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Earthquake Readiness Analysis of Pamantasan ng Lungsod ng Maynila Students Using Simulation Application

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Abstract

Despite the Philippines being recognized as a major need for enhanced disaster education and evacuation planning in every community, the ongoing pandemic has made it more difficult for institutions to execute required evacuation drills. As a result of a lack of repetition and participant involvement during mandatory earthquake simulations, participants overlook which routes are designated for evacuation and do not establish a lasting understanding of necessary procedures. Technology and gaming aspects may be used to simulate disasters for educational purposes. The Earthquake Simulation Application, which is based on a model of the structures around the Pamantasan ng Lungsod ng Maynila, was tested on a group of university students to confirm that the system complies with the standards outlined in ISO 25010. The purpose of the Earthquake Simulation Application created in this study is to advise students of the appropriate actions to take during and after an earthquake. To prevent unfavorable results, there are features that inform users of what constitutes incorrect behavior. This earthquake application repeatedly simulates the events that occur during an earthquake to support the retention of correct evacuation routes. Most responders who got earthquake simulation application instructions were able to fail the procedure at least once, but few were able to complete it. It was established that the earthquake simulation program was exceptional in terms of both functional stability and usability, as well as performance.

Keywords: Evacuation Route; Earthquake Drills; Unity; Earthquake Simulation; NavMesh.

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1. Introduction

Considering the alarming frequency of earthquakes in the Philippines, disaster education has assumed unprecedented significance. Regrettably, the current pandemic has imposed formidable barriers to the execution of mandatory evacuation drills within educational institutions. In response to this predicament, this study advocates the use of technology and gamification to continue delivering disaster education through immersive virtual simulations.

Within the context of earthquake drills, a critical issue arises the retention of evacuation routes during actual seismic events. The infrequent repetition of mandatory earthquake drills contributes to forgetfulness among students, rendering traditional methods, such as written documentation, inadequate for instilling enduring knowledge about the correct procedures to follow both during and after earthquakes. Moreover, earthquake drills often fall short of simulating the authentic experience of seismic disasters within educational settings. Consequently, students may display inappropriate behaviors in real earthquake scenarios because of the lack of feedback following these drills. There is a distinct gap between real evacuations and earthquake drills since the tangible tremors experienced during actual evacuations cannot be accurately simulated in drills. This contrasts with fire drills, where evacuees do not encounter actual smoke and flames. It's important to note that having knowledge about major natural disasters does not necessarily correlate with the preparedness of Filipinos for earthquake calamities [1]. Furthermore, evacuation drills may inadvertently cultivate behaviors not typically observed during real evacuation scenarios. A study underscores the potential of Serious Games (SGs) to bridge this gap between drills and real evacuations through lifelike simulations. It also highlights the pedagogical challenges associated with ensuring the effectiveness of evacuation drills due to the absence of comprehensive feedback. Studies conducted in Istanbul underscore the pivotal role of risk awareness in fostering earthquake preparedness [2]. However, it is worth noting that the extensive knowledge pertaining to earthquake-related risks often remains limited to awareness of the risks themselves, with inadequate attention given to risk mitigation and preparedness. Traditional methods of disaster education, characterized by their lack of interactivity, struggle to motivate students to proactively engage with disaster-related information.

To address these shortcomings, this study explores three distinct educational methods for earthquake preparedness: Digital Games, Practical Drills, and Traditional Training [3]. The research reveals that among the experimental groups, practical drills emerged as the most effective educational method. However, it is arguable that digital games can also offer an effective educational experience, enhancing students' understanding of earthquake-related concepts and increasing their awareness of natural disasters. The study concludes by recommending the integration of digital games as a supplementary tool in earthquake education, recognizing that traditional methods may fall short of meeting the educational needs of today's digitally native students.

2. Literature Review

Numerous studies across the country have utilized virtual reality and simulation in disaster education and preparedness training. This study describes an early concept for an adaptive virtual reality (VR) game designed to educate community members about the best practices for their households in the event of a typhoon or flood [4].

The game customizes its content by gathering user information. The post-test scores achieved by respondents after playing the game were significantly higher than their pre-test scores, indicating an increase in content understanding. Another research paper proposes a concept for a virtual reality (VR) application tailored for senior high school students and instructors, with the intention of enhancing classroom instruction [5]. The application incorporates features such as virtual hands, movement options, and the recording of user actions for future reference. A study has unveiled the challenges faced by government agencies in enhancing their strategies for natural disaster mitigation, commonly known as disaster risk reduction and management (DRRM). It explores the potential of virtual reality in replicating disaster risk management training through simulation exercises. Participants from various agencies have shared insights into gaps and issues within their disaster response methods, especially in earthquake drills. The framework analysis was then employed to gather essential information from these group discussions. Ultimately, recommendations for enhancing disaster risk response and implementing other mitigation techniques were formulated and presented to the government entities involved in the study. The noteworthy aspect is the utilization of simulation environments and other technology-based training, along with the presentation of various awareness issues and scenarios [6].

3. Limitations of the Study

The study is limited to the "Gusaling Corazon Aquino" building of the university "Pamantasan ng Lungsod ng Maynila" due to the building's location and the university's large structure. Other buildings are only designed and placed inside the application's environment, to recreate the vicinity of the university, and these buildings are not accessible for the user to spawn and roam around. In terms of the building layout of "Gusaling Corazon Aquino, the study meticulously recreated the current floor plan given by the architecture office of the university, and no other floor plan is added or used as a reference. Furthermore, the area surrounding the environment leading to the end goal can be accessed and freely roam around as well, only the buildings in this vicinity are limited to openly explore. Moreover, the study is limited to the WebGL and Windows platforms, no other platform is used such as Android mobile.

4. Structure

4.1 System Design

Figure 1 below illustrates the system design of the study, encompassing the following key components: the Unity Engine and the C# language, the WebGL API, the Unity Play website, and the users who will utilize the earthquake simulation application.

Figure 1: The System Design of the Study.

The researchers utilized Unity as the engine for the earthquake simulation application and developed its mechanics using the C# language. Subsequently, the earthquake simulation application was implemented using WebGL, enabling it to run seamlessly on the Unity Play website. This approach provides users with the ability to access and engage in earthquake drills freely via their web browsers, without requiring any installations or Unity account requirements. It's worth noting that Unity Play is accessible without users needing to log in. Following the completion of each simulation, the system records instances in which users failed to achieve specific objectives. This data is then collected and used to generate a simulation analysis, contributing to the university's disaster planning and risk assessment efforts.

4.2 Data Modeling

The figure below represents the main navigation menu of the application.

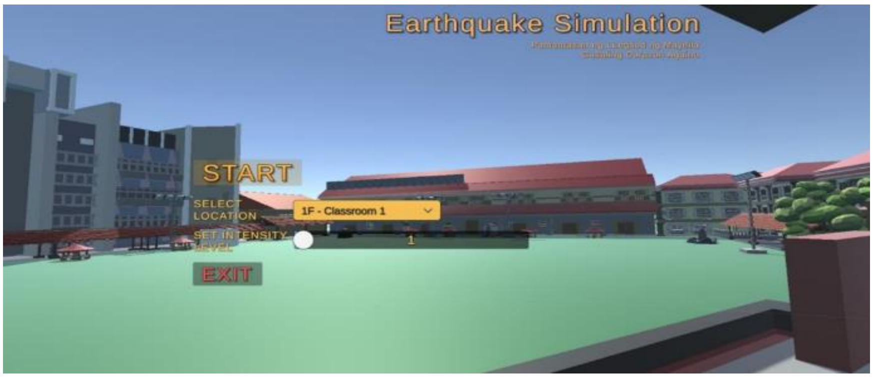

Figure 2: Main Menu.

The main menu comprises a start button that, when pressed, initiates the first simulation scene based on the user's chosen options. Clicking the location dropdown menu reveals a list from which the user can select the initial position of their character within the GCA building for the earthquake simulation. By clicking and dragging the Intensity Level Slider from left to right with the mouse, the user can adjust the intensity level of the earthquake during the simulation. Pressing the Exit button will close the entire application.

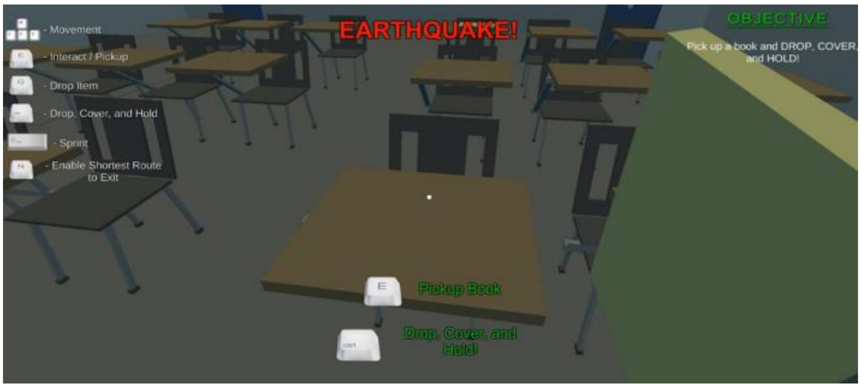

Figure 3: Pick up a book and Drop, Cover, and Hold Panel.

The initial objective involves tasks such as picking up, dropping, covering, and holding. Various sets of keyboard buttons are provided for character control. Each specific type of keyboard button grants the user access to a particular action.

Figure 4: Incoming Aftershock! Do the Drop, Cover, and Hold Panel.

In the event of an aftershock, the user should perform the drop, cover, and hold procedures. In this scenario, the same character controls that were used in the initial goal are applicable.

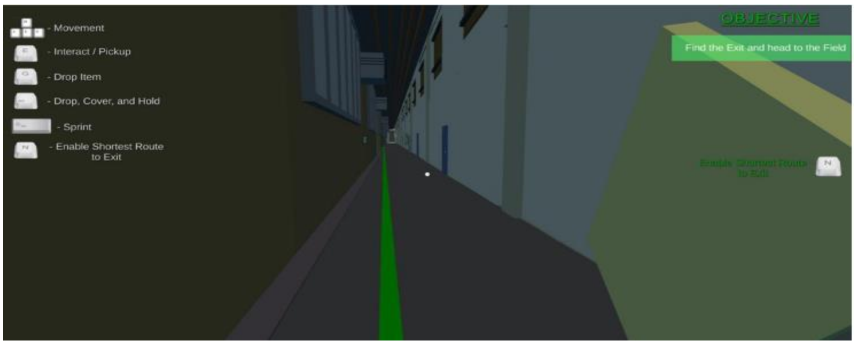

Figure 5: Get Out of the Classroom and Find the Exit Panel.

The user should exit the classroom to find the shortest path to the exit. In this scenario, the same character controls as in the initial goal apply. In this situation, the user can press the 'N' key on the keyboard to activate the quickest route to the exit. The user must now safely evacuate the GCA building and make their way to the university's open field. In this scenario, the same character controls as in the initial objective apply.

Figure 6: Successfully Evacuate the GCA Building - Earthquake Simulation Finished Panel.

The user is presented with their earthquake simulation analysis results, after which they can click the bottom button to return to the main menu.

Figure 7: Objective Failed - Lost Screen.

This illustration depicts a losing screen within the application. When a user fails to achieve the objective, a lost screen is presented, serving to inform the user of incorrect behavior during and after an earthquake.

Figure 8: After any Objective - Good Job!

Upon successfully achieving any objective, an on-screen trivia question related to the correct earthquake response methods is displayed.

4.3 A-Star Algorithm

Researchers utilized the A-star Algorithm to determine the shortest path from the player to the final objective. This approach was chosen because the Unity Game Engine supports this type of algorithm by giving the required heuristics for the algorithm to run properly [7]. The Game Engine also enables the method to be utilized in a convenient manner by enabling the developers to use the built-in network of linked nodes that can be put on Game Objects that serve as platforms inside the game and modify the values accordingly. Navigation Components are a Unity Game Engine component that may automatically establish the groundwork for letting Game Objects navigate inside the game environment. In the simulation, the subcomponents of Navigation

Components with their specific functions were used to construct the shortest-path guide. The NavMesh Surface component is applied to game objects with "Walkable" surfaces, and then the Unity Engine places linked nodes on the game object's surface. NavMesh surface components are present on the building's floors and exterior platforms, as they are the game objects that the player walks on. The NavMesh Obstacle component is applied to all "not walkable" game objects in the playing area. The NavMesh Obstacle considers game objects as obstacles and prevents Unity from constructing nodes on their surfaces. After properly applying and setting such components on our game objects, it is just needed to use a Line Renderer component to make the lines connecting the nodes visible from the user's perspective.

To create the simulation, the researchers have also made a flowchart of the gameplay to follow during development:

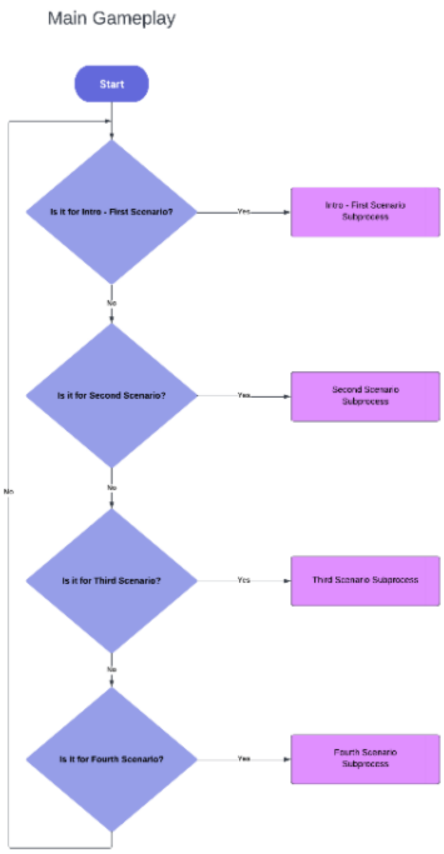

Figure 9: Main Gameplay Flowchart.

The primary gameplay flowchart is depicted in the image above, showing the first, second, third, and fourth scenarios along with their respective subprocesses if you tried to proceed to yes, and taking you back to the beginning if you tried the no option.

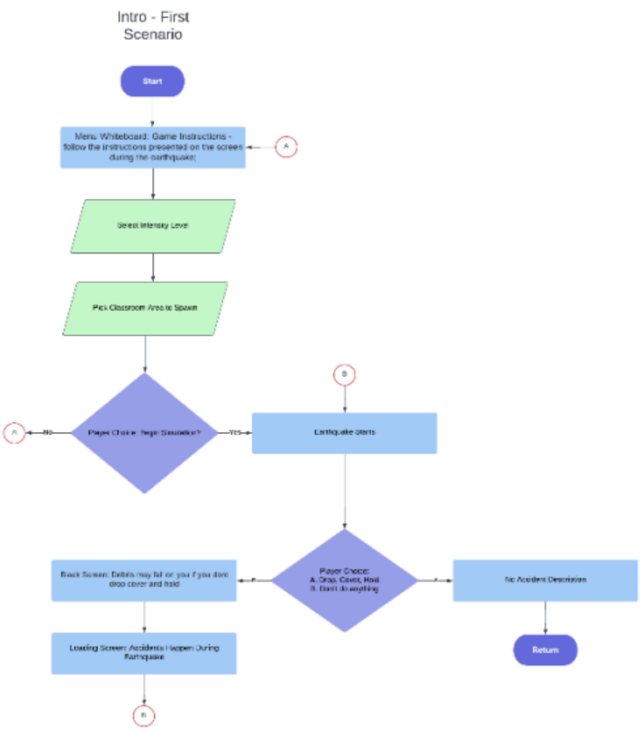

Figure 10: Intro – First Scenario Gameplay Flowchart.

The above figure is the first scenario flowchart. To initiate the earthquake simulation, you must first select an intensity level, a classroom area in which the earthquake should occur, and a simulation option. Alternatively, you may choose to either display, drop, cover, and hold, or do nothing at all. Drop, cover, and hold will prevent an accident from occurring, and the screen will go black, and the loading screen will appear if you do nothing.

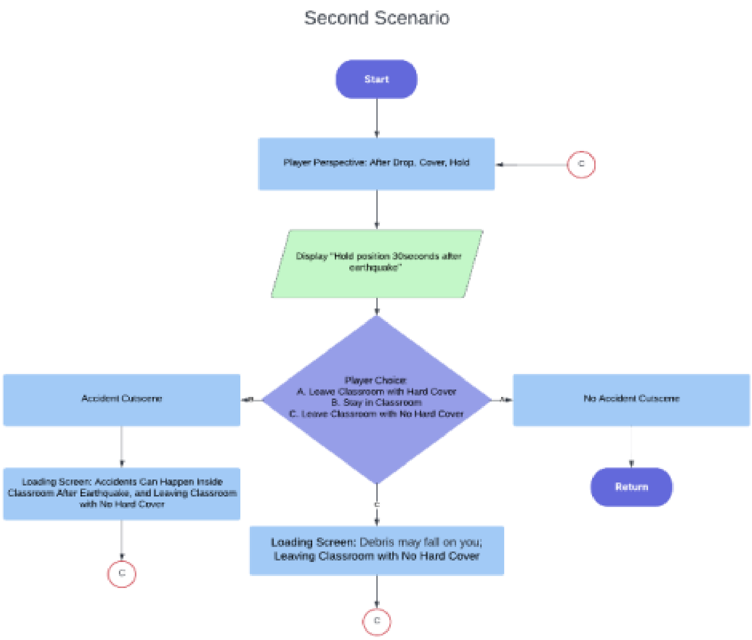

Figure 11: Second Scenario Gameplay Flowchart.

Gameplay from the second scenario is depicted in the figure above. After a successful drop, cover, and hold, the action will shift to the player's point of view. You, the player, will get to decide whether you want to take your textbooks with you when you leave class, stay for the rest of the period, or not take any textbooks with you at all. The first option skips the accident sequence altogether, the second shows a loading screen with falling debris, and the third takes you directly to a cutscene and loading screen depicting the accidents that will inevitably occur.

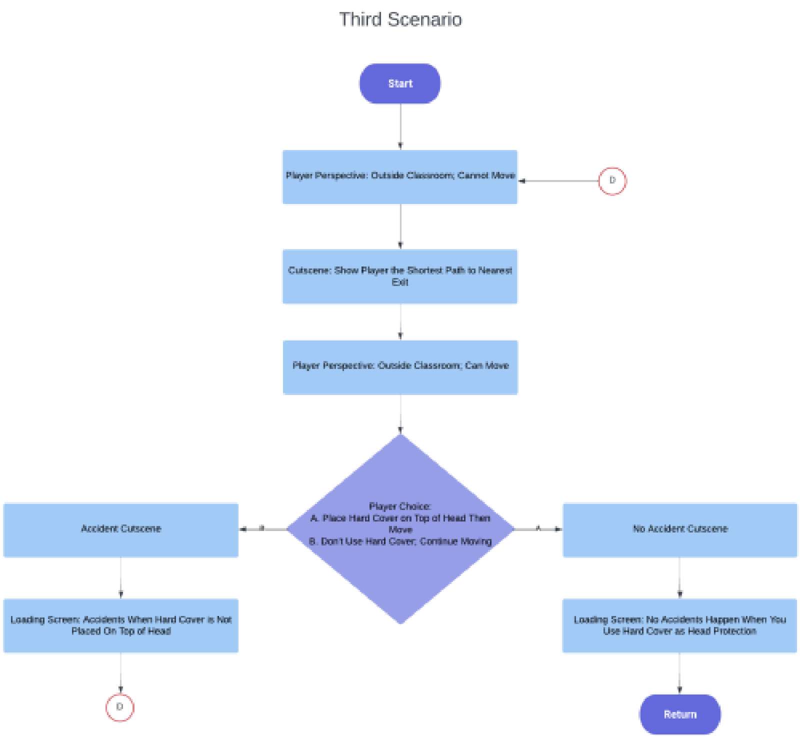

Figure 12: Third Scenario Gameplay Flowchart.

The figure represents the gaming flow for the third scenario. The first part of the game is from the player's point of view, and it takes place in a classroom where you have no freedom of movement. In the scene, the user will be directed to the nearest exit. The next view is from the player's point of view, remaining outside the classroom but with the freedom to wander about. The next step involves deciding whether to utilize a hard cover on top of your head before continuing to move. The former option will skip the accident cutscene before moving on to the loading screen, while the latter will play the accident sequence before taking you to the loading screen.

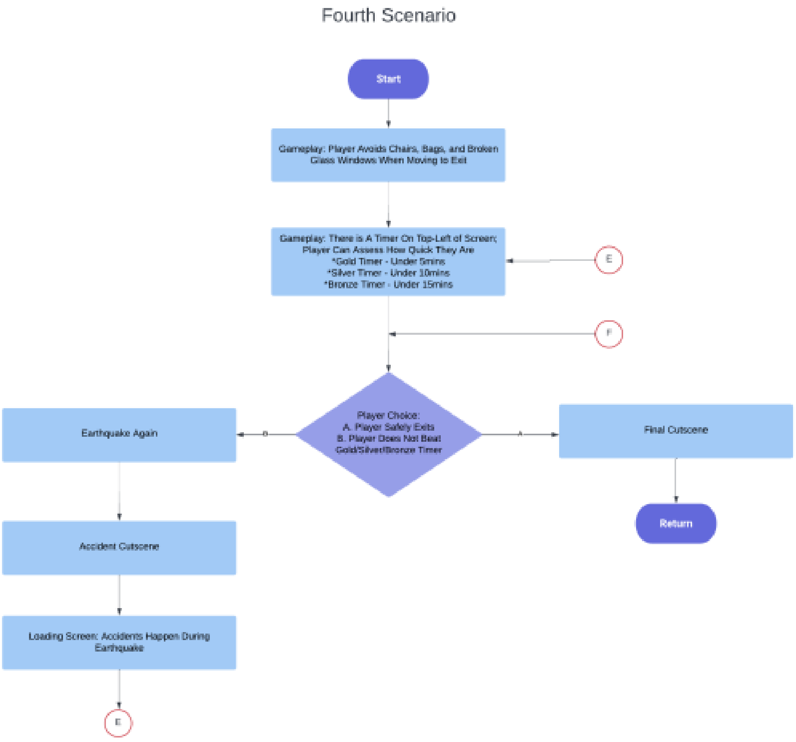

Figure 13: Fourth Scenario Gameplay Flowchart.

The figure above represents the fourth scenario gameplay where the player avoids chairs, bags and broken glass windows when moving to exit. There will also be a Timer on the top-left of the screen where there are timers for under 5, 10, and 15 minutes. There will be a player choice where the user safely exits, or user does not beat the timer. For the first one, you will proceed to the final cutscene then the end. For the second one, there will be an earthquake again, then an accident cutscene and a loading screen where it will show the accidents.

4.4 Evaluation Metrics

The ISO 25010 standard evaluation serves as a valuable tool for software development, particularly in the context of user community elements, which are considered high-level attributes due to their substantial impact on both construction and product acceptability [8]. This standard model provides a framework for establishing criteria to regulate the quality of software products from the perspective of individual responders. However, it requires techniques for eliciting, specifying, analyzing, and validating quality criteria while considering limited resources. A study [9] outlined an approach to mitigate the influence of subjective factors in the assessment by using an established evaluation method based on objective product criteria. In this study, we followed the system evaluation process guided by the ISO 25010 model. The respondents assessed and rated the system using a 5-point Likert scale questionnaire that examined the following attributes based on ISO requirements for standard software development: (1) Functional Suitability - the system is sufficiently adaptable to handle a wide range of hardware, software, and operational settings; (2) Performance Efficiency - the system is capable of achieving the specified level of performance; (3) Usability - the system allows the users better control with its wide range of characteristics and capabilities to accomplish a goal in a specific context of use; and the following table displays the verbal interpretation of the Likert ratings.

Table 1: Likert Scale for System Evaluation.

Rating	Mean Range	Verbal Interpretation
5	4.51-5.0	Excellent
4	3.51-4.50	Very Good
3	2.51-3.50	Satisfactory
2	1.51-2.50	Fair
1	1.00-1.50	Poor

In addition, the researchers briefed the respondents on the purpose of the study and demonstrated how to mark the Likert scales by marking the area corresponding to the rating for each performance indicator based on ISO standards. According to Table 1 of this study, respondents will be drawn from the College of Engineering and Technology's Pamantasan ng Lungsod ng Maynila, which presently enrolls 656 Information Technology students in the first semester of the academic year 2022-2023. The researchers of this study will collect information from students of Information Technology using techniques of convenience sampling. Convenience sampling is possibly the simplest sampling technique, as participants are picked solely on their availability and desire to participate [10].

5. Results

Following the ISO 25010 standard, the table below displays and defines the weighted mean for the sub-characteristics of Functional Suitability, Performance Efficiency, and Usability. It presents findings from evaluations by one hundred (100) respondents.

Table 2: Overall Mean for the Sub-Characteristics under Functional Suitability.

Sub-Characteristics	Weighted Mean	Verbal Interpretation
Completeness	4.63	Excellent
Correctness	4.59	Excellent
Appropriateness	4.55	Excellent
AVERAGE	**4.59**	**Excellent**

As shown in Table 2 above, it is evident that, on average, respondents who evaluated the developed system based on the Functional Suitability criteria responded with an "Excellent" rating, achieving a notable weighted mean score of 4.59. These high scores across the sub-characteristics indicate a strong performance in terms of Functional Suitability. The "Completeness" sub-characteristic achieved a particularly high rating of 4.63, indicating that the system's ability to handle a wide range of tasks was perceived as excellent by the participants. Similarly, the "Correctness" and "Appropriateness" sub-characteristics received scores of 4.59 and 4.55, respectively, emphasizing the system's effectiveness in executing tasks accurately and appropriately. This data reflects a robust and well-accepted functionality of the system in fulfilling its intended purpose. These impressive results affirm the success of the system's Functional Suitability, which is crucial for its overall performance and user satisfaction.

Table 3: Overall Mean for the Sub-Characteristics under Performance Efficiency.

Sub-Characteristics	Weighted Mean	Verbal Interpretation
Time-behaviour	4.46	Very Good
Resource Utilization	4.33	Very Good
Capacity	4.41	Very Good
AVERAGE	**4.40**	**Very Good**

As indicated in Table 3, respondents who evaluated the developed system based on Performance Efficiency criteria, on average, responded with a "Very Good" rating, resulting in a notable weighted mean score of 4.40. These results reflect the system's commendable performance in terms of Performance Efficiency. Specifically, the "Time-behavior" sub-characteristic achieved a weighted mean score of 4.46, indicating that respondents found the system's response time and behavior to be highly effective. The "Resource Utilization" sub-characteristic received a rating of 4.33, signifying that the system efficiently utilizes resources. Similarly, the "Capacity" sub-characteristic was rated at 4.41, suggesting that the system effectively handles its expected load. These findings affirm that the system performs exceptionally well in terms of Performance Efficiency, ensuring that tasks are completed efficiently, resources are used optimally, and the system can handle the expected workload. Such high ratings in these sub-characteristics demonstrate the system's effectiveness and responsiveness, factors critical to user satisfaction and overall performance.

Table 4: Overall Mean for the Sub-Characteristics under Usability.

Sub-Characteristics	Weighted Mean	Verbal Interpretation
Appropriateness Recognizability	4.56	Excellent
Learnability	4.59	Excellent
Operability	4.56	Excellent
User Error Protection	4.32	Very Good
User Interface Aesthetics	4.53	Excellent
Accessibility	4.50	Very Good
AVERAGE	**4.51**	**Excellent**

In Table 4, it presents the Overall Mean for the sub-characteristics related to Usability. On average, respondents who evaluated the system based on Usability criteria responded with an "Excellent" rating, yielding a notable weighted mean score of 4.51. These results emphasize the system's commendable performance in terms of Usability. Specifically, the sub-characteristics indicate strong performance in various areas. "Appropriateness Recognizability," "Learnability," and "Operability" scored notably high, each receiving an "Excellent" rating. These sub-characteristics demonstrate that the system is well-suited, easy to recognize, and simple to learn and operate. While "User Error Protection" and "Accessibility" received "Very Good" ratings, indicating that the system effectively safeguards against user errors and ensures accessibility for a diverse user base. The "User Interface Aesthetics" sub-characteristic achieved a rating of 4.53, reflecting that the system's visual appeal is appreciated by users.

These results collectively indicate that the system excels in Usability, ensuring a positive user experience by providing appropriateness, learnability, operational ease, and an aesthetically pleasing interface. Such high ratings in these sub-characteristics affirm the system's overall excellence in Usability and user satisfaction.

6. Conclusion and Recommendations

6.1 Summary of Findings

The findings of the researchers based on the comprehensive evaluation of the Earthquake Simulation Application using earthquake simulation software, were indeed impressive. The application effectively achieved its primary objective of educating students about the correct procedures to follow and discouraging inappropriate behavior during and after an earthquake. Furthermore, the software successfully modeled the structures of Pamantasan ng Lungsod ng Maynila, providing users with a realistic understanding of potential earthquake-related events.

In alignment with the ISO 25010 standard, the researchers collected evaluation results from one hundred (100) respondents. The outcomes were remarkable, with the earthquake simulation application receiving high praise across multiple dimensions. In terms of Functional Suitability, it achieved a weighted mean score of 4.59 out of 5 on the Likert Scale, indicating its high suitability for its intended purpose. Moreover, the application excelled in terms of Usability, receiving a weighted mean score of 4.51 on the Likert Scale, signifying excellent usability. The researchers observed that the application's Performance Efficiency was also very good, with an overall weighted mean of 4.40.

6.2 Conclusions

In conclusion, the earthquake simulation application has effectively imparted crucial guidance on the "drop, cover, and hold" procedure to students. Clear objectives delineating appropriate actions during an earthquake have yielded significant results. Among the 100 respondents, 28% successfully completed the procedure, while 26% initially erred but subsequently rectified their actions, underscoring the application's success in providing valuable instructions. Moreover, the inclusion of specific objectives assisted users in identifying inappropriate actions, with 35 individuals adhering to the recommended guidelines. The researchers conclude that users will recognize their prior misconceptions and enhance their earthquake preparedness through repeated simulations. The application's capacity to enable users to revisit previous stages and refresh their memory serves as a valuable learning tool, allowing them to comprehend both building layouts and the correct sequence of actions during an earthquake.

6.3 Recommendations

Based on the evaluation data, we recommend that future researchers focus on further refining the "drop, cover, and hold" objectives to provide more precise instructions. Additionally, it is advisable to integrate user movement tracking within the simulation to validate the proper placement of signage within the university premises. Expanding the simulation to encompass various buildings within Pamantasan ng Lungsod ng Maynila will enhance students' familiarity with campus structures. This expansion also presents an opportunity to offer guidance on recommended actions and behavior within specific buildings, as well as optimal signage placement based on population activities.

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