effectively engages students and enhances learning outcomes. Future research should investigate the long-term impacts and the influence of different game mechanics on learning and behavior change, contributing to the Sustainable Development Goals related to health and well-being.

**Keywords:** Antimicrobial Resistance, Antibiotics, GERMiE, Game-Based Learning, Healthcare

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## INTRODUCTION

The advent of antibiotics in the early 20th century has revolutionized medicine, rescuing innumerable lives. Antibiotics are frequently used to treat infections in both humans and animals and have also been widely utilized as growth promoters in livestock (Almeida Santimano & Foxcroft, 2017). However, the development of new antibiotics has halted, leading to an alarming increase in antimicrobial resistance (AMR) (Jian et al, 2021; Muteeb et al., 2023). AMR occurs when bacteria, viruses, fungi, and parasites become resistant to antibiotics that were previously effective in eradicating them (Morrison & Zembower, 2020; Medernach & Logan, 2017). According to Tarín-Pelló et al. (2022), this growing resistance makes treating common infections increasingly challenging, resulting in prolonged hospitalizations and escalating healthcare costs. Addressing this issue is crucial for achieving the Sustainable Development Goals (SDGs), particularly those related to health and well-being (United Nations General Assembly [UNGA], 2015).

Educational initiatives are crucial in this battle. However, the curriculum lacks a strong focus on hygiene education, particularly regarding the use of antibiotics and the growing issue of antibiotic resistance. Although students learn general concepts like human anatomy, physiology, and disease prevention, practical lessons on personal hygiene and its critical role in controlling infections are limited. The curriculum rarely emphasizes how poor hygiene practices contribute to the spread of infections, which often leads to the misuse of antibiotics. By teaching young generation about infection prevention and the responsible use of antibiotics, it helps to build a foundation of knowledge and awareness that can lead to more informed and responsible behaviors. This early education is essential in promoting both knowledge and attitudes towards preventing the spread of microbes especially bacteria (Medernach & Logan, 2017). The growth of technology has dramatically revolutionized education, providing new and inventive approaches to improve learning experiences (Rafiza Rosli & Nor Asniza Ishak, 2024; Xu et al., 2023). One such innovation is game-based learning (GBL), which combines educational content with engaging game mechanics (Al-Azawi et al., 2016; Saidatul Ainoor Shaharim et al., 2022).

## **BACKGROUND TO THE STUDY**

### **The Concept of Game-Based Learning (GBL)**

Game-based learning (GBL), often known as "serious games," "educational games," or "gamification" (Anastasiadis et al., 2018; Xu et al., 2023). Deterding et al. (2011) defined the GBL as the game design features to non-game settings. Additionally, GBL entails acquiring knowledge through active gameplay (Whitton, 2012), which encompasses competition and engagement (Nor Asniza Ishak et al., 2021). This approach takes advantage of the widespread use of mobile devices or laptops, allowing students to learn anytime and anywhere, thus extending learning beyond the traditional classroom (Alaklubi & Zaharudin, 2023; Situmorang et al., 2024; Hartt et al., 2020).

Studies have shown that GBL can be highly effective in various educational settings (Xu et al., 2023). For example, Qian and Clark (2016) found that game-based learning can improve essential cognitive skills like problem-solving, critical thinking, and decision-making. Games often simulate real-life scenarios, allowing learners to practice decision-making and develop healthy behaviors in a safe environment (Mayr et al., 2017). These skills are vital in today's fast-paced world, where individuals must quickly process information and make informed decisions. Additionally, GBL can make learning more enjoyable and motivating (Hartt et al., 2020), which can lead to increased student engagement and better educational outcomes (Anastasiadis et al., 2018; D'Mello & Graesser, 2012; Connolly et al., 2012).

In healthcare education, game-based learning has shown promise in enhancing knowledge and shaping attitudes toward health practices. For instance, Cicchino (2015) found that a mobile game designed for diabetic patients significantly improved their knowledge and self-management behaviors. Mobile games in health education can create interactive and experiential learning opportunities, making complex health concepts more accessible and relatable (Spires, 2015). Research has demonstrated that GBL can boost self-efficacy in managing health conditions (Aster et al., 2024; DeSmet et al., 2014). This hands-on learning can lead to a deeper understanding of the consequences of health-related decisions and encourage a proactive approach to health maintenance (Bengtsson et al., 2020). Additionally, the social aspect of games can promote collaboration and knowledge sharing among learners, reinforcing positive health attitudes through peer influence (Van't Riet et al., 2018).

The potential of GBL in education is particularly relevant for promoting personal hygiene practices among students (Tubelo et al, 2019). Good hygiene is crucial for preventing the spread of infectious diseases and maintaining overall health. However, traditional methods of teaching hygiene may not always be effective in instilling lasting habits, especially among young adults (Singh et al., 2023). The GBL, with their engaging and interactive formats, can be powerful tools for educating individuals about the importance of personal hygiene and encouraging consistent hygienic behaviors (Shegog et al., 2015).

By incorporating GBL into education, particularly in healthcare, presents a valuable opportunity to enhance knowledge (Tubelo et al, 2019) and attitudes towards health practices (Katonai et al., 2023). The engaging nature of games can make learning more enjoyable and effective, leading to better educational outcomes. As technology continues to evolve, the potential for GBL to transform education and promote health awareness will likely expand, offering innovative solutions to the challenges of traditional educational methods.

### **GERMiE's Role in Infection Prevention and Antibiotic Use**

With the advancements in GBL today, we developed GERMiE to improve students' knowledge and attitudes towards health practices, particularly regarding hygiene and antibiotics resistance. GERMiE (Germs Eradication Mission for Education) is an innovative interactive game application designed to educate the younger generation about infection prevention and the responsible use of antibiotics in a fun and engaging manner. GERMiE blends fun interactive gameplay with educational content, creating an engaging learning experience. It fosters an engaging learning experience, making it easier for young generation to absorb valuable information.

The game is available on both Windows PC and Android-based phones. As an educational adventure game with role-playing game (RPG) elements, GERMiE provides an immersive learning experience through its well-structured gameplay including interactive storytelling, visual feedback and element of quiz.

The game is composed of eight distinct levels and missions as shown in Table 1.

Table 1. Game Missions in GERMiE

<b>Mission</b>	<b>Title</b>
1	Good food for healthy and strong body
2	Clean water source reduces the risk of waterborne infectious diseases
3	Safe water supply system provides clean drinking water
4	Clean public toilet to prevent the spread of infectious diseases
5	Consult your doctor if you are sick
6	Communication system for news and updates regarding antibiotics & health issues
7	Share your knowledge on rational use of antibiotics
8	Live a healthy lifestyle

Each mission focusing on various critical aspects of health education. These aspects include the collection of nutritious food, the maintenance of proper hygiene, and participation in activities that promote a healthy community. Figure 1 shows the example of GERMiE's interface.



Figure 1. The Example of GERMiE's Interface

By engaging with these activities, students are not only entertained but also educated on important health practices. Each mission within GERMiE is designed to incrementally build the students' understanding and skills in infection prevention. For instance, students might be tasked with collecting and identifying nutritious food items, which helps them learn about balanced diets and the role of nutrition in health. Other missions may involve scenarios that require students to practice good hygiene, such as washing hands correctly or cleaning living spaces, which reinforces the importance of cleanliness in preventing infections.

Additionally, GERMiE emphasizes the responsible use of antibiotics. Through gameplay, students encounter various situations that demonstrate the consequences of antibiotic misuse, such as the development of antibiotic resistance. By navigating these challenges, students gain valuable insights into when and how antibiotics should be used responsibly. Overall, GERMiE effectively combines educational content with engaging gameplay to deliver a comprehensive learning experience. By completing the game's missions, students not only enhance their digital literacy and critical thinking skills but also acquire essential knowledge on maintaining personal and community health. Figure 2 shows the intervention setting through GERMiE.



Figure 2. The Intervention Setting Through GErMiE

### Statement of the Problem

The ongoing evolution of antibiotic resistance in bacteria continues to pose an escalating threat to all populations, including the youth (William et al., 2018). Many of them lack essential knowledge about basic infection prevention practices, such as proper handwashing, maintaining personal hygiene, and understanding the importance of vaccinations. This gap in knowledge can lead to higher rates of preventable diseases and infections among the youth. Traditional school curricula often do not place enough emphasis on practical health education, resulting in students not receiving comprehensive information about maintaining health and preventing diseases (Jasim Alsadaji et al., 2022; Rajbhandari et al., 2018). Additionally, many students lack of health literacy, which includes the ability to understand and effectively use health information, resulting in poor health decisions and increased susceptibility to infections (Singh et al., 2023), which raises disease risk (Han et al., 2020).

Furthermore, there is widespread misunderstanding about the appropriate use of antibiotics, including overuse and improper use, contributing significantly to the growing problem of antibiotic resistance, making common infections harder to treat (Demoré et al., 2017; Santimano & Foxcroft, 2017). This lack of awareness is compounded by disparities in health knowledge among different socioeconomic and geographic groups, with students from underserved communities having less access to health education resources, leading to poorer health outcomes and increased vulnerability to infections (Hsiao et al., 2006; Verweij, 2019).

The attitudes of students towards health and hygiene practices significantly influence their behavior and health outcomes. There is often a lack of engagement and interest in conventional health education methods, leading to a disinterest in adopting healthy practices (Yu et al., 2014). Many students do not see the immediate benefits of maintaining hygiene or the long-term consequences of antibiotic misuse, resulting in complacency towards these important issues (Oh et al., 2018).

Moreover, parental attitudes and involvement in health education play a crucial role in shaping students' behaviors. However, many parents may not prioritize or have sufficient knowledge to instill positive health attitudes in their children, further contributing to a lack of emphasis on preventive health measures at home (Agustina et al., 2013; Rouusunides et al., 2011). This situation is exacerbated by a general underestimation of the severity of antibiotic resistance and its impact on health, leading to irresponsible behaviors such as self-medication and non-compliance with prescribed treatments (Panagakou et al., 2011). Dealing with these attitudinal barriers is critical for encouraging students to take a proactive approach to health and hygiene,

ensuring they adopt and maintain healthy habits throughout their lives. By addressing these issues, GErMiE hopes to improve students' knowledge and attitudes toward health practices, particularly regarding hygiene and antibiotics resistance, promoting healthier behaviors and contributing to the well-being of the next generation.

### Objective of Research

The primary objectives of this study are as follows: (1) to determine the effectiveness of GErMiE in enhancing students' knowledge of health practices, and (2) to determine the effectiveness of GErMiE in enhancing students' attitudes towards health practices. The research problem has led to the following research questions:

1. Is there a significant change in mean scores of students' knowledge of health practices after using GErMiE?
2. Is there a significant change in mean scores of students' attitude of health practices after using GErMiE?

### Research Hypothesis

To explore this research questions above, the following hypothesis was tested:

H<sub>01</sub>: There is no significant change in the mean scores of students' knowledge of health practices after using GErMiE.

H<sub>02</sub>: There is no significant change in the mean scores of students' attitudes towards health practices after using GErMiE.

## METHODOLOGY OF RESEARCH

The study adopted a quantitative research approach using a survey, employing a one-group pretest-posttest experimental research design. According to Creswell and Creswell (2018), this design consists of a pretest measure followed by a treatment and a posttest for a single group. In this study, the research design included administering a pretest, followed the intervention using the GErMiE, and then a posttest as shown in Figure 3.

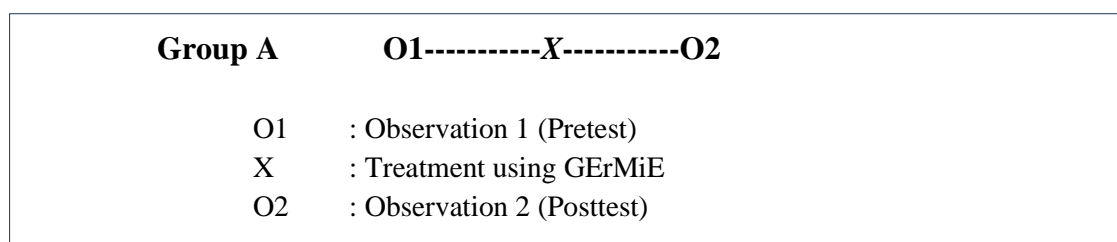


Figure 3. One group pretest-posttest design

The samples of the study were 44 students from pre-university colleges in northern Malaysia. The students answered the pretest in week 1, followed by an 8-week intervention using GErMiE, and then took the posttest in week 10. This duration is suitable to determine the effectiveness of GErMiE (Creswell & Creswell). The teaching and learning process using GErMiE was carried out by the facilitator during tutorial class.

A structured questionnaire served as the primary instrument. This questionnaire consists of three sections, namely Section A: Demographic Information, (ii) Section B: Students' Knowledge Towards Personal Hygiene Care, and (iii) Section C: Students' Attitudes Towards Personal Hygiene Care. For Section B and C, both sections comprising of 10 items. Responses were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly

agree). Data collection involved distributing the questionnaires to participants and allowing ample time for completion.

The collected data were analyzed using descriptive statistics, including mean and frequency. Meanwhile, inferential statistics was analysed using paired samples t-test. Paired samples t-test is used when to compare the mean scores for the same group of participants on posttest and pretest results (Pallant, 2020). The paired samples t-test is suitable for this study because it directly evaluates the impact of the GERMiE intervention on the same group of students by comparing their knowledge and attitudes towards healthcare before and after the intervention. Both descriptive and inferential data were analyzed using SPSS 28.0.

## FINDINGS AND DISCUSSION

### Findings

#### Demographic Findings

Figure 4 shows a bar chart displaying the percentage of gender information respondents involved. Out of 44 respondents, 18 respondents (41%) were male students and 26 respondents (59%) were female students.

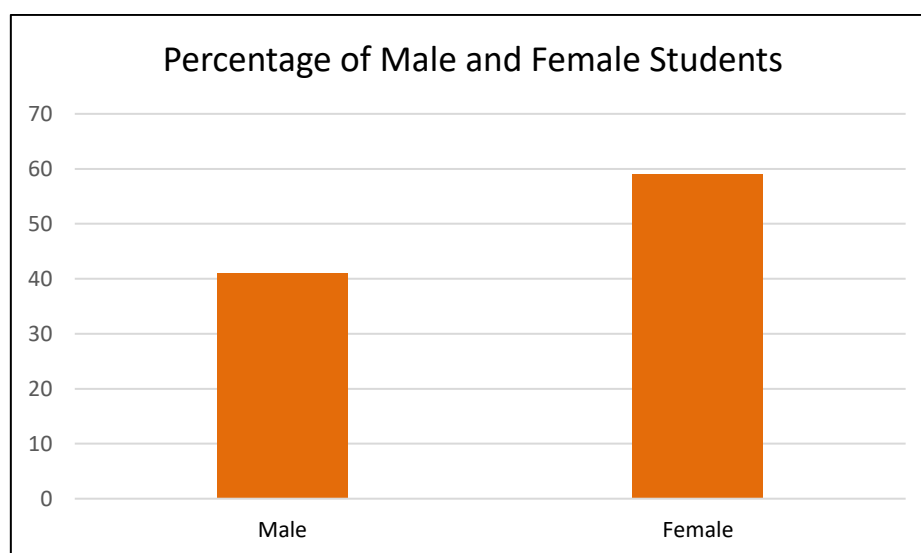


Figure 4. Percentage of Male and Female Students

Meanwhile, Figure 5 shows a bar chart displaying percentage information on the module of respondents participated. Of the 44 respondents, 23 (52%) were Module 1 students, taking Biology, Chemistry, Physics, and Mathematics, and the remaining 21 (47%) were Module III students, taking Biology, Chemistry, Computer Science, and Mathematics subjects.

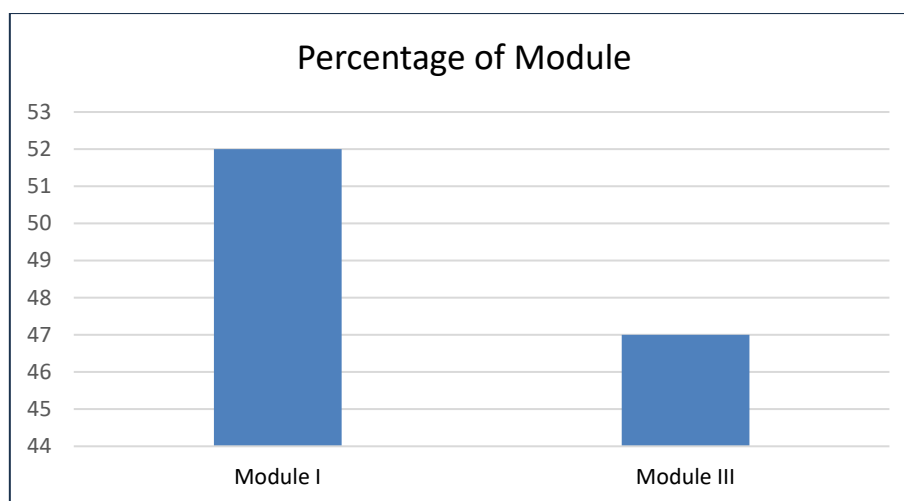


Figure 5. Percentage of Module

### The Effectiveness of GErMiE in Enhancing Students' Knowledge of Health Practices

Table 2 shows the descriptive statistics of the effectiveness of GErMiE in enhancing students' knowledge of health practices.

Table 2. Descriptive Statistics (Knowledge)

	Pretest	Posttest
N	44	44
Minimum	3.40	4.00
Maximum	5.00	5.00
Mean	4.60	4.78
Standard Deviation	0.40	0.31

Based on Table 2, the descriptive statistics indicate an increase in the mean scores from the pretest ( $M=4.60$ ,  $SD=.40$ ) to the posttest ( $M=4.78$ ,  $SD=.31$ ), suggesting an improvement in participants' knowledge of health practices after using the GErMiE application.

The null hypothesis constructed to answer this research question was there is no significant change in the mean scores of students' knowledge of health practices after using GErMiE. A paired-samples t-test was conducted to compare the pretest and posttest scores for students' knowledge of health practices. Table 3 shows the results from paired-samples t-test.

Table 3. Results From Paired-Samples T-Test (Knowledge)

		Paired Differences					t	df	Sig. (2 tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
Pair 1	Pre-Post				Lower	Upper			
		-.18	.52	.07	-.34	-.03	-2.34	43	.02

According to Table 3, a paired-samples t-test was conducted to evaluate the effectiveness of GErMiE in enhancing students' knowledge of health practices. There was a statistically significant increase in knowledge scores from pretest ( $M=4.60$ ,  $SD=.40$ ) to posttest ( $M=4.78$ ,  $SD=.31$ ),  $t(43) = -2.34$ ,  $p .02$  (two-tailed). The mean increase in knowledge scores was 0.18,



with a 95% confidence interval ranging from  $-.34$  to  $-.03$ . The eta squared statistic (.50) indicated a large effect size (Cohen, 1988). This suggests that the GERMiE intervention explains 60% of the variation in students' knowledge.

From the results of Table 3, it can be seen that the p value is less than .05 ( $p < .05$ ), hence the null hypothesis is rejected ( $t = -2.34$ ;  $p = .02$ ) which is there is a significant change in the mean scores of students' knowledge of health practices after using GERMiE. As a conclusion, GERMiE is effective in increasing students' knowledge of health practices.

### The Effectiveness of GERMiE in Enhancing Students' Attitudes Towards Health Practices

Table 4 shows the descriptive statistics of the effectiveness of GERMiE in enhancing students' attitude of health practices.

Table 4. Descriptive Statistics (Attitude)

	Pretest	Posttest
N	44	44
Minimum	3.60	3.90
Maximum	5.00	5.00
Mean	4.61	4.79
Standard Deviation	.44	.30

Based on Table 4, the descriptive statistics indicate an increase in the mean scores from the pretest ( $M = 4.61$ ,  $SD = .44$ ) to the posttest ( $M = 4.79$ ,  $SD = .30$ ), suggesting an improvement in participants' attitude of health practices after using the GERMiE application.

The null hypothesis constructed to answer this research question was there is no significant change in the mean scores of students' attitudes towards health practices after using GERMiE. A paired-samples t-test was conducted to compare the pretest and posttest scores for students' attitude of health practices. Table 5 shows the results from paired-samples t-test.

Table 5. Results from paired-samples t-test (Attitude)

		Paired Differences					t	df	Sig. (2 tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
Pair	Pre-Post				Lower	Upper			
Pair 1	Pre-Post	-.17	.57	.09	-.34	-.00	-2.03	43	.04

According to Table 5, a paired-samples t-test was conducted to evaluate the effectiveness of GERMiE in enhancing students' attitude of health practices. There was a statistically significant increase in attitude scores from pretest ( $M = 4.61$ ,  $SD = .44$ ) to posttest ( $M = 4.79$ ,  $SD = .30$ ),  $t(43) = -2.03$ ,  $p = .04$  (two-tailed). The mean increase in knowledge scores was 0.18, with a 95% confidence interval ranging from  $-.34$  to  $-.00$ . The eta squared statistic (.60) indicated a large effect size (Cohen, 1988). This means that 60% of the variance in the students' attitude can be attributed to the effect of the GERMiE intervention.

From the result of Table 5, it can be seen that the p value is less than .05 ( $p < .05$ ), hence the null hypothesis is rejected ( $t = -2.03$ ;  $p = .04$ ) which is there is a significant change in the mean scores of students' attitude of health practices after using GERMiE. Therefore, GERMiE is effective in increasing students' attitude of health practices.

## Discussion

This study demonstrates the significant impact of the GERMiE (Germs Eradication Mission for Education) application on enhancing students' knowledge and attitudes towards health practices. The findings indicate that integrating GBL into health education can effectively improve understanding and foster positive attitudes, which are essential for maintaining good personal hygiene and preventing the spread of infectious diseases.

Firstly, the results reveal a significant increase in the mean scores of students' knowledge of health practices after using the GERMiE application. The marked increase in the mean scores of students' knowledge of health practices post-intervention suggests that the interactive and engaging nature of the game facilitated effective learning. Meanwhile, the results of the paired samples t-test indicated a significant increase in the mean scores of students' knowledge of health practices post-intervention ( $t=-2.34$ ,  $p=.02$ ). According to Cohen's guidelines (1988), an eta squared value of .50 is considered a large effect size, indicating that the intervention had a substantial impact on the knowledge of health practice among students. This finding is consistent with prior studies demonstrating that GBL can considerably enhance the delivery of challenging scenarios and provide immediately feedback, enabling better understanding and retention of knowledge among healthcare professionals (Qian & Clark, 2016; Mayr et al., 2017). Meanwhile, Whang and Zheng (2021) revealed that students in GBL groups outperformed traditional lecture groups in terms of topic knowledge.

The immersive environment created by GERMiE allowed students to practice health-related decisions in a simulated setting, which reinforced their understanding of essential health concepts. An engaging narrative in GERMiE within the game educates students about AMR and the importance of responsible antibiotic use. Moreover, the integration of quiz questions related to AMR and antibiotics into the game, lead to in-game advantages, motivating students to absorb and apply the knowledge presented. A study by Nuci et al. (2021) found that the competitive attributes, music, and bonus points connected with game-based quizzes contributed to a more engaging learning environment, therefore boosting their understanding of the lecture material. A study by DeSmet et al. (2014) found that serious digital games could significantly improve health knowledge and self-efficacy, supporting the outcomes observed in our study.

Secondly, the study revealed a significant improvement in students' attitudes towards health practices following the intervention. The paired samples t-test results showed a significant improvement in the mean scores of students' attitudes towards health practices following the intervention ( $t=-2.03$ ,  $p=.04$ ). According to Cohen's guidelines (1988), an eta squared value of .60 is considered a large effect size, indicating that the intervention had a substantial impact on the attitude of health practice among students. The enjoyable and interactive format of the game likely contributed to this positive shift by making learning more motivating and relatable. Visual cues and animations in GERMiE illustrate the consequences of in-game actions related to infection prevention and antibiotic use. For example, when a student successfully follows a hygiene practice, the app shows positive outcomes like germ reduction. The creative use of multimedia animations enhanced students' attitudes, making them more engaged and motivated in the learning process (Budakoğlu et al., 2023; Sastradika et al., 2021).

Nor Asniza Ishak et al. (2021) found that students had positive perceptions of Kahoot!, particularly in terms of engagement and enjoyment. Positive experiences with educational tools like Kahoot! can enhance students' attitudes towards learning by making the process more enjoyable and interactive (Nor Asniza Ishak et al., 2021). On the other hands, Dondlinger and McLeod (2015), who observed that mobile games could significantly improve knowledge and self-management behaviors in health education. For this study, by presenting health education

in an engaging and fun manner, GERMiE helps students internalize positive health behaviors and attitudes, which are crucial for long-term health maintenance. The increase in engagement and positive attitudes towards learning can also be linked to higher educational outcomes, as highlighted by Anastasiadis et al. (2018) and Hartt et al. (2020).

The effectiveness of GERMiE also emphasizes the potential of educational technology to bridge gaps in traditional health education. Many students lack essential knowledge and positive attitude due to conventional teaching methods that fail to engage them (Singh et al., 2023). GBL offers a dynamic and interactive approach that not only educates but also captivates students' interest. This can lead to better educational outcomes, as demonstrated by the significant increases in both knowledge and attitude scores in this study. Additionally, the real-time feedback and adaptive learning paths offered by GERMiE ensure that students remain engaged and motivated, tailoring the learning experience to individual needs (Huang et al., 2016).

The social aspects of the game, which promote collaboration and knowledge sharing among peers, further reinforce positive health attitudes through peer influence (Altawalbeh, 2023; Ruggiero, 2015). The collaborative elements of GERMiE, where students can share their progress and strategies, likely contributed to the overall effectiveness of the intervention. Peer engagement is crucial for sustaining interest and reinforcing learned behaviors, as highlighted by Connolly et al. (2012). This peer-to-peer interaction not only enhances learning but also builds a supportive community that encourages healthy practices.

Furthermore, the integration of GERMiE into the curriculum aligns with the broader goals of public health education. Effective health education is essential for preventing the spread of infectious diseases and promoting overall well-being. By leveraging the engaging nature of mobile games, educators can overcome the limitations of traditional methods, which often fail to engage students adequately (Winand et al., 2022). The use of technology in health education also aligns with the Sustainable Development Goals (SDGs), particularly those related to health and well-being. Addressing health education through innovative methods such as GERMiE can contribute significantly to achieving these global targets.

In addition to improving knowledge and attitudes, GERMiE's success highlights the importance of incorporating technology into educational strategies to address contemporary health challenges. As antibiotic resistance and emerging infectious diseases continue to pose significant threats to global health, educating the public, especially young people about preventive health practices becomes increasingly important (Muteeb et al., 2023; Jian et al., 2020). Game-based learning applications like GERMiE offer an effective means to disseminate crucial health information and encourage proactive health behaviors particularly regarding hygiene and antibiotics resistance.

## CONCLUSION

In conclusion, the findings of this study support the integration of game-based learning into health education curricula to enhance knowledge and attitudes towards health practices particularly regarding hygiene and antibiotics resistance. GERMiE proves to be a valuable tool in this regard, offering an innovative solution to the limitations of traditional education methods. As technology continues to evolve, the potential for such applications to transform education and promote health awareness will likely expand, providing new opportunities for improving public health education and outcomes. A well-prepared game, tailored to the subject, makes it possible to master the material in less time than a traditional lecture. Games not only help to organize knowledge, engage, and motivate students to learn difficult material, but also

encourage students to take responsibility for their own learning. This aspect of game-based learning is evident in the improved knowledge scores of the students, highlighting the potential of GERMiE to make learning more efficient and effective. Future research should explore the long-term impacts of such interventions and investigate how different game mechanics influence learning and behavior change.

### **Limitation of The Study**

One key limitation of this study is the lack of a control group, as it employs a one-group pretest-posttest experimental design. The results of this study may face challenges in generalizability. Without a control group to provide a comparison, it is difficult to determine whether the findings can be applied to other populations, contexts, or interventions. As such, the conclusions drawn from the study may only be relevant to the specific group studied.

### **Declaration of Interest**

The authors declare that there is no conflict of interest.

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