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Cawangan Melaka

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College of Computing, Informatics, and Mathematics
Universiti Teknologi MARA Cawangan Melaka, Kampus Jasin
77300, Merlimau, Melaka Bandaraya Bersejarah

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EDITORS

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PREFACE

Welcome to the inaugural volume of the **Progress in Computing and Mathematics Journal (PCMJ)**, a publication proudly presented by the College of Computing, Informatics, and Mathematics at UiTM Cawangan Melaka.

This journal represents a significant step in our commitment to fostering a vibrant research culture, initially providing a crucial platform for our undergraduate students to showcase their intellectual curiosity, dedication to scholarly pursuit, and potential to contribute to the broader academic discourse in the fields of computing and mathematics. However, we envision PCMJ evolving into a beacon for researchers both nationally and internationally. We aspire to cultivate a space where groundbreaking research and innovative ideas converge, fostering collaboration and intellectual exchange among established scholars and emerging talents alike.

The manuscripts featured in this first volume, predominantly authored by our undergraduate students, are a testament to the hard work and dedication of these budding researchers, as well as the guidance and support provided by their faculty mentors. They cover a diverse range of topics, reflecting the breadth and depth of research interests within our college, and set the stage for the high-quality scholarship we aim to attract in future volumes.

As editors, we are honored to have played a role in bringing this journal to fruition. We extend our sincere gratitude to all the authors, reviewers, and members of the editorial board for their invaluable contributions. We also acknowledge the unwavering support of the college administration in making this initiative possible.

We hope that PCMJ will inspire future generations of students and researchers to embrace research and innovation, to push the boundaries of knowledge, and to make their mark on the world of computing and mathematics.

Editors
Progress in Computing and Mathematics Journal (PCMJ)
College of Computing, Informatics, and Mathematics
UiTM Cawangan Melaka

TABLE OF CONTENTS

LIST OF EDITORS ..... **iii**

PREFACE ..... **iv**

TABLE OF CONTENTS ..... **v**

SIMPLIFIED DRONE GAME FOR INITIAL REMEDIAL INTERVENTION FOR DYSPRAXIA AMONG KIDS 1

DEVELOPMENT OF STORAGE BOX WITH AUTOMATED AND REMOTE LOCK CONTROL SYSTEM IN WLAN ENVIRONMENT 16

COMPARATIVE ANALYSIS OF PASSWORD CRACKING TOOLS 29

SPORT FACILITIES FINDER USING GEOLOCATION 50

READ EASY AR: INTERACTIVE STORYBOOK FOR SLOW LEARNER 60

MATHMINDSET: GAME-BASED LEARNING TO REDUCE MATH ANXIETY 87

NETWORK PERFORMANCE ANALYSIS ON DIFFERENT ISP USING ONLINE CLASS PLATFORM ON DIFFERENT DEVICES 101

CIVIC HEROES; ENHANCING CIVIC AWARENESS THROUGH GAME-BASED LEARNING 115

ENHANCING COMMUNITY SQL INJECTION RULE IN INTRUSION DETECTION SYSTEM USING SNORT WITH EMAIL NOTIFICATIONS 124

LEARNING ABOUT MALAYSIA THROUGH GAME 138

STUDENT CHATROOM WITH PROFANITY FILTERING 150

ARCHITECTURE BBUILD AND DESIGN BUILDING THROUGH VIRTUAL REALITY 162

VEHICLE ACCIDENT ALERT SYSTEM USING GPS AND GSM 174

MARINE ODYSSEY: A NON-IMMERSIVE VIRTUAL REALITY GAME FOR MARINE LITTER AWARENESS 187

GAME BASED LEARNING FOR FIRE SAFETY AWARENESS AMONG PRIMARY SCHOOL CHILDREN 207

SIMULATING FLOOD DISASTER USING AUGMENTED REALITY APPLICATION 220

CRITICAL THINKER: VISUAL NOVEL GAME FOR BUILDING CRITICALTHINKING SKILLS 231

POPULAR MONSTER: 239

FIGURE SPRINTER: EDUCATIONAL ENDLESS RUNNING GAME TO LEARN 2D AND 3D SHAPE 252

AR MYDREAMHOUSE: AUGMENTED REALITY FOR CUSTOMISING HOUSE 265

RENTAL BIKE SERVICES WITH REAL TIME CHAT ASSISTANCE 308

IDOBI: IOT INTEGRATED SELF-SERVICE WASHING MACHINE RESERVATION SYSTEM WITH CODE BASED BOOKING TOKEN 321

TRADITIONAL POETRY OF UPPER SECONDARY STUDENTS VIA MOBILE APPLICATION 332

A MOBILE TECH HELPER RECOMMENDATIONS APPLICATION USING GEOLOCATION WITH AUTOMATED WHATSAPP MESSENGER..... 347

TURN-BASED ROLE-PLAYING GAME BASED ON MUSIC THEORY 370

FADTRACK: DEVELOPMENT OF VEHICLE TRACKING SYSTEM USING GPS 384

MENTALCARE: GAME-BASED LEARNING ON MENTAL HEALTH AWARENESS 397

HALAL INTEGRITY INSPECTOR:..... 411

MOBILE APPLICATION FOR REAL TIME BABY SIGN LANGUAGE RECOGNITION USING YOLOV8..... 434

TRAVEL TIME CONTEXT-BASED RECOMMENDATION SYSTEM USING CONTENT-BASED FILTERING 448

DETECTION SYSTEM OF DISEASE FROM TOMATO LEAF USING CONVOLUTIONAL NEURAL NETWORK 460

VIRTUAL REALITY (VR) FOR TEACHING AND LEARNING HUMAN ANATOMY IN SECONDARY SCHOOL..... 471

LEARNING KEDAH'S DIALECT VIA GAME-BASED LEARNING 490

AUTOMATED FACIAL PARALYSIS DETECTION USING DEEP LEARNING 504

ENHANCING CRIMINAL IDENTIFICATION: SVM-BASED FACE RECOGNITION WITH VGG ARCHITECTURE..... 517

WEB BASED PERSONALIZED UNIVERSITY TIMETABLE FOR UITM STUDENTS USING GENETIC ALGORITHM..... 528

SMART IQRA' 2 MOBILE LEARNING APPLICATION 545

ANIMAL EXPLORER: A WALK IN THE JUNGLE..... 557

FOOD RECOMMENDATION SYSTEM FOR TYPE 2 DIABETES MELLITUS USING CONTENT-BASED FILTERING 569

WEB-BASED PERSONAL STUDY HELPER BASED ON LESSON PLAN USING GAMIFICATION 580

DIETARY SUPPLEMENT OF COLLABORATIVE RECOMMENDATION SYSTEM FOR ATHLETE AND FITNESS ENTHUSIAST..... 596

AUTOMATED HELMET AND PLATES NUMBER DETECTION USING DEEP LEARNING 611

VIRTUAL REALITY IN MATHEMATICAL LEARNING FOR SECONDARY SCHOOL..... 622

VIRTUAL REALITY (VR) IN CHEMISTRY LEARNING FOR SECONDARY SCHOOLS STUDENTS 634

GOLD PRICE PREDICTION USING LONG SHORT-TERM MEMORY APPROACH 651

ARTQUEST: A VIRTUAL REALITY ESCAPE ROOM FOR LEARNING ART HISTORY LESSONS..... 664

FIRE SURVIVAL: A FIRE SAFETY GAME USING GAME- BASED LEARNING..... 675

ANIMALAR: AN INTERACTIVE TOOL IN LEARNING EDUCATIONAL ANIMAL KINGDOM THROUGH AUGMENTED REALITY 690

PCMJ

Progress in Computer and Mathematics Journal (PCMJ)
volume 1 [October, 2024]
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FIRE SURVIVAL: A FIRE SAFETY GAME USING GAME-BASED LEARNING

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Abstract

Traditional fire safety methods, like evacuation drills, struggle to create realistic environments, hindering skill development for real emergencies. Online platforms, including videos and quizzes, may result in poor knowledge retention due to the challenge of applying theoretical knowledge to actual emergencies. This project is a non-immersive virtual reality (NIVR) game that Game-Based Learning (GBL) elements to educate individuals on fire safety. The target users are individuals interested in learning about fire safety. The project uses the Game Development Life Cycle (GDLC) model that ensures a structured framework for smooth project progression. Usability testing outcomes show a high 87.8% satisfaction level across learnability, effectiveness, efficiency, and satisfaction. The score surpasses the 80% score, indicating good and satisfactory usability performance. This suggests the application is suitable for learning about fire safety.

Keywords: fire safety; game-based learning; virtual reality; education; usability testing

INTRODUCTION

Hazards, whether arising from natural phenomena or human activities, have the potential to endanger human lives and cause damage to structures and property. Natural disasters such as earthquakes, hurricanes, and floods happen as a result of natural processes can result in significant damage and casualties. Man-made hazards, stemming from human activities like industrial accidents, can have severe consequences. Among these hazards, fire, a man-made hazard, poses a serious threat to lives, buildings, property, and the environment. Fire safety involves procedures to prevent the spread and control the effects of fires, whether accidental or intentional (Kodur, V., Kumar, P., & Rafi, M. M., 2020). Fire hazard identification, evacuation through fire drills, and the use of fire safety equipment are some of the examples of the measures that are involved in fire safety.

Evacuation drills serve as a methods to educate people about fire safety, aiming to prepare them for real-life emergencies (Menzemer, L. W., Ronchi, E., Karsten, M. M. V., Gwynne, S., & Frederiksen, J., 2023). However, actual fire emergencies are not included in the traditional fire evacuation drills (Kwegyir-Afful, E., 2022). The effectiveness of fire drills relies on their ability to closely mimic reality, offering simulated experiences in controlled environments. However, creating realistic environments for various emergency drills, including fires, poses challenges. The lack of a sense of reality in these environments can lead to drawbacks (Chen, S. Y., & Chien, W. C., 2022). The absence of realism in fire drills may hinder skill development and response mechanisms during actual fire incidents. Enhancing the sense of presence in simulations, as suggested by Iriye and St. Jacques (2021), may improve memory accuracy. Thus, immersion in a realistic fire drill environment may enhance retention of fire safety information. The visualization of three-dimensional spaces in Virtual Reality (VR) offers a realistic and engaging learning environment for simulating fire incidents (Somerkoski, B., Oliva, D., Tarkkanen, K., & Luimula, M., 2020).

Another way to learn fire safety is through conventional means like seminars, lectures, and non-interactive materials (Zakaria, S., Ahmad, D., Abdan, K., & Rafee, M., 2019). However, these methods have limitations as they primarily delivering information passively, which challenges people in envisioning the application of their knowledge in real emergency situations. The drawbacks include poor knowledge retention, a lack of enthusiasm, and low engagement (Abbas, A., Seo, J., Ahn, S., Luo, Y., Wyllie, M. J., Lee, G., & Billinghurst, M., 2023). To address these limitations, game-based learning (GBL) offers an interactive and engaging learning experience that goes beyond conventional knowledge delivery. GBL helps learners focus better, pay closer attention, and become more interested (Bhat, A. Z., Ahmed, I., Kameswari, L., & Khan, M. S., 2023). By incorporating interactive elements and virtual simulations, GBL provides an alternative approach to fire safety education, making the learning process more enjoyable and efficient.

The purpose of this project is to create an interactive game by employing game-based learning approach for educating people about fire safety, offering an alternative method of learning about fire safety. This application offers a game scenario where players confront various obstacles and challenges inside a building structure, requiring them to complete these challenges to escape and finish the game while inadvertently learning about fire safety. Through this gameplay, players acquire basic fire safety measures, preparing them for potential

fire emergencies. The game imparts fundamental fire safety measures, enhancing people's readiness in emergency situations. Therefore, people can acquire knowledge of fire safety in a new interactive way through the application.

LITERATURE REVIEW

Fire Safety

Fire is one of the emergency situations that can occur at any time or place, leading to damages and severe outcomes ranging from property loss to fatalities. Unfortunately, a significant contributing factor to fire-related casualties and injuries is the insufficient personal fire safety knowledge among the general public (Lovreglio, R., Duan, X., Rahouti, A., Phipps, R., & Nilsson, D., 2021). Fire safety encompasses a set of practices used to prevent the spread of fire and mitigating their effects, whether unintentionally or on purpose (Kodur et al., 2020). Educating people on fire safety becomes crucial to impart essential knowledge about potential fire hazards and preventive measures such as fire hazard identification, evacuation drills, and the use of safety equipment.

A. Fire Hazard Identification

Fire risk assessment procedures involve the systematic and regular identification of potential fire hazards that pose a threat to people, along with developing strategies to minimize these hazards and save lives (Hassanain, M. A., Al-Harogi, M., & Ibrahim, A. M., 2022). According to Yuan, C., He, Y., Feng, Y., and Wang, P. (2018), fire hazards can be caused by environmental factors, building structures, and human actions. Predicting fire hazards serves as the initial stage in implementing fire safety measures, forming the basis for decisions on actions to reduce risks associated with fires (Rzaij, W. A., & Al-obaidi, B. H. K., 2022). Identifying fire hazards are a fundamental aspect of fire safety, involving the recognition of potential factors capable of generating heat or sparks which can increase the risk of fire ignition. Knowledge about identifying fire hazards empowers people to take proactive measures to prevent fires. Common fire hazards include electrical hazards, flammable substances, and cooking hazards.

B. Fire Evacuation

Another step in fire safety measures is fire safety training, which includes various activities such as learning how to use fire extinguishers, understanding evacuation procedures, and implementing emergency evacuation plans (Shokouhi, M., Nasiriani, K., Cheraghi, Z., Ardalan, A., Khankeh, H., & Fallahzadeh, H., 2019). Fire drills are essential to this training as fire drills simulate real-world fire emergencies, enabling learners to practice and test their reactions in a secure environment. Fire drills are primarily intended to familiarize participants with the evacuation process and impart fundamental concepts of fire safety. Moreover, fire evacuation drill helps to understand people's actions and responses during fire emergencies (Bourhim, E. M., & Cherkaoui, A., 2020). Participation in these training programs equips individuals with the skills necessary to respond effectively to fires and ensure their own safety. Table 1 shows the steps of building evacuation procedures.

Table 1: Steps of Building Evacuation Procedures

Steps	Actions
1	Activate the fire alarm
2	Call the emergency responders and provide information
3	Exit the building following emergency maps
4	Assist others if it is possible to a secure area
5	Do not use the elevators
6	Stay low if confronted with smoke
7	Stay away from the building until it is safe to return

C. Fire Safety Equipment

A fire extinguisher is one of the fire safety equipment designed to combat small fires effectively. It is a portable tool containing extinguishing agents tailored to extinguish different classes of fires. Early-stage fires can often be extinguished with the proper tools and their correct use (Lovreglio et al., 2021). Fire extinguishers are crucial tools in the early stages of a fire when the fire is still manageable, allowing people to suppress or control the fire before it spreads. Understanding how to use a fire extinguisher is essential for basic fire safety due to its simple design and ease of use, making it a significant tool for extinguishing flames (Y. Chen, 2020). Possessing adequate knowledge about fire extinguisher, including their proper usage, is important for people to be prepared for emergency situations. Table 2 shows the procedures using fire extinguisher.

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Table 2: Procedures using Fire Extinguisher

Action	Description
Pull	Pull the pin of the fire extinguisher
Aim	Aim the nozzle at the base of the fire
Squeeze	Squeeze the handle of the fire extinguisher
Sweep	Sweep the nozzle side to side

Game-Based Learning (GBL)

Game-based learning involves using computer and video games designed to achieve learning outcomes (Mohanty, A., Alam, A., Sarkar, R., & Chaudhury, S., 2021). Qian and Clark (2016) define game-based learning as achieving predetermined learning outcomes through gameplay and enhancing learning through problem-solving scenarios and challenges, providing learners with a sense of accomplishment (Krath, J., Schürmann, L., & von Korflesch, H. F. O., 2021). This results in learners to better remember and apply essential information in real-life situations. By incorporating game-based learning into the lesson plan, educational tasks can be integrated into a gaming environment, offering learners the opportunity to acquire information in a fun yet serious learning environment. Table 3 shows the game-based learning elements and its description.

Table 3: Game-based Learning Elements

Elements	Description
Goal	The objective in the game.
Rule	A set of guidelines that manages the game's internal structure.
Feedback	The textual information sent to players in response to their actions.
Challenge	A challenge that is part of a game that has a range of difficulty depending on the player's skill, knowledge, and game advancement.
Narrative	The foundation for a player's participation in the game. The storyline is necessary for learning to take place.
Interactive	A connection or reaction involving either the player and the game environment or the player and other players.

Prensky has modified the three conventional game components of rule, goal, and feedback into six different categories which are rule, goal, feedback, interaction, challenge, and narrative. The application of these components depends on the game's structure, including its concept and design (Yunus, E., & Zaibon, S. B., 2021). Overall, the game integrates these elements to offer players an optimal learning experience, enabling them to engage in gameplay

while simultaneously acquiring lessons and knowledge about fire safety through game-based learning method.

Adventure Game

Adventure games are games that typically contain a story that drives the gameplay and are typically linked to a quest-like structure (Qaffas, 2020). The player's connection with the virtual world created by the adventure game is central to its gameplay functions. Players aim to complete specific objectives, facing challenges that the protagonist must overcome, with the focus on the character's storyline (Tassya Nindyapratama, L., & Aziz Ahmad, H., 2021). Normally, players assume the role of a protagonist navigating a fictional universe, unraveling mysteries, solving puzzles, and advancing the storyline. Introducing the adventure game genre into the proposed application allows people to explore a virtual environment, enhancing player engagement in the learning process.

Non-immersive Virtual Reality (NIVR)

Alternately, a simulation can be played on a regular display through non-immersive virtual reality (NIVR). In NIVR, users manually adjust the viewing orientation using tools such as a computer mouse and keyboard, a smartphone, or a tablet. NIVR creates a partial digital environment without complete isolation from the outside world. The user is aware of their actual surroundings without feeling physically present in the virtual environment (Omlor, A. J., Schwärzel, L. S., Bewarder, M., Casper, M., Damm, E., Danziger, G., Mahfoud, F., Rentz, K., Sester, U., Bals, R., & Lepper, P. M., 2022). The main benefit of using NIVR is the simulation can be utilized without the need for specialized equipment, offering users a more portable and affordable option for virtual experiences. However, the drawback of NIVR is that it may not provide the same level of sensory engagement and immersion as immersive virtual reality (IVR), potentially reducing the sense of presence and participation. Nevertheless, NIVR still offers beneficial possibilities for various applications, giving users a more convenient way to explore the virtual world. This project proposes the development of a non-immersive virtual reality game for individuals interested in learning about fire safety, aiming to provide an alternative and interactive way for them to gain information about fire safety.

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METHODOLOGY

Game Development Life Cycle (GDLC)

The methodology employed for this project is the Game Development Life Cycle (GDLC), a model designed for the development of video games. The GDLC is a game development methodology adapted from the Software Development Life Cycle (SDLC) (Roedavan, R., Pudjoatmodjo, B., Siradj, Y., Salam, S., & Hardianti, B. Q. D., 2021). However, in the real world of game development, relying solely on the SDLC model is insufficient. To address this limitation, game development organizations utilize the GDLC to guide game development (Dhawale, S. A., & Dubey, K., 2019). Due to the straightforward processes, the GDLC is regarded as the most suitable method for creating video games (Husniah, L., Pratama, B. F., & Wibowo, H., 2018). Recognized for its ease of understanding and implementation, this model proves suitable for various types of game production. Figure 1 shows the GDLC model and the stages of the methodology.

Figure 1: Phases in GDLC Model

Figure 1 shows the Game Development Life Cycle (GDLC) process sequence. According to Irfan Ainul Afif Refnaldi (2023), there are six stages in the GDLC: initiation, pre-production, production, testing, beta, and release (Ainul, I., Refnaldi, A., Kusuma, P. D., & Dinimaharawati, A., 2023). The methodology used for this project is Game Development Life Cycle (GDLC) as it provides a structured framework that allows for the systematic development of the game and ensuring that the project progresses smoothly.

Use Case Diagram

In the second phase of the GDLC model known as pre-production, the focus is on shaping the game concept and designing the game design that involves the creation of use case diagrams based on the developed game concept. The use case diagrams serve as a description of the player's interactions within the game, outlining the player's journey through different scenarios to achieve the game's objective. Figure 1 shows the use case diagram for the game.

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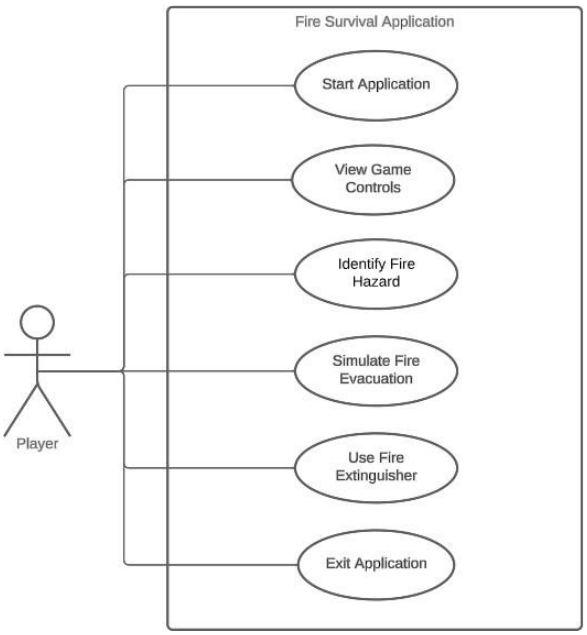

Figure 2: Use Case Diagram

Six use cases are shown in Figure 2 along with the actor, the user, also referred to as the player. The first use case is when the user first launches the application. In the second use case, when users start the game, they encounter information showing the gameplay controls. The third use case focuses on identifying fire hazards, where the user receives learning notes and engages in quiz challenges related to recognizing fire hazards. The fourth use case involves simulating fire evacuation, where the user learns about fire evacuation procedures, answers related questions, and simulates escaping from a burning building. In the fifth use case, use fire extinguisher, the user learns the proper steps to use a fire extinguisher and participates in a drag and drop challenge related to using the equipment. Finally, the last use case involves the user exiting the game and closing the application.

Usability Testing

In beta testing phase, the game is made available to a selected group of external users for usability testing. Usability testing focuses on assessing how well users can use the system to accomplish their intended goals (Sunday, K., Oyelere, S. S., Agbo, F. J., Aliyu, M. B., Balogun, O. S., & Bouali, N., 2022). Insights obtained from usability testing are important in refining the game's design, functionality, and overall usability before its final release. Usability evaluation involves the collection of information about the system's usability using methods such as thinking aloud, field observations, and questionnaires, providing insights into user

perspectives (Hariyanto, D., Triyono, M. B., & Köhler, T., 2020). Jacob Nielsen, a usability expert, defines usability based on attributes like learnability, efficiency, memorability, errors, and satisfaction (Tuena, C., Pedroli, E., Trimarchi, P. D., Gallucci, A., Chiappini, M., Goulene, K., Gaggioli, A., Riva, G., Lattanzio, F., Giunco, F., & Stramba-Badiale, M., 2020). According to Raffi and Halim (2023), Nielsen has defined the five usability attributes as following:

1. Learnability is measured by how familiar users become with the system they are using.
2. Efficiency is defined by how quickly a user can complete a task after learning the design.
3. Memorability is defined by how easily users can regain proficiency when the user returns after a period of not using it.
4. Error is measured by the number and severity of errors users make and how easily they can recover from them.
5. Satisfaction is measured by how pleasant users find the experience of using the design.

Weichbroth (2018) adds that usability, according to ISO 9241-11 and the expert reviews by Bevan, is evaluated based on measures of effectiveness, efficiency, and satisfaction. Additionally, Weichbroth mentioned that Brian Shackel further explains that effectiveness in a system is all about how smoothly it works, considering factors like speed, error handling, and task versatility. This includes how easy it is to learn and use the system, as well as how it performs across various activities. Therefore, a thorough usability evaluation requires the consideration of multiple attributes and the evaluation questionnaire specifically focuses on learnability, effectiveness, efficiency, and satisfaction.

RESULT AND DISCUSSION

The Fire Survival application is developed for individuals interested in learning fire safety, and it is open to the public with no age restrictions. The assessment involved 15 participants spanning various age groups, including those below 18, between 18 to 25, and 26 and above. Participants received an introduction to the study's objectives, the game application, and its features, along with instructions on operation. Each participant received a laptop to play the game and was encouraged to seek assistance if needed. After completing the game,

participants filled out a questionnaire using a 5-point Likert Scale, consisting of four usability attributes which are learnability, effectiveness, efficiency, and satisfaction. Feedback from all participants was documented and analysed, with mean scores calculated for each attribute. The analysis results are summarized in Table 4, presenting the mean percentage values for questions covering the usability attributes from the questionnaire.

Table 4: Percentage of Overall Mean

Usability Attributes	Percentage of Mean (%)
Learnability	86.4
Effectiveness	89.0
Efficiency	87.1
Satisfaction	88.7
Percentage of Overall Mean	**87.8**

Table 4 displays the average levels of satisfaction or agreement for each usability attribute, along with the overall satisfaction across all attributes. On average, a majority of respondents positive evaluations for the game application concerning learnability, effectiveness, efficiency, and satisfaction. As indicated in Table 4, the overall mean score for usability testing score is 87.8%, signifying a generally high satisfaction level across all four usability attributes. According to the Nielsen Usability Test, a score surpassing 80% is commonly regarded as "good" and satisfactory (Jono, M. N. H. H., Samah, K. A. F. A., Nasir, Z. M., Saad, S., Latif, W. A., & Kamarudin, N. A., 2023).

CONCLUSION

In conclusion, this research highlights the limitations of traditional and online fire safety education methods and introduces an innovative solution, which is a non-immersive virtual reality game using game-based learning elements. The goal of this research is to develop a fire safety game using game-based learning on the PC platform, offering a virtual environment that simulates fire emergency scenarios. The Fire Survival application is significant for its innovative approach to educating individuals about emergency safety measures, particularly during fire outbreak. Through simulated scenarios, the game allows people prepare for various fire safety challenges, enabling them to practice decision-making and critical thinking in a secure virtual space. The integration of VR technology in fire safety education aligns with facilitating learning and practicing fire safety skills, allowing people to interact with virtual scenarios and understand the consequences of their actions. Additionally, incorporating game-

based learning enhances learning experience, capturing, and maintaining people's attention throughout the process of acquiring fire safety knowledge. The success of the Fire Survival game development indicates its potential as an effective tool for fire safety education, with room for future improvements such as expanding language options, considering diverse platforms, and exploring immersive VR experiences.

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