Universiti Teknologi MARA
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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
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VIRTUAL REALITY IN MATHEMATICAL LEARNING FOR SECONDARY SCHOOL

DANIAL IMRAN BIN SULASTREE
College of Computing, Informatic, Mathematic, danialimrano11@gmail.com

DR. CHEW CHIOU SHENG
College of Computing, Informatic, Mathematic Branch, cschew@uitm.edu.my

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Abstract

A persistent gap exists in the comprehension of high school mathematics education due to various challenges, including limited instructional materials, insufficient equipment, and a lack of effective visual aids during the learning process. To address these obstacles, a proposal for a 3D simulation game utilizing the Simulation-Based Edutainment Model within the ADDIE methodology has been put forward to foster deeper learning among students. Virtual Reality (VR) in Mathematical Learning for Secondary School Students employs the systematic approach of the ADDIE Model to analyze, design, develop, implement, and evaluate VR applications tailored for mathematical education. Adopting the ADDIE Model as a methodology aims to create a VR learning experience that is both instructive and engaging, serving as a viable alternative method for mathematical education. An evaluation of usability, conducted through the System Usability Score (SUS) questionnaire, yielded positive results with a score of 87.25%, underscoring the efficacy of the Virtual Reality application in enhancing mathematical learning outcomes for high school students. Future work that could be demonstrate was a VR's potential in learning mathematics for all ages, highlighting the importance of accessibility, privacy, and user experience in designing more learning methods.

Keywords: virtual reality, mathematics education, secondary school, VR- based learning platform, simulations, interactive scenarios, functionality test, system testing, fully immersive virtual reality, and SUS questionnaire.

INTRODUCTION

Math is essential for producing new generations of professionals capable of addressing the issues posed by volatility, uncertainty, complexity, and ambiguity (VUCA). However, research indicates students who study mathematics may need help using their skills outside of the classroom (Vos, 2018). Model Eliciting Activities (MEA), which encourage

the contextualization of mathematics, have been created to solve this problem (Dede et al., 2017). MEAs support students in making connections between mathematical models and actual issues, which can inspire mathematical thinking and the development of creative solutions. Practical learning activities also help university students develop the ability to evaluate their solutions and determine their importance critically. Because it encourages relatedness and autonomy, contextual mathematics is an effective teaching method that can raise students' motivation to study. Furthermore, research indicates that knowledge is acquired deeper when learning situations promote inquiry, experimentation, and critical thinking. This learning environment can also enhance motivation and support lifelong learning (Peña- Becerril et al., 2023).

Learning is a lifelong process of observation supported by evidence and put into practice through applications. Globalization and subsequent technical advancements have also had an impact on traditional education. E-learning has developed into an accessible, affordable, and technologically advanced teaching approach that enables thousands of students to learn and develop their abilities. Encouraging techniques have allowed teachers and students to get closer and strengthen the relationship between the two parties involved in providing education. Virtual Reality education is a novel approach that has been embraced by many universities worldwide to deliver instruction and provide students with a unique experience. It is founded on constructivism, which is concerned with learning through experience (Banerjee et al., 2013).

Virtual reality (VR) technology can significantly improve education in mathematics, mainly because it gives students access to a safe and controlled environment to explore and study. To ensure that students are comfortable and supported while they engage with mathematical concepts, instructors can carefully tune the amount of 14 complexity and detail in virtual content using VR. In this secure environment, students can freely explore and experiment with mathematical concepts, which promotes a pleasant learning environment (Häfner et al., 2018).

Furthermore, the use of VR in mathematics education provides students with immersive, interactive experiences that help them learn math ideas better. Students can participate in practical exercises that vividly illustrate abstract mathematical ideas through virtual manipulatives, simulations, and visualizations. They have the ability to work with geometric shapes, see mathematical changes, and communicate with dynamic mathematical models in three dimensions. These engaging activities encourage active learning, develop

spatial thinking abilities, and deepen conceptual knowledge. Additionally, students' attention is captured and they are inspired to actively participate in mathematical assignments by VR's engaging character, which increases interest, enjoyment, and achievement in the subject (Häfner et al., 2018).

LITERATURE REVIEW

Mathematics in Secondary School

The term "knowledge of science" in ancient Greek is where the name "mathematics" originates. The spatial forms and the quantitative interactions between them are the focus of mathematics. Students are taught this set of mathematical knowledge using specific techniques. The Greek word "methodology" means "way"; "method" is the root of the word. A significant shift in the subject matter of teaching mathematics has resulted from the school's decision to focus on current learners and their educational objectives. The instructor must be proficient in both the subject matter and the methods used to teach secondary school students to do it successfully (Mirzaxolmatovna and Fozilov., 2021).

One of the topics that will be learned by secondary school students is SI prefixes. The calculation is one of the most crucial abilities people employ to address challenges they come across. It is claimed that although we frequently perform mental calculations in our daily lives, we occasionally use specific tools (a paper pencil, calculator, or computer). Some illiterate people could calculate the money in their daily lives using creative mental calculation techniques. Furthermore, a study showed that although kids who peddle with their parents on the streets have trouble with school math, they could mentally calculate without making a mistake by coming up with various answers to the same questions that were rephrased as street math (Ulu and Ozdemir., 2018).

Type of Teaching and Learning Style for Mathematics

The need for the development of an adaptive learning platform that can analyze and visualize the student's performance to recommend educational concepts and personalize the teaching method for each student is driven by the imbalanced teacher and student ratio and the teacher's inability to deal with the strengths and weaknesses of every student. Every system has its primary objective of assisting the student in establishing objectives and providing assistance

when required. Because every student has a unique learning style, there are differences in learning styles and patterns between students. Their learning style characterizes a user's psychological and cognitive behavior during the learning phase.

Therefore, an exemplary system not only suggests concepts based on knowledge level but also the kind of learning materials that will aid the student in learning or developing a skill in the most efficient ways possible (Sharma, 2017).

Table 1: Comparisons on the Type of Teaching and Learning Style for Mathematics

Key Aspects	**Gamified Learning**	**E -Learning**	**Virtual Reality**
Description	Incorporates game techniques and components into the educational process.	The application of technology and the internet for learning scenarios.	Immersion simulation in computer-generated surroundings
Academic experience	Interactive, interesting, and playing video games	Online, with both synchronous and asynchronous options	Extremely realistic and concentrated, giving a sense of presence
Engagement	Incorporates gaming components including points, badges, and leaderboards	Consists of interactive multimedia content as well as communication tools.	Enables users to control virtual worlds and objects
Educational design	Emphasizes game mechanics, difficulties and player growth	Uses a variety of pedagogical techniques and e-learning strategies	Immersive and engaging experiences, can make learning is improved
Evaluation	Includes gamified evaluations and feedback mechanisms	Provides online tests, exams, and feedback tools	May provide real-time evaluation and feedback in virtual environments.
Availability and adaptability	Accessible through a variety of electronics (computers, tablets, and cellphones)	Accessible from any location that has an internet connection	Requires appropriate equipment and VR headsets
Educational material	Includes a variety of topics, including mathematics	Covers a variety of topics and issues	Suitable for a variety of academic areas and real-world simulations
Interest and immersion	Motivates more through the use of rewards and game mechanics	Uses multimedia engagement techniques and instructional design to engage students.	Makes an individual feel present and emotionally involved

Cooperative learning	Can have both collaborative and competitive characteristics.	Encourages cooperation through forums and group projects	Allows for cooperative interactions in shared virtual areas
Growth potential	Capable of supporting an extensive number of users	Can hold a huge number of students in online classes	Restricted by the lack of VR equipment and funding
Budget and resources	Cost-effective yet requires the development of gamified material	Requires use of digital resources and e-learning platforms	Requires use of digital resources and e-learning platforms

Based on the comparisons in Table 1, gamified learning provides interactive and exciting experiences, although creating gamified content can need more resources. Although e-learning depends on technology resources and platforms, it offers flexibility, accessibility, and evaluation tools. Although virtual reality (VR) offers a compelling emotional experience, its deployment may be constrained by financial and resource issues. When utilizing any approach, it is essential to consider its benefits and drawbacks.

Fully Immersive Virtual Reality

Virtual reality (VR) systems and Fully Immersive Virtual Reality (FIVR) offer a realistic virtual experience in a surround-sound setting. The user needs a VR headset or a Head Mounted Display (HMD) with small screens in front of each eye to provide a bi-visual or monocular image to experience and interact with the FIVR system. VR headsets offer vast fields of view and highly definition digital content. The immersive training and education sectors are among the many showing much interest in this type of VR, which has been modified for VR gaming and enjoyment 29 (Radhakrishnan et al., 2021).

Related Work

Numerous approaches and procedures have been devised, analyzed, and compared to see which has the best functionality and recognition precision of the developed system. This topic will cover the research on how virtual reality can be used to enhance secondary students' learning of mathematics.

Table 2: Comparison Among Three Studied Related Work

Aspect	**Virtual Reality (VR) with Brainwave Sensor**	**Augmented Reality (AR) Technology**	**Virtual Reality (VR)**
Purpose	Interactive Math's Game	Learn Cube Expansion Diagram in Spatial Geometry	STEM Education, Simulation, and Assessment
Main Technologies used	Virtual Reality, Brainwave Sensor	Augmented Reality (AR)	Virtual Reality (VR)
Learning Focus	Math's game and brainwave interaction	Cube expansion diagram in spatial geometry	STEM education and exceptional children
Target Audience	Not specified	Elementary school students	Students with intellectual disabilities
Key Features	Integration of brainwave sensor and VR	Visualization and interaction in spatial geometry	VR-based educational Resources
Research Methods	Experimental study, mixed methods design	Pre or post-tests, questionnaires, interviews	Systematic design, school-based textbooks
Findings and Evaluations	Not mentioned	Influence of academic achievement on learning	Enhancement of knowledge acquisition
Technology Application in Education	Interactive math learning, rehabilitation	Teaching spatial geometry, removing barriers	Education for exceptional children

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Upon reviewing the literature, it shows that Virtual Reality (VR) outperforms Augmented Reality (AR) in enthusing young students to learn mathematics. Students may fully immerse themselves in the learning environment thanks to VR's immersive experience, which heightens the sense of presence and encourages intense engagement. Students can interact physically with mathematical ideas thanks to the interactive manipulation of virtual objects in virtual reality, which helps them develop multisensory learning. Additionally, the visualization skills of VR successfully convey abstract mathematical concepts in a concrete and understandable way and also aid with comprehension.

METHODOLOGY

The methodology is explained in this part, highlighting its importance in directing the study's approach to data gathering and accomplishing the research goals. It focuses on developing the system architecture, identifying the hardware and software requirements, and creating user interfaces according to the requirements from the analysis and design stages. Figure 1 illustrates the flow of the development process as it gives a general idea of the actions that must be taken one after the other to carry out the recommended project from the beginning to the end.

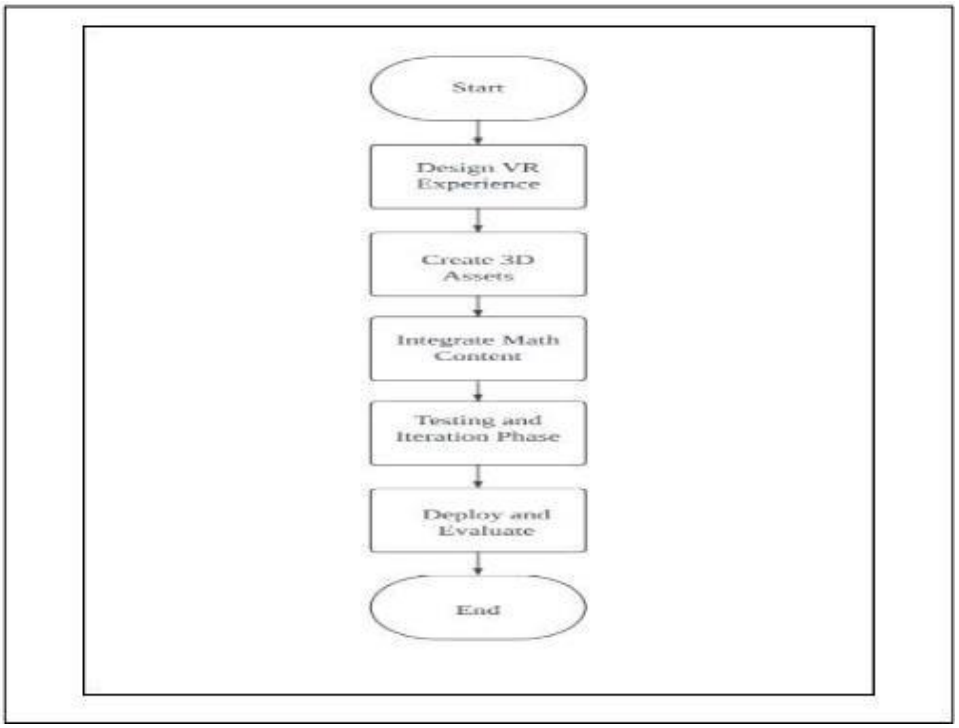

Figure 1: Flowchart of the research

The hardware specifications required to construct this project are shown in Table 3 and Table 4. The performance of the used hardware will be average. The hardware and system software are the two main components in creating the system. Table 3 shows hardware requirement for laptop and Table 4 shows hardware requirement for VR setup.

Table 3: Hardware Requirements for Laptop

Hardware	Specification
Laptop Model	Asus ROG GL552VW
Operating System	Windows 10
Processor	Intel i7-6700HQ
Memory (RAM)	12.00 GB
Graphic Card (GPU)	NVIDIA GTX960M 2GB
Storage	SSD 500 GB

Table 4: VR Hardware Requirements

Hardware	Specification
VR Setup	Quest 2 VR Headset Quest 2Controller
Tracking	Supports 6 degrees of freedom (6Dof)
Memory (RAM)	6GB LPDDR5 RAM
Chipset	Qualcomm Snapdragon XR2 (7 nm), Adreno 650
Audio	Built-in stereo speakers and microphone, 3.5mm audio jack, support for 3D audio
Storage	256GB

TESTING & EVALUATION

Ten questions measuring agreement on a statement comprise the System Usability Scale (SUS) questionnaire. A value between 1 and 5 is assigned to each response. According to Guerci (2020), it states that even things (2, 4, 6, 8, and 10) should remove five points from their score, and odd items (1, 3, 5, 7, and 9) should only receive one point. Add each

respondent's item scores and multiply the result by 2.5 to get their overall score. Add together all of the respondents' complete scores to find the average. Table 5 shows the survey:

Table 5: SUS Questionnaire

No	Function
1	This VR application is easy to use
2	I cannot finish tasks and scenarios quickly with this VR application
3	I feel comfortable when using this VR application.
4	I think I cannot get things done fast with this VR application.
5	If I make a mistake, it's easy to fix quickly with this VR application
6	The messages on the screen and the papers that come with this VR application are hard to understand
7	The information helps me do tasks and scenarios well with this VR application
8	The interface of the VR application looks bad and hard to use.
9	This VR application has all the functions and capabilities I expect it to have
10	The VR application operates with noticeable disruptions, frequently getting stuck and exhibiting sluggish performance

For this suggested project, the ADDIE Model was used in order to produce a suitable project result within the given time frame. ADDIE is a method that might fulfil every need and primary objective of the project. Caution must be given at each ADDIE step to prevent errors and development problems. Then, Unity and other key programmes and processes will be employed. These are the best resources for developing game-based learning applications that might increase efficiency and effectiveness.

RESULT AND DISCUSSION

The study's assessment and testing phase focused on to determining the system's usability and functionality. Functionality testing entailed assessing the software application's numerous features and functionalities to make sure they fulfilled the requirements and functioned as intended. In order to cover scenarios like normal operation, boundary conditions, and error handling, test cases were created. All tested functionalities functioned as predicted, according to the functionality test results, which are shown in Table 6.

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Table 6: Functionality Test Results

No	Function	Expected Output	Actual Output
1	Start button at menu page	After clicking, app will start.	Pass
2	Exit button at menu page	After clicking, app will end	Pass
3	Setting button at menu page	After clicking, app will open setting Page	Pass
4	About button at menu page	After clicking, app will open about page.	Pass
5	Task 1: Walk to video room	User should be able to walk to the video room	Pass
6	Task 2: Walk to display information	User should be able to walk to the display information	Pass
7	Task 3; Enter Mini Puzzle	User should be able to enter mini puzzle	Pass
8	Task 4: Grab interactable	User should be able to grab the interactable .	Pass
9	Task 5: Put the interactable into the correct place	User should be able to grab and place the interactable to the correct places.	Pass
10	Task 6: Lifting the trophy after completing the puzzle	User should be able to grab and hold the trophy	Pass

The System Usability Scale (SUS), which consists of ten questions scored on a 5- point scale, is a commonly used questionnaire to assess how usable a system is regarded to be. The feedback from participants produced an above-average SUS score of 87.25 in the evaluation for Virtual Reality in Mathematical Learning for Secondary School, suggesting good usability. Although the SUS offers a fast and accurate way to assess usability, it might not be able to identify some usability issues, which suggests that other evaluation techniques should be used in combination with it to provide a deeper understanding of a system's usability.

In conclusion, the immersive and engaging platform provided by the Virtual Reality in Mathematical Learning education tool which is based on the Unity game engine, secondary

school mathematics instruction has been enhanced. In order to accommodate diverse learning styles and handle common classroom challenges, the project integrates various teaching approaches. Despite several drawbacks, such as platform exclusivity and performance issues, the project establishes a solid foundation for ongoing enhancement by appreciating user input and iterative development. In the future, the emphasis will be on investigating the potential for multiplayer cooperation and enhancing realism with visual elements such as physical algebra representations. Through cutting-edge technology, this effort marks a massive leap in revolutionizing mathematics teaching by giving students real-world, engaging learning experiences.

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