# The Efficacy of REV-OPOLY Augmented Reality Board Game in Higher Education

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**Abstract**—Augmented Reality (AR) in the classroom is a new trend that incorporates technology into the teaching of specific topics in a course. An instance of technology used in the classroom is an AR board game that is designed to aid in learning through games. This study is a continuation of a preliminary work, which will concentrate on designing, developing, and testing phases of REV-OPOLY, a board game with AR intervention in the area of the emerging technology revolution. This study employs a quantitative method of quasi-experimental design using pre-test and post-test and test assessment. It was conducted over one semester on 100 undergraduate students who enrolled in the Computer Application in Management subject in Universiti Utara Malaysia. Two types of assessments were employed to determine the students' knowledge gained from REV-OPOLY: pre-test and post-test, as well as course assessments. The findings show improvements in students' scores in all tests preceding the use of REV-OPOLY. The number of high performers increased twofold in the post-test compared to the pre-test, while the number of low performers decreased in each test. The students provided positive feedback on the use of REV-OPOLY, and they improved on each test as they gained a better understanding of the topic.

**Keywords**—Augmented Reality, board game, e-learning, educational technology

## 1 Introduction

With the emergence of technology, teaching and learning are also evolving. Following the implementation of IR4.0, the teaching and learning of undergraduate students in higher education should be adopted and reflected in the modern age of technology to ensure better learning outcomes in their core subjects. Sánchez-Mena and Martí-Parreño [1] mentioned in their study, conducting games during online or offline classrooms is quite challenging as it consumes more time and is difficult to adapt in teaching and learning. Moreover, Glover [2] stated that in a video game-dominated world, applying video games for educational purposes would inspire new generations of students

to learn. In addition, Lin et al. [3] found that using board games' application in teaching enhances students' participation and motivation.

In line with the Sustainable Development Goal 4: Quality Education, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, the use of technology in curricula and assessments could be a catalyst in the higher education sector. For instance, Augmented Reality (AR) could improve students' engagement in the classroom. AR technology, when combined with an effective pedagogy, has the potential to promote inclusive education by representing content, expressing knowledge, and engaging students in learning. It has the potential to promote innovative and cooperative learning environments, allowing for the achievement of learning outcomes through slightly different but successful methods.

As smartphones are being used by the majority of the world's population; AR is regarded as a widely accessible technology. Smartphones are also equipped with a gyroscope and accelerometer, which are required for AR applications, therefore applying AR in any situation would be simple. In an overview of augmented reality in education, Yuen et al. [4] stated that one of the primary goals of research in the field is to increase productivity in real-world tasks. AR is regarded to have the power to engage and excite pupils, promote innovation and imagination [5], and aid in the teaching of topics that are difficult, if not impossible, to encounter in the actual world. For instance, Dünser et al. [6] investigated the application of a book with a Hand-Held Device (HHD) to improve high school physics comprehension. They conducted a quantitative study with a group of students, where half of the students studied the book with augmentation, and the other half without. The findings demonstrated that augmented reality has the potential to aid in the teaching of spatial concepts that would benefit from being visualized in the 3D form [7].

Similarly, gamification with AR features in the classroom provides students with a variety of interactive activities capable of managing a variety of learning paths in which the main goal can be met based on the students' personality, abilities, and other qualities. Another benefit of gamification is that it emphasizes the visual aspect of the learning process, particularly progress visualization and the chosen learning path. According to Kaufmann [8], gamification can help students be more involved just by playing an online app with a short-term reward notion, which can assist students to avoid procrastination on a certain activity. In terms of receiving feedback and advancement, gaming and learning are considered similar. When students are playing, they will receive immediate feedback, as they would in a normal setting, in written (scores or grades, comments) or oral form (remarks).

For example, Computer Application in Management, which is offered as one of the electives courses at Universiti Utara Malaysia (UUM), attracts students from a variety of backgrounds and programs, including Law, Communication, Business Administration in Logistics and Transportation, Entrepreneurship, Marketing, Public Management, International Business Management, and Human Resources Management. These programs require students to have a certain level of understanding and ability in fundamental knowledge of the latest technologies, as these technologies are used as intermediary methods to assist in many management-related applications that are common among professionals in their respective professions. As a result, students should be able

to understand basic computer technology information and its progress in relation to the new Industrial Revolution 4.0 (IR4.0) by the end of the course. Moreover, students will be able to identify, present, and execute suitable technical solutions to various business and management issues as a result of their exposure to the evolution of technology and future trend analysis.

The Computer Application in Management course is an elective course for the majority of UUM's programs as computer applications help with daily activities in a variety of contexts such as business, communication, economics, education, entertainment, recreation, and so on. After completing the course, students should have a basic understanding of the latest information and communication technology, as well as competency in using a variety of management-related applications that are popular among professionals and entrepreneurs.

## 2 Literature review

Numerous educational sectors and organizations have used the Monopoly board game as a model in inventing their own games. Several fields in education such as health [9], tourism [10], financial [11], and psychology, sociology, entrepreneurship [12] have been adapting Monopoly board games in their fields in recent times.

Cumulatively, adapting board games have extensively brought positive reactions among students and educators. For example, in a study by Lin et al. [3] a board game with Augmented Reality is adapted in health education. They found that the students could understand concepts better when playing augmented reality board games associated with human education. It is found in the study that by using this method, students were attracted to certain functions offered, such as how simple it was to get into the game. Moreover, the students also felt more motivated to learn the subjects with the application of AR [13][14].

Pinto et al. [15] implemented an Augmented Reality Board Game (ARBG) on concepts and traditions of Nasa indigenous culture. Their main objectives were to determine how active participation in the board game could contribute to teaching and learning and identify students' motivation. They wanted to connect the concepts in the game to students' daily lives. It is found that the board game could enhance understanding and students felt motivated to learn the concepts. However, the findings were not able to be generalized to the population at large as the result was derived from a small-scale sampling.

In a study using tangible programming with AR [16], the authors demonstrated the prototype that was created to merge concrete items and augmented reality virtual features (AR). The prototype was created for touch-based devices (tablets or smartphones) and marks a step forward in the process of making elementary programming ideas more appealing for learners. In a similar study, ARQuest [17], a collaborative mobile augmented reality game for primary school students to improve their computational thinking skills were presented. Students use the game's actual board and tactile tokens, as well as animated 3D information, to design and solve tasks in a gamified setting. AR and holographic technology [18] have also been applied to board games to enhance the

user experience. Non-players may have other means to see the battleship due to the AR Battleship board game's integration with a pyramid hologram display. However, further work is needed to evaluate the usability of the system.

In a related study, AR games are also used in assisting vocabulary acquisition [19]. Results found that AR games contribute to vocabulary learning, higher motivation, and active participation from students. On the emotional level, students showed higher intrinsic motivation to do well during the activities, which is an important component in encouraging an anxiety-free and supporting learning environment in the classroom.

A company called Ally Financial also uses Augmented Reality to teach the public about financial literacy in an interactive way [20]. It was named Ally Monopoly, which takes the concept of a popular financial board game and applies it to six cities across the United States. When players join the game, they will be given hints to help them locate virtual reality game squares in their city. When they arrive at their destination, Mr. Monopoly AR will appear and assist them in completing tasks and winning prizes. The AR experience has the potential to change the way people teach and learn all over the world. AR technology will continue to evolve, from classic board games to mobile applications, possible by the use of AR goggles, which are popular in video games.

On the contrary, Jursenaite and Bengtsson [21] found in their study that board games with or without AR can be used without any significant differences in terms of "competence, immersion, flow, tension/annoyance, challenge, negative and positive effects, psychological involvement consisting of empathy and negative feelings, behavioral involvement, positive and negative experience, tiredness and return to reality" (p.3). The results showed that AR board games do not have a negative impact on the user experience; however, developers should consider whether it is necessary in the games as an added value or to provide a better experience for the players.

## 3 Methodology

In this study, the Agile software development approach is used as it allows continuous iteration throughout the work process [22]. There are five main stages in this approach which are planning, designing, developing, testing, and finally deploying. The objectives and research questions were identified during the planning stage of the preliminary work, which was to introduce aboard game with augmented reality named REV-OPOLY, on the emerging technology revolution area to enhance and assist the students' comprehension level during learning [23]. This study concentrates on the designing, developing, and testing phases of REV-OPOLY. The feedback and suggestions by the pilot testers were used for further improvement by iterating the cycles in the approach before it could be formally deployed.

### 3.1 Design and development

REV-OPOLY is a web-based interactive monopoly-inspired board game with augmented reality in the area of the emerging technology revolution. It consists of a board, four moveable player pieces, two animated dice, and cards that act as AR markers as

shown in Figure 1. REV-OPOLY is a web-based game that can be seen and played on any device with an internet connection.

REV-OPOLY is developed with HTML, CSS, JavaScript, and WebAR tools. The board is fully functional even without the AR component as several devices may not be able to support it. REV-OPOLY is made up of four-player pieces that displays the name of each character when pointed to in the game. These pieces can be moved around the board by pressing specific keyboard keys based on the total number of moves shown after rolling the dice. This is done to mimic a traditional board game and to keep players engaged rather than passively watching the game. The movement can also be programmed to move automatically based on the values of the dice.


**Fig. 1.** REV-OPOLY interface

Players can also claim cards by dragging them to the Players tab (Figure 2), which contains four buttons for each player represented by a character image. The rules for claiming the cards would be determined by the participants' agreement. By default, the game is set up to be played such as the classic monopoly board game, with the player having the option to buy the space they land on if it is available.

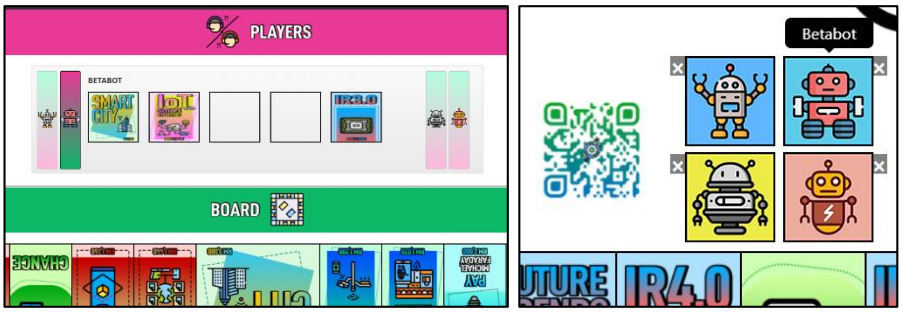


**Fig. 2.** Player cards and character's

Every image on the board is an AR marker that can be scanned to reveal 3D characters or information in the form of 3D texts, images, animations, audio, and videos (Figure 3). These AR characters and information can be customized and edited without modifying the board itself. REV-OPOLY also consists of two types of cards, which are REV-OPOLY's Question cards and REV-OPOLY's Did You Know? cards. The question cards contain questions related to the emerging technology revolution while the other type displays information. Both types of cards are coded in such a way that each time the player selects the card, a different text is displayed. By scanning the AR image on the board, players can see sample answers to all of the questions.

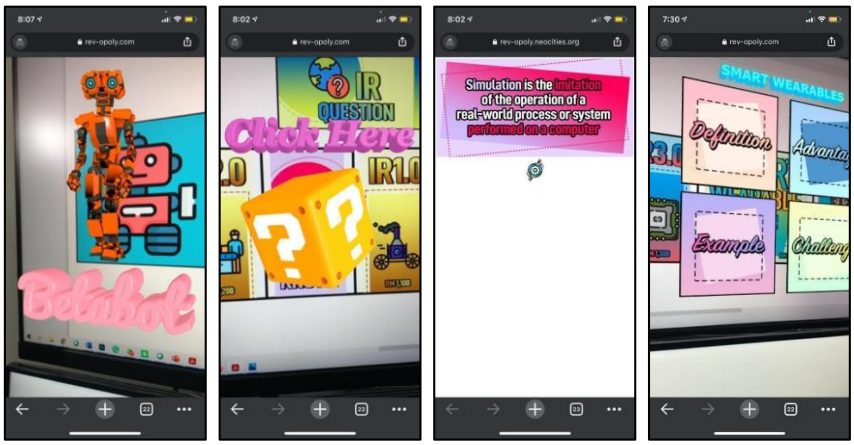


**Fig. 3.** AR markers on the board to reveal 3D texts, images, and videos

REV-OPOLY can be played without the AR components. Instead of scanning the photos and cards, many of the game's components, such as questions and other information, can be retrieved by clicking on them. However, from the preliminary study conducted amongst students; 72 out of 100 respondents were interested in the use of AR as part of their learning experience. By augmenting the objects into various multimedia types such as 3D, texts, images, audios, and videos, REV-OPOLY can support

and accommodate different learning styles such as visual, kinaesthetic, and auditory learners to retain information more effectively.

In summary, REV-OPOLY provides a new learning experience for students in acquiring knowledge. Through games, students can enjoy the informal learning process which helps to assist and enhance their comprehension level in a more casual and fun way.

### 3.2 Data collection and sampling

This study employs quantitative method of quasi-experimental design using pre-test and post-test, and test assessment. It was conducted within one semester on 100 undergraduate students enrolled in the Computer Application in Management subject in Universiti Utara Malaysia. The pre-test and post-test were used to measure the students' knowledge gained from REV-OPOLY. To ensure the validity of this study, students were asked to complete the pre-test before REV-OPOLY was demonstrated. Students were not informed of the study prior to it being conducted to be able to test the effectiveness of REV-OPOLY towards their understanding based on their pre-existing knowledge of the topic as the baseline. However, the topic was covered during previous lectures. Subsequently, the students were given an explanation and demonstration of REV-OPOLY. Their interactions when playing the game were observed and recorded to be analysed. After the game ended, students were required to complete a post-test in order to re-evaluate and measure the outcome of the REV-OPOLY intervention.

### 3.3 Pre-test and post-test design

The pre-test and post-test contained 15 questions of multiple-choice types (MCQ) focusing on the key points of the emerging technology revolution such as the definition, causes, examples, benefits, and impacts of the technology. The questions have a simple and direct structure that is easy to understand. Furthermore, clear distinct answers to the questions are based on the content covered during lessons and in the lecture notes. For example, question 1 of the test is on the definition of Industrial Revolution 1.0. The question is, "What does the term Industrial Revolution 1.0 mean?" and the options are "A. transition from manual to machine production", "B. development of electrical machines", "C. expansion of computer and microprocessor" and "D. expansion to allow automated communication amongst machines". Each option in this example refers to a different stage of the industrial revolution and is not plausible to answer by guessing. Therefore, it could be assured that the questions and list of possible answers in the pre-test and post-test were well-developed in assessing the students' knowledge on the subject matter.

In the pre-test and post-test, the questions were separated into three main categories which were the industrial revolution, the smart concept and Internet of Things, and the pillars of Industrial Revolution 4.0. These categories were also used in REV-OPOLY. Thus, the questions and the game were related and supported the knowledge required

in the Computer Application in Management subject on the fundamentals of the emerging technology revolution. After playing REV-OPOLY, the students are expected to properly answer the majority of the post-test questions.

Students were briefed on the study and the stages that they required before proceeding with the pre-test, testing REV-OPOLY, and completing the post-test at the end of the session. All students gave their informed consent, with the option to opt out at any time during the study. REV-OPOLY was played for 30 minutes in groups of at least four players via Webex breakout sessions, followed by a post-test consisting of the same set of questions as the pre-test. The pre-test and post-test were conducted using the UUM Online Learning Portal, which has a 15 minutes countdown timer and the results were synchronized and linked to the students' profiles for analysis.

### 3.4 Assessment

Relying solely on the pre-test and post-test results might be insufficient to assess REV-OPOLY's effectiveness. Thus, the results that are obtained from the post-test were compared to the results from the course assessment, Test 2, on the same topic. The assessment was conducted several days after REV-OPOLY was introduced and used by the students. The questions used in Test 2 were developed and moderated by at least four different experts in the Computer Application in Management subject for validity. Test 2 covered five different topics in the syllabus (60 MCQ questions) and ten of the questions were on the emerging technology revolution topic. The assessment questions were securely protected and could only be viewed on a specific date. Even though the questions used in the post-test and Test 2 were different, they had similar difficulty levels and covered the same categories which were the industrial revolution and the pillars of Industrial Revolution 4.0. However, Test 2 did not contain questions on the smart concept and Internet of Things category.

## 4 Results and discussion

### 4.1 Students' demography

Out of 100 students, 88 of them answered the pre-test and only 58 for the post-test. The results of students who completed both tests were selected to be analysed (Table 1). In total, 55 students completed the pre-test and post-test. In Test 2, all 100 students sat for the assessment. Test 2 results of the 55 students who previously completed the pre-test and post-test were used for further analysis. Among the 55 respondents, 38 (69.09%) were female and 17 (30.91%) were male, and 10 (18.18%) were first semester's students, 43 (78.18%) which were the majority, in their second semester, and 2 (3.64%) in the fourth semester.

The respondents had different backgrounds and studied different programs which are not technologically based. 35 (63.64%) enrolled in the School of Business Management pursuing Bachelor in Business Administration, Bachelor in Entrepreneurship, Bachelor in Human Resource Management, and Bachelor in Marketing. Whereas, 8

(14.55%) from School of International Studies, Bachelor in International Business Management, 8 (14.55%) from School of Technology Management & Logistic, Bachelor in Logistic & Transportation Business Administration, 3 (5.45%) from School of Government, Bachelor of Public Management and 1 (1.82%) from Islamic Business School, Bachelor in Islamic Finance and Banking.

**Table 1.** Demographic distribution

| Profile Factors | Particulars | *N* | *P* |
|---|---|---|---|
| Gender | Female | 38 | 69.09 |
| | Male | 17 | 30.91 |
| Semester | 1 | 10 | 18.18 |
| | 2 | 43 | 78.18 |
| | 3 | 0 | 0.00 |
| | 4 | 2 | 3.64 |
| Department | School of Business Management | 35 | 63.64 |
| | School of International Studies | 8 | 14.55 |
| | School of Technology Management & Logistics | 8 | 14.55 |
| | School of Government | 3 | 5.45 |
| | Islamic Business School | 1 | 1.82 |

[*] *N* number of respondents, *P* percentage of respondents (%)

### 4.2 Students' performance

The correct responses for each question (15 questions in total) in the pre-test and post-test were tabulated as shown in Table 2. Questions 1 to 5 (Q1 – Q5) are in relation to the industrial revolution, questions 6 to 10 (Q6 – Q10) are on the smart concept and Internet of Things, and questions 11 to 15 (Q11 – Q15) are on the pillars of Industrial Revolution 4.0. After the students completed the pre-test, they were not informed of the results. Therefore, they were not aware of the answers to all the questions. However, by playing REV-OPOLY, similar information and knowledge can be gained in order to see improvements in their answers during the post-test, as the post-test contains the same questions as the pre-test.

Based on the results in Table 2, in the first category, there are improvements (gain) in all questions with the obvious increase in Q5, with an increase of 23.64%. In the second and third categories, Q9 shows no changes. However, even though the majority of the questions indicated improvement, two questions (Q8 and Q10) and one question (Q11) revealed a reduction in the number of students with correct answers. Even though the percentage is small (3.64%, 5.45%, and 1.82%), these three questions need to be analysed to find the reasons for these negative values.

**Table 2.** Students' pre-test and post-test responses (n = 55)

| Questions | Pre-test | | Post-test | | Gain |
|---|---|---|---|---|---|
| | ***N*** | ***P*** | ***N*** | ***P*** | ***P*** |
| Q1 | 38 | 69.09 | 43 | 78.18 | 9.09 |
| Q2 | 24 | 43.64 | 28 | 50.91 | 7.27 |
| Q3 | 24 | 43.64 | 25 | 45.45 | 1.82 |
| Q4 | 14 | 25.45 | 19 | 34.55 | 9.09 |
| Q5 | 19 | 34.55 | 32 | 58.18 | 23.64 |
| Q6 | 41 | 74.55 | 45 | 81.82 | 7.27 |
| Q7 | 39 | 70.91 | 44 | 80.00 | 9.09 |
| Q8 | 29 | 52.73 | 27 | 49.09 | -3.64 |
| Q9 | 20 | 36.36 | 20 | 36.36 | 0.00 |
| Q10 | 29 | 52.73 | 26 | 47.27 | -5.45 |
| Q11 | 28 | 50.91 | 27 | 49.09 | -1.82 |
| Q12 | 38 | 69.09 | 47 | 85.45 | 16.36 |
| Q13 | 21 | 38.18 | 24 | 43.64 | 5.45 |
| Q14 | 30 | 54.55 | 36 | 65.45 | 10.91 |
| Q15 | 31 | 56.36 | 35 | 63.64 | 7.27 |

[*] *N* number of respondents, *P* percentage of respondents (%)

Firstly, Q8. "Which of these is NOT the benefit of IoT in a smart city?", was provided with answer choices that are straightforward: "A. Able to have smart air quality control of the city", "B. Able to use smart traffic control in the city", "C. Able to implement smart parking system in the city", "D. Able to control individual smart devices within the city". However, the students were confused with the term smart air quality and smart traffic control. Supposedly, it should be clear that individual smart devices should not be controlled by unauthorized personnel. Perhaps the question should be reconstructed to be a positive statement to avoid misleading the students. Secondly, Q10. "What is the use of smart grid?", was provided with the answer choices: "A. To remotely control connected home appliances", "B. To automate the connected machinery", "C. To control the changes in electricity usage and issues", "D. To virtually control and monitor field operations". In this question, students had a misconception of the smart grid. In REV-OPOLY, the definition of the smart grid was provided. Students might have overlooked it when they were using REV-OPOLY.

Similarly, for Q11. "What is the purpose of system integration?", "A. To access the system over the Internet", "B. To link different systems to act as a single system", "C. To join process that builds the system parts layer by layer", "D. To overlay virtual objects to the real-life", students misunderstood the concept of system integration as additive manufacturing or cloud computing. Based on these findings, a clear comparison of the different types of technologies should be included in REV-OPOLY in the form of texts, videos, or images to avoid misconceptions from happening, especially in the definition of the terms which is crucial in understanding the emerging technology revolution topic.

In terms of the overall gain in the three categories, based on the responses in Table 2, the first category has a total percentage gain of 10.18% (average of all correct pre-

test Q1 to Q5, is 43.27%, post-test 53.45%), the second category was 1.45% (average correct pre-test Q6 to Q10, is 57.46%, post-test 58.91%) and in the third category was 7.63% (average correct pre-test Q11 to Q15, is 53.82%, post-test 61.45%). This shows that most students showed an improvement when answering questions in the first and third categories, while in the second category, subtle improvement was observed. This can be due to the high value of 57.46% in the second category of the pre-test, which is used as the baseline, compared to the other categories. It can be assumed that the respondents were conversant with the content covered in Q6 to Q10, thus through REV-OPOLY, less added value in the knowledge gained. Overall, students showed improvement in all categories, especially on their knowledge of the industrial revolution (first category). This is considered an improvement as the respondents tested and used REV-OPOLY for a limited duration of an estimated 20 to 30 minutes before they were asked to complete the post-test. It is expected that better results can be achieved in all categories if the respondents were given more time to explore REV-OPOLY.

Table 3 categorize the students' pre-test and post-test scores based on their performance, low (at most with 5, inclusive, correct answers or 33.33%), moderate (6 to 10 correct answers or 40% to 66.67%), and high (more than 10, exclusive, correct answers, 66.67% to 100%). Even though the number of moderate performers decreased (39 to 33), this was a positive result as the number of high performers showed an increase by doubling the number compared to the pre-test (from 8 to 16) and low performers have slightly decreased (8 to 6). In terms of the time spent during the pre-test and post-test, on average, students spent 13.11 mins and decreased by 3.42 mins to 9.69 mins during the post-test. This suggested that students knew the answers to the questions better than they did during the pre-test, allowing them to complete faster.

**Table 3.** Students' pre-test and post-test scores (n = 55)

| Scores | Pre-test | | | Post-test | | |
|---|---|---|---|---|---|---|
| | ***N*** | ***P*** | ***t*** | ***N*** | ***P*** | ***t*** |
| <=5 (low performers) | 8 | 14.55 | 12.99 | 6 | 10.91 | 11.68 |
| 6-10 (moderate performers) | 39 | 70.91 | 10.77 | 33 | 60.00 | 7.70 |
| >10 (high performers) | 8 | 14.55 | 13.57 | 16 | 29.09 | 9.68 |

[*] *N* number of respondents, *P* percentage of respondents (%), *t* average time taken by respondents to complete the test (minutes)

In terms of the scores, 16 students showed an improvement of 13.33% and 6.67% each, compared to their initial pre-test score. 3 students showed great improvement with an increase of 46.67% in their post-test scores. One student had a decrease in score by 46.67%. By further analysis, it was found that the student had an Internet connection problem where the student was not able to complete the post-test. The system used for the pre-test and post-test automatically submitted the students' answers when the timer expired, regardless of whether or not the students have completed the test. Thus, the student could not continue with the test when the Internet had stabilized as the timer had expired. One of the ways to avoid this situation is by enabling the system to pause

the timer such as the case of the student with the Internet connection problem and enabling them to continue with the questions so that the effect of REV-OPOLY on the student's performance can be included for analysis.

To further support this result, Table 4 shows that 29 students (52.73%) improved in the number of correct answers obtained compared to the pre-test. However, 16 (29.09%) received the same scores in both tests and 10 (18.18%) obtained a lower score. Pre-test scores that did not change during the post-test should be investigated further as they may indicate several issues, such as students having difficulty understanding the questions and the suitability of the game, which may need to be altered and modified to meet the various needs and interests of all types of students. This information can be gained through the feedback provided by the students. One particular feedback received for the lower score achieved was regarding the AR elements. Several respondents reported that the augmented videos were taking a long time to load and that they were unable to view them as it was not supported by their device. This affects the learning experience tremendously as most information is being presented more effectively through augmented objects (such as explanations through the audios or videos) rather than through static texts. REV-OPOLY can be played without the AR elements. However, it needs to be closely monitored to ensure similar information and knowledge can be gained when using AR. Students who showed improvement agreed that the AR elements in REV-OPOLY helped them to understand the topic more promptly.

**Table 4.** Students' post-test performance scores and results (n = 55)

| **Scores** | **Post-test** | | | |
|---|---|---|---|---|
| | ***N*** | ***P*** | ***mode*$_{score}$ *(N)*** | ***max*$_{score}$ *(N)*** |
| Less score | 10 | 18.18 | 6.67 (7) | 46.67 (1) |
| No changes | 16 | 29.09 | - | - |
| Improvement | 29 | 52.73 | 13.33 (8)<br>6.67 (8) | 46.67 (3) |

[*] *N* number of respondents, *P* percentage of respondents (%), *mode*$_{score}$ highest frequency of scores, *max*$_{score}$ maximum score achieved (%)

Results of the post-test were then compared to another assessment; Test 2. It covered similar types of questions and information that could be obtained in REV-OPOLY. However, the main difference is in the way the assessment questions are structured. In the pre-test and post-test, simpler words are used, while in Test 2, the questions were more descriptive. For example, one of the questions in Test 2 was as follows:

Refer to the statement below:

*"A cluster of technologies that produce objects by adding material in the sequential layer which can be from metals, plastics, and composite materials."*

*From the above statement, this is one of eleven enabling technologies that is highlighted by the National Policy on Industry 4.0 – Industry4WRD. This enabling technology is referring to _____.*

*A. Artificial technology* *B. Cybersecurity*
*C. Advance materials* *D. Additive manufacturing*

Table 5 shows the students' scores compared to the post-test. As mentioned in the previous section, the questions are categorized into different topics; industrial revolution (5 questions), and technology (5 questions) which gives a cumulative value of 275 (55 students * 5 questions) from each category. Test 2 showed an improvement with a gain of 3.65% in the first category (from 53.45% to 57.09%) and 5.45% in the second category (from 61.45% to 66.91%), as 10 and 15 students performed better in Test 2 compared to the post-test.

**Table 5.** Comparison of Test 2 and post-test responses based on the categories of the questions (Σn = 275)

| Question Categories | Post-test | | Assessment (Test 2) | | Gain |
|---|---|---|---|---|---|
| | ***ΣN*** | ***P*** | ***ΣN*** | ***P*** | ***P*** |
| Industrial Revolution | 147 | 53.45 | 157 | 57.09 | 3.64 |
| Technology | 169 | 61.45 | 184 | 66.91 | 5.46 |

**ΣN* number of cumulative respondents in all questions within the category, *P* percentage of respondents (%)

Table 6 demonstrates the students' performance which can also be compared to Table 3. The number of low performers decreases from 6 to only 1 in Test 2. The majority of the students are within the moderate to high categories (a total of 98.18%) compared to a total of 89.09% in the post-test and 85.46% in the pre-test. By looking at the pre-test, post-test, and Test 2 results, it can be concluded that the students showed improvement in each test as they have a better understanding of the topic.

**Table 6.** Students' post-test and Test 2 scores (n = 55)

| Scores | Post-test | | Assessment (Test 2) | |
|---|---|---|---|---|
| | ***N*** | ***P*** | ***N*** | ***P*** |
| <=50% (low performers) | 6 | 10.91 | 1 | 1.82 |
| 50-75% (moderate performers) | 33 | 60.00 | 22 | 40.00 |
| >75 (high performers) | 16 | 29.09 | 32 | 58.18 |

**N* number of respondents, *P* percentage of respondents (%)

Further assessments are required to see a significant impact on the students' assessment results to assess the effectiveness of REV-OPOLY. While the results do not directly indicate the effectiveness of REV-OPOLY on the students' results. However, based on their perceptions of REV-OPOLY through a feedback form collected from the students, positive feedback was received from the students in terms of their confidence in learning and understanding of the topic through REV-OPOLY compared to traditional methods (self-revision through books and other materials). The majority of them agreed that with the use of games and AR elements, REV-OPOLY as a whole is useful as one of the tools that can be utilized to assist in their learning process.

## 5 Conclusion

The implementation of AR board games in the classroom is undoubtedly exciting and attracts players to be more involved in the learning process. Although it takes time to learn the rules and features of the board game, once the players are accustomed to the gameplay it is a fun and interactive method to learn and review a topic in their studies. The positive side to the AR board game is the attractive 3D features that allow the players to be immersed in the game. However, the downside of it is that it requires good internet connections, as these features may be too heavy to support multiple devices and users at once.

The important component of REV-OPOLY is retained together with digitization by incorporating AR into board games. Players in augmented reality games have a vast and perhaps limitless number of interaction options. Therefore, the addition of augmented reality to the game adds value which may improve the game by merging the greatest aspects of traditional and online board games. Additionally, by incorporating the Emerging Technology Revolution subject to the game, students were able to grasp important concepts from the IR1.0 to IR4.0 era.

In particular, it was demonstrated from the post-test and Test 2 scores, students were able to pick up on the basic concepts, definitions, causes, examples, benefits, and impacts of the technology. However, a clear comparison of the different types of technologies should be included in REV-OPOLY in the form of texts, videos, or images to avoid misinterpretations, especially in the definition of the terms which is crucial in understanding the emerging technology revolution topic.

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