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Exploring the Impact of Mobile Augmented Reality on COVID-19 Prevention Education in Primary Schools

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ABSTRACT

This study aimed to evaluate the effectiveness of an interactive mobile Augmented Reality (AR) game to increase the knowledge about COVID-19 prevention primary school students. We tested the application for usability and effectiveness through pre- and post-tests, questionnaires, and interviews. 12 participants from four states in Malaysia took part in the study. Their average age is 9.5 years old. Results indicated a significant improvement in student performance from the pre-test to the post-test, with a mean score has increased from 3.67 to 8.25. The average System Usability Scale (SUS) score was 75%. These findings show the effectiveness of our mobile AR application as a tool to increase the knowledge about COVID-19 prevention among primary school. The findings of this study contribute to the body of research on the use of AR in COVID-19 prevention education among primary school students. This study provides both theoretical and practical implications for educators, researcher and policymakers seeking to use mobile AR to support the prevention education of any future pandemic or infectious disease.

1. Introduction

COVID-19, also known as the coronavirus disease, is a viral illness caused by the SARS-CoV-2 virus that emerged in late 2019 and spread rapidly throughout the world. The COVID-19 pandemic has had a significant impact on all aspects of society [1], including education [2]. Meanwhile, mobile Augmented Reality (AR) is a type of mobile technology that allows users to view and interact with digital content in the real world. AR can create immersive and interactive learning experiences that enhance student engagement and learning outcomes.

Despite the increasing use of mobile AR, there is a lack of research on their effectiveness, particularly in COVID-19 prevention education [3]. To the best of our knowledge, this is the first study to examine the use of mobile AR technology for COVID-19 prevention education in primary schools in Malaysia. The findings of this study contribute to the limited body of research on the use of AR in primary school disease prevention education. The research question for this study is twofold:

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i. can an interactive mobile AR game be an effective method for educating primary school students about COVID-19 prevention?
ii. what is the effectiveness level of the developed interactive mobile AR game in delivering COVID-19 prevention educational content?

The aim of this study is:

i. to develop an interactive mobile AR game for teaching primary school students about COVID-19
ii. to assess its functionality and effectiveness in delivering COVID-19 prevention educational content.

We organised this paper as follows: Section 2 (Literature review) will provide an overview of existing research on the use of augmented reality in education, with a focus on its application in COVID-19 prevention education. Next, Section 3 (Design and development) will describe the design and development of our app. In the Methodology (Section 4), we will explain about the app evaluation and process. In the next section (Section 5), the results of the study will be discussed in relation to the effectiveness of the app. Finally, the Conclusion section (Section 6) will summarize the main findings and will suggest areas for future work.

2. Literature Review

The COVID-19 pandemic has highlighted the importance of innovative tools to support education. This includes mobile augmented reality (AR). AR has been used in various educational contexts to engage students and improve learning outcomes on various topics, such as mathematics [4], biology [5] and ICT [6]. One study evaluated the relationship between motivation and meaningful learning for students through mobile AR, as well as the effects and implications of its use in supporting teaching and learning. The results demonstrated a positive relation between mobile AR and the learning level achieved by students [7]. However, the effectiveness of AR in disease prevention has been the subject of debate, with mixed results reported in the literature. While some studies have found that AR can be an effective way to enhance student learning and engagement, others have found no significant differences in learning outcomes compared to traditional methods [8,9].

For COVID-19 prevention education, one study [3] developed a mobile application using AR to educate urban and rural communities on hand washing to prevent COVID-19 infection. The results indicated statistical significance for factors related to the hand washing technique. This suggests that mobile AR can be an effective tool for promoting proper handwashing techniques.

In addition, another study aimed to develop an AR learning model that could be accessed using smartphones to support online learning during the COVID-19 pandemic. The results showed that the AR learning model was useful for independent learning and motivated students to learn about COVID-19 [10]. Another study developed an AR game to teach primary school students about COVID-19 prevention [11]. The results indicated a significant improvement in student performance from pre- to post-test and a high usability score, indicating the effectiveness of the AR game in promoting COVID-19 prevention education. Meanwhile, *Escape COVID-19*. It is a serious game designed to promote safe behaviours among Health Care Workers (HCW) and hospital employees during COVID-19 pandemic [12]. Another mobile app is called "COVID-19–Did You Know?" It is a mobile serious game designed to bring scientific-based information on prevention and personal care about COVID-19 [13]. However, no AR is used in the development of the serious game.

In addition, it is interesting to explore the use of mobile AR in combination with other educational technologies, such as virtual reality [14] or gamification [15]. For example, the combination of VR and AR in a science education setting led to increased engagement [16] and motivation among students [17]. Similarly, studies by Lee [18] and Cai *et al.,* [19] found that gamifying a mobile AR-based language learning application led to improved language acquisition among learners. Future research could also explore the potential of mobile AR to enhance the effectiveness of teacher professional development [20,21].

Overall, the literature suggests that mobile AR can be a useful tool for supporting health education, particularly in the COVID-19 prevention. However, further research is needed to explore the long-term effectiveness of AR in promoting COVID-19 prevention behaviours.

3. Design and Development

To begin the development process, we first had to install the Unity3D and Vuforia software on our computers. The first step in the development process was to create marker cards that would trigger the AR content. We designed these marker cards during the testing phase. Figure demonstrates the general system architecture of our app.

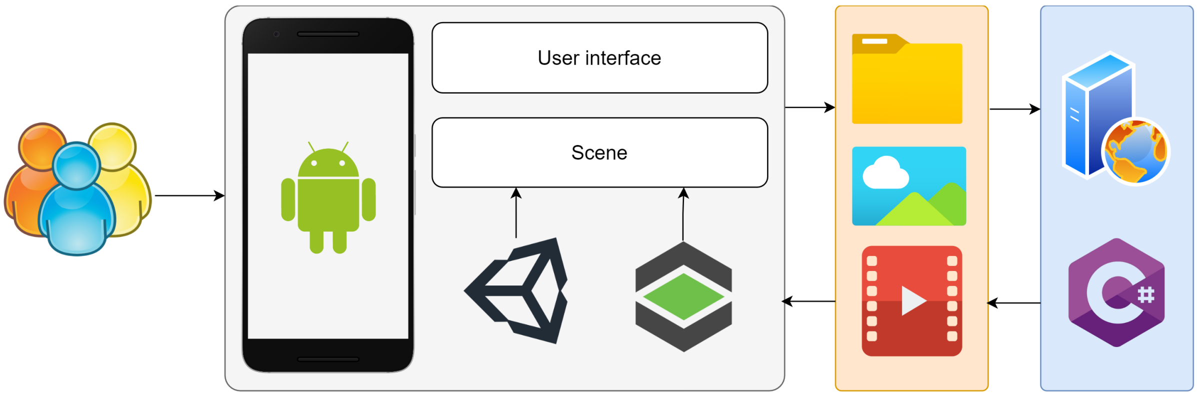

Fig. 1. The general app system architecture

Based on Figure 1, installing the app on an Android device involves downloading the APK file, which is a package file format used to install Android apps. The user can download the file. Once the APK file is downloaded, the user can tap on it to begin the installation process. After the app is installed, the user can open it and proceed to the next step, which is scanning a marker card. The marker card can be a physical card or a digital image that serves as a trigger for the AR content.

By scanning the marker card, the user activates the AR content, which is then displayed through the app's user interface. The AR content includes text, images, and video, which have been compiled into Unity and Vuforia. The content is sent to the app by the server through C# code instructions. Overall, this process allows users to access and interact with the AR content provided by the app. Figure 2 shows the selected user interface screens of our app.

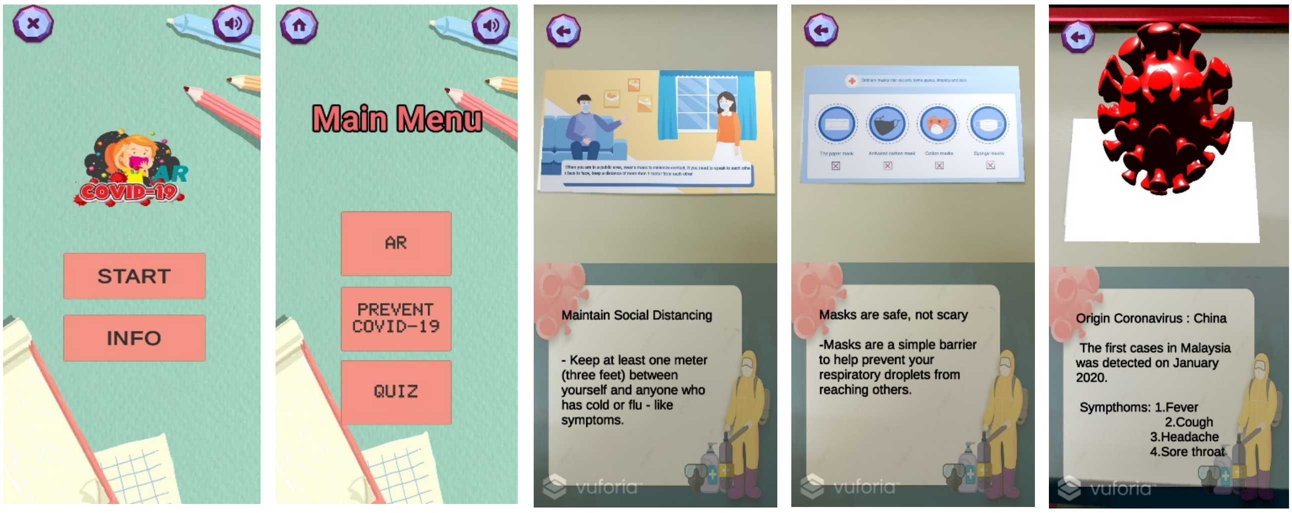

Fig. 2. The user interface screens

4. Methodology

This study employed a simultaneous nested mixed-methods approach, combining qualitative usability data with quantitative data collected as part of a larger project (e.g., scores from a standardised measure). The analysis was conducted following the Good Reporting of Mixed-Methods Studies framework [22] and the Standards for Reporting Qualitative Research guidelines [23]. Data collection and qualitative methods were conducted according to these guidelines. The first section of the questionnaire asked about the demographic data of the participants. The result is intentionally presented in this section. 12 students from four elementary schools in the Malaysian states of Sarawak (66.7%), Sabah (16.7%), Melaka (8.3%) and Selangor (8.3%) participated in the study. The sample size was a pool of 7- to 12-year-old participants (mean = 9.5). They were asked to test the mobile application, complete a questionnaire, and interviewed of their feedback. Table 1 shows the characteristics of the respondents.

Table 1
Participants' background information

Participant	Age	Gender	State
P1	7	Female	Sarawak
P2	10	Male	Sarawak
P3	12	Female	Sarawak
P4	12	Male	Sabah
P5	11	Male	Sarawak
P6	9	Male	Sarawak
P7	9	Female	Melaka
P8	8	Male	Sabah
P9	7	Female	Selangor
P10	8	Female	Sarawak
P11	11	Female	Sarawak

The purpose of the app testing sessions was to determine if the app was effective in helping students learn more about COVID-19 prevention. The researchers administered a pre-test and a post-test. Both tests contained 10 questions and students were given a time limit of 5 minutes to complete each quiz. By comparing the results of the pre-test and post-test, the researchers could see if there was any improvement in the students' knowledge about COVID-19 after using the app. Figure 3 shows the selected photos of the students took part in the testing sessions.

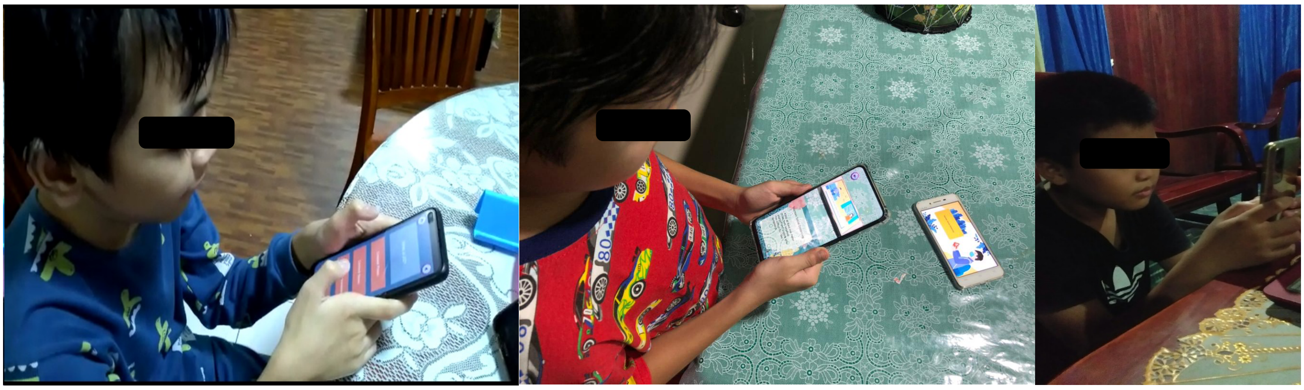

Fig. 3. The testing session

5. Results and discussion

Before the pre-test, the subjects received primary intervention. This intervention includes the use of the mobile augmented reality (AR) game created for this study to educate participants on COVID-19 prevention. It was used to familiarize players with the game's content and dynamics before assessing their knowledge and comprehension of COVID-19 prevention via pre- and post-test.

5.1 Pre and Post-Test

The results of the pre-test and post-test for each student were recorded and analysed. In the pre-test, all participants scored between 1 and 5 out of 10 questions, with a mean score of 3.66 and a standard deviation of 1.303. After participating in the AR testing sessions, all participants scored between 5 and 10 (out of 10 questions) during the post-test. The mean score for the post-test was 8.25, with a standard deviation of 1.658. These results suggest a significant improvement in student performance following the use of the AR app. Figure 4 shows mean and standard deviation values for both the pre-test and post-test.

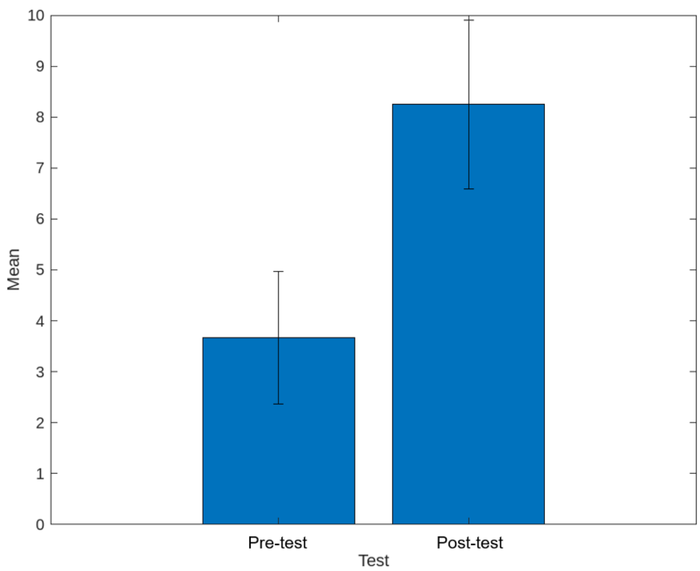

Fig. 4. The testing session mean and standard deviation values

Based on the graphs above, the mean has increased by 4.58 in the post-test. The increased in mean and standard deviation result shows that the AR app could deliver the information in a more effective way and can enhance student's understanding of COVID-19 prevention messages.

5.2 System Usability Testing

The System Usability Scale (SUS) was used for evaluating perceived usability. The System Usability Scale (SUS) scores had been used to collect a quantitative data. SUS heat map is a graphical representation of usability scores, easy to identify problem areas, allows for quick comparison of scores, provides visual representation of scores, easy to interpret and communicate the results [24]. Participants provided feedback on their experiences with mobile application via questionnaires. Quantitative data was also collected, including agree and disagree elements, and provided more insight into how they used the mobile application. The SUS (10 items on a 5-point agree scale) was also completed by participants to measure their impressions of the mobile application usability. The SUS measures app complexity, ease of use, app performance, and user confidence, among other elements of system usability [25]. Figure 5 shows the detail view of SUS heat map matrix.

No	Survey Question	1	2	3	4	5	6	7	8	9	10	11	12
1	I think that I would like to use this mobile application frequently.	3	3	4	4	3	4	5	4	4	4	5	5
2	I found the mobile application unnecessarily complex.	3	3	5	3	4	4	5	4	5	4	5	5
3	I thought the system was easy to use.	3	4	5	5	5	4	5	5	4	4	4	5
4	I think that I need the support of technical person to be able to use the system.	4	2	1	2	2	3	1	2	1	2	2	2
5	I found the various functions in this mobile application were well integrated.	3	3	5	5	4	4	5	4	4	5	5	5
6	I thought there was too much inconsistency in the mobile application.	3	2	1	2	1	3	1	2	2	3	2	1
7	I would like to imagine that most people would learn to use this mobile application quickly.	3	3	5	5	5	4	5	5	5	5	5	5
8	I found the system very cumbersome.	2	2	1	1	1	1	1	2	2	2	2	1
9	I felt very confident using the system.	3	4	5	5	5	4	5	4	5	4	5	5
10	I needed to learn a lot of things before I could get going with this mobile application.	3	3	1	3	2	1	1	1	1	1	3	3

Fig. 5. SUS heat map matrix

Figure 6 shows the graph of the result SUS score calculation by question from the questionnaire.

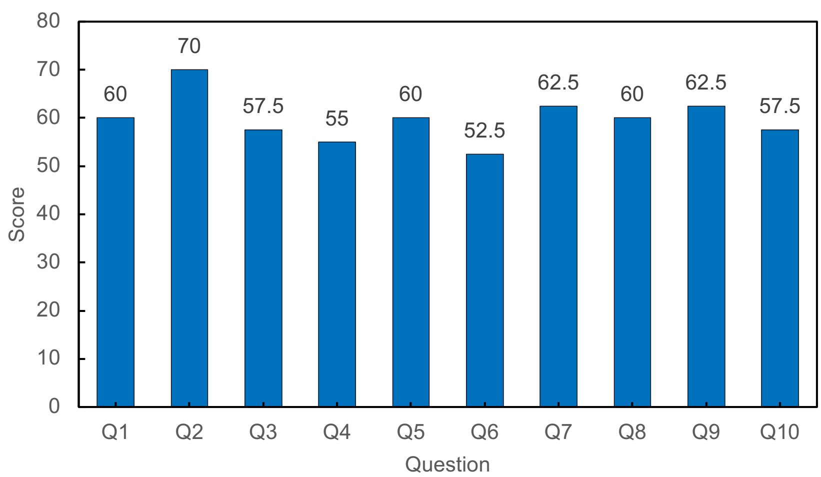

Fig. 6. SUS score by question number

Based on Figure 6, the highest score by question is the Q2 followed by the lowest score is Q4 and Q6. Q2, Q6, and Q9 evaluate the relevance level of the content in our AR. The relevancy of content means it can contribute towards better attention of the participants. For Q2, five participants (P3, P7, P9, P11 and P12) said they are strongly agreed with the question (scale = 5) while P5, P6, P8 and P10 agreed with the statement (scale = 4). For Q6, four participants (P3, P5, P7 and P12) said they were strongly disagreed with the statement (scale = 1). P2, P4, P8, P9 and P11 voted disagree (scale = 2). For Q9, participants P3, P4, P5, P7, P9, P11, and P12 said they were strongly agreed with the statement given (scale = 5). Participants P2, P6, P8 and P10 mentioned that they agreed with the statement given (scale = 4).

While for Q4, Q5 and Q7, the user towards the content presented in our AR. For Q4, the P3, P7 and P9 said they are strongly disagreed (scale = 1). Several participants (P2, P4, P5, P8, P10, P11 and P12 votes disagree (scale = 2), and P6 vote in between (scale = 3). P1 votes agree (scale = 4). For Q5, several participants (P3, P4, P7, P10, P11, and P12) said they are strong agreed (scale = 5). P5, P6, P8 and P9 votes agree (scale = 4), and P1 and P2 votes in between (scale = 3). For Q7, several participants (P3, P4, P5, P7, P8, P9, P10, P11, and P12) said they are strong agreed (scale = 5). P6 vote agree (scale = 4) and P1 and P2 votes in between (scale = 3).

Q1 and Q3 focus measuring the confidence level using the mobile application. The user's understanding of the content determines their confidence level. For Q4, (P7, P11, and P12) said they are strongly agreed (scale = 5). Several (P3, P4, P6, P8, P9, and P10) votes agree (scale = 4), and P1, P2, and P5 votes in between (scale = 3). For Q3, several participants (P3, P4, P5, P7, P8, and P12) said they are strong agreed (scale = 5). P2, P6, P9, P10, and P11 votes agree (scale = 4), and P1 vote in between (scale = 3).

The last two questions which is Q8 and Q10 measured the satisfaction level of our app. For Q8, five participants (P3, P4, P5, P6 and P7) said they are strongly disagreed (scale = 1) with the statement. P1, P2, P8, P9, P10 and P11 votes disagree (scale = 2). For Q10, several participants (P3, P6, P7, P8, P9 and P10) said they are strongly disagreed (scale = 1). P5 vote disagree (scale = 2), and P1, P2, P4, P11 and P12 votes in between (scale = 3). Figure 7 shows the result of SUS score calculation by participants.

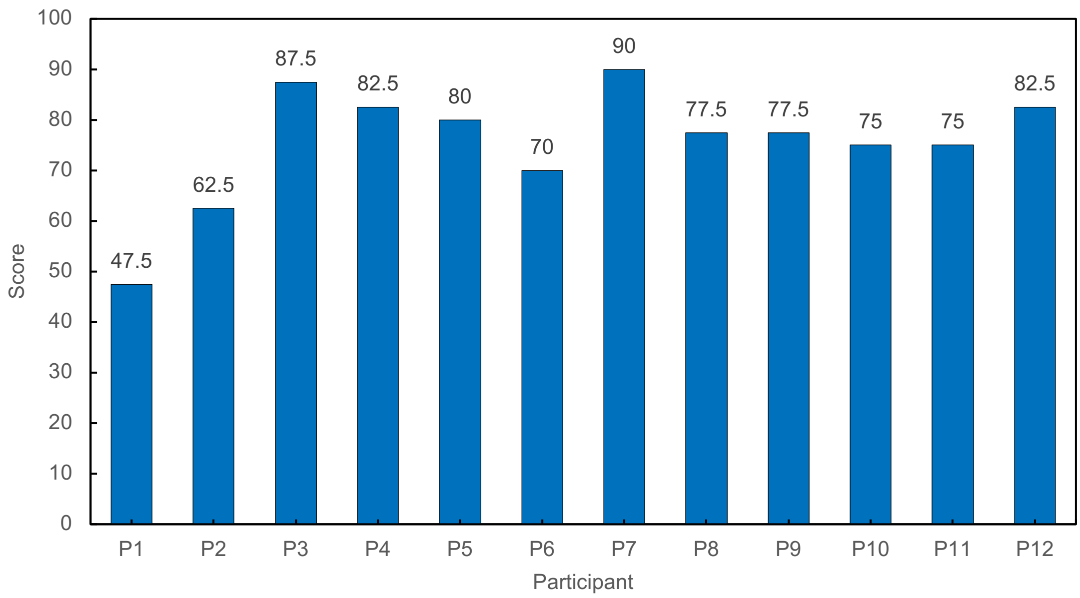

Fig. 7. SUS score by participant number

Based on Figure 7, P7 scores the highest score with 90 percent followed by P3 is 87.5 percent score. The rating of above 68 percent indicates above-average usability, while any scores below that point indicate below-average or insufficient usability. Therefore, the overall SUS Score is 75.63% that means the method in the mobile application is indicate above-average usability.

5.3 Interview Session and Lesson Learned

During the interview, twelve of the participants gave the opinion and feedback on using our AR. There are three questions in the interview session. Table 2 shows selected feedback from the interview session.

Table 2
Participants' responses

Question	Responses (Participant number)
Did you find the apps burdensome to use? Why?	A little bit. The AR for the video sometimes takes time to appear (P1). No. It easy to use and straight forward apps (P3). No. Because the apps are simple, and youngest no need a complex app to learn since they are still young (P11). No. because it easy to use it and simple for primary school student (P12).
Would you recommend this AR system to others for educational purposes? Why?	Yes. Because it is easy to use for primary school students (P3). Yes. It was great and looking alive while learning. In this way, I can remember fast what I learn. Each of the button in this apps help the students (P6). Yes, because currently, we need to learn by using technology (P9). Yes. Because youngster fast to learn if using a visual material (P10). Yes. Because AR is a new technology today and it is fun things for youngster to learn (P11).
Any other feedback of the mobile application?	This app needs to include the detailed instruction (P3). The mobile application easy to use for primary school students (P5) Add more questions to the quiz (P8). Very good game and easy to primary school to learn about COVID-19 in another way (P12).

5.4 Implications

Theoretical Implications include:

i. The use of mobile AR technology as an educational tool may have the potential to improve student engagement and learning outcomes in other subjects as well.
ii. Incorporating 3D models and other interactive elements into AR content may be an effective way to capture students' attention and promote further exploration of a topic.
iii. Using mobile AR technology in education may be beneficial for students who prefer visual or interactive learning approaches.

Meanwhile, practical implications include:

i. Schools and educators may consider incorporating mobile AR technology into their COVID-19 education programs.

ii. App developers of AR educational content should consider the inclusion of interactive elements and 3D models to enhance engagement and learning.

5.5 Limitations

Although the results indicated a significant improvement in student performance, the study had several limitations. Budget constraints limited the number of participants and the sample size was limited to only 12 students from four states in Malaysia. Additionally, the usability test was conducted in a limited time and the study only assessed the short-term effectiveness of the mobile AR application. Furthermore, the study did not compare the effectiveness of the mobile AR application to other methods of teaching about COVID-19 prevention. These limitations should be considered when interpreting the results of the study.

6. Conclusion and Future Work

In conclusion, the aim of this study was to assess the efficacy of a mobile Augmented Reality (AR) game in enhancing primary school pupils' awareness of COVID-19 prevention. According to the System Usability Scale (SUS), the programme showed a high level of usability and was effective at boosting student performance. The findings of this study contribute to the growing body of literature on the use of augmented reality in COVID-19 prevention education. It has important implications for educators, researchers, and policymakers who wish to use mobile augmented reality to support prevention education for future pandemics or infectious diseases.

In the future, to further enhance the app and improve its results, we propose to expand the app's content to include information about vaccines and their potential side effects, test the app's usability with a larger and more diverse group of students, conduct a study with a larger sample size, extend the duration of usability testing sessions, and conduct a longer-term study to determine the durability of the mobile AR application's effects. These initiatives will assist in enhancing the application and its utility for teaching COVID-19 to elementary school pupils.

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