Combined the Mixed Reality Technology in Design an Interactive Learning Environment

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Abstract

Currently, atomic energy plays a crucial role in science education, industry, and research. Nonetheless, persistent safety concerns about nuclear power predominantly stem from a lack of comprehensive comprehension of nuclear energy and radiation. The study sought to deepenstudents' understanding of nuclear power by delivering essential knowledge about nuclear energy and its safety considerations. To achieve this, e-learning platforms were used to provide detailed scientific information on the Tsing Hua Open-Pool Reactor (THOR). This resource provided students with opportunities to deepen their knowledge of nuclear power. Utilizing a quasi-experimental approach, the research assessed how the Nuclear Energy 3D eBook influenced user engagement with three-dimensional educational content. The results provide insight into the practical application of THOR. This research produced three primary findings: firstly, it established an interactive educational setting for nuclear energy instruction,employing a standardized approach utilizing mixed reality; secondly, it utilized mixed reality technology to reinforce fundamental scientific knowledge; and thirdly, it validated mixed reality via quasi-experimental techniques to support users in gaining practical field expertise within a digital educational context.

Keywords: Nuclear education, Augmented reality, THOR, Serious game

1. Introduction

Today, due to the popularity of wireless cable, telecommunication, PDAs and iPads, and broadband wireless mobile phones, marketing advantages can be seen anytime, anywhere. Currently, the United States, Taiwan, and numerous other nations across Europe and Asia are delving into materials that prioritize digital content. Research suggests that individuals demonstrate heightened perseverance and drive when seeking information online in contrastto conventional and digital sources [1]. However, effectively locating information aboutnuclear technology on the internet poses challenges for users [2]. The 3D eBook is emerging as an essential multimedia tool for future learning environments. This research is dedicated to A 3D eBook on Nuclear Energy, delving into its educational potential and the creation of an Augmented Reality (AR) integrated 3D eBook. Moreover, introducing a mobile platform to assist educators in tracking and analyzing student learning behaviors through the nuclear energy 3D eBook is a promising idea. The features of this 3D eBook, combined with the application of virtual 3D products, can make it easier for students to understand nuclear energy concepts.

Currently, the United States, Taiwan, and numerous other nations across Europe and Asia are delving into materials that prioritize digital content. Studies indicate that users exhibit greater persistence and motivation when searching for information on the internet comparedto traditional and online sources [3]. However, effectively locating information about nuclear technology on the internet poses challenges for users [2]. A 3D eBook emerges as a crucial multimedia tool for the future. As a result, this study focuses on A 3D eBook on Nuclear Energy, investigating its educational advantages and the integration of Augmented Reality (AR) technology in its design and development. Furthermore, the introduction of a mobile platform is proposed to help educators monitor and evaluate student learning behaviorsthrough the nuclear energy 3D eBook. The functionalities of the 3D eBook, combined with virtual 3D products, are provided to assist students in deepening their understanding ofnuclear power concepts.

2. Literature Review

In recent years, augmented reality (AR) technologies have garnered significant interest inthe scientific community [4-5]. Numerous studies have examined the latest advancements in AR technology, systems, and applications [6]. AR merges real-world elements with creative and media components. AR is a combination of virtual objects and the real environment. AR enhances an individual's perception of reality by enabling interactions with virtual elements [7]. It is a new technology that integrates reality with creativity and the media world. To fully understand AR, it is better to first consider Virtual Reality abbreviated as VR, a computer-simulated environment with which users can interact and gain feedback, as though they experience the real world. By employing technologies like 3D graphics, tactile feedback systems, or sound input and output devices, users can immerse themselves in highly visual,3D environments. Virtual Reality (VR) encompasses computer-simulated environments that replicate real-world and imaginary settings, enabling users to interact with these environments.

Milgram (1994) proposed a “Reality Virtuality Continuum”, consolidating the theoreticalbasics of AR’s development. AR broadens that basic to VR, adding the experience of a real environment. Milgram classified AR according to its presentation [8]. In regard to reproduction fidelity, the fidelity of the simulation is closely related to the computer’s graphic capacity. However, for immediate presentation, high definition is difficult to achieve using current techniques. In terms of the Extent of Presence Metaphor, Milgram stated current technology remains low-end. The Extent of Presence Metaphor is closely related to the degreeof immersion [9]. There are at least three features for AR: (1) it integrates reality with virtuality, (2) it allows immediate interaction and (3) it operates in a 3D environment. Superimposition is not the only advantage of AR. The difficulty lies in the immersion of the “real” and the “virtual”, in which the correctness of information is affected. In AR, the “real”, the “virtual” and the “connection”, are all interrelated.

A fundamental necessity in constructing an Augmented Reality (AR) system involves seamlessly blending the real with the virtual. Numerous studies have focused on minimizing registration errors of virtual objects and enhancing their realism [10]. To address occlusion issues encountered by a dynamic virtual target, the proposed method calculates 3D information at the specific point of concern [11]. This study aimed to cooperate with industry, to integrate AR with marketing, improve function, and allow innovation. This approach enabled the government to enhance its marketing and industrial policies while offering guidance to users. In this strategy-driven educational method, mobile-based e-book digital content was employed in this paper to facilitate learning about nuclear energy, specifically using the Tsing Hua Open-pool Reactor [12]. A concept map is a graphical illustration that shows the relationships between different concepts. Engaging in concept mapping can enhance a learner's metacognitive awareness during information processing, thereby assisting them not only in establishing suitable monitoring strategies but also in enhancing the utilization of retrieval and memorization techniques [13-21].

Is concept mapping an effective strategy for improving reading proficiency among learners at all levels? Novak et al. (1983) suggested that learners of all types can derive benefits from employing conceptual mapping [13]. Seaman (1990) and Wu and Zeng (2003) showed that users with higher proficiency levels exhibited enhanced reading comprehension skills when using concept mapping, as opposed to those with lower proficiency levels [22-23]. Nevertheless, Guastello (2000) and Lipson (1995) discovered that concept mapping strategies provided more significant benefits to students with lower proficiency levels [24-25]. For students with intermediate and lower abilities, learning various concept mapping strategies is more effective in organizing information and enhancing comprehension compared to traditional reading methods. However, while the aforementioned studies suggest that concept mapping strategies benefit students at all or specific proficiency levels, Chen (1998) contended that concept mapping did not enhance students' reading comprehension or summarization skills. Hence, the employment of concept maps to aid students in organizing information is advocated [26].

Mixed Reality (MR) visual displays represent a distinctive virtual reality (VR) technology that integrates the real and virtual worlds along the "virtual continuum," seamlessly bridging completely real environments with entirely virtual ones [9]. These technologies encompass mobile devices like phones and tablets, offering mobility and enhanced camera perspectives, as well as physical interfaces and immersive environments that blend virtual and physical elements, collectively known as "mixed reality." The term "Mixed Reality Learning Environment" (MRLE) is used to describe such systems [27]. This paper showcases a mixed reality learning environment (MRLE) developed through a mobile interface and motor testing platform, aimed at enhancing understanding of dynamic systems and control concepts. Virtualreality (VR) and augmented reality (AR) are increasingly embraced in medical applications such as medical education, training, surgical simulation, neurological rehabilitation, psychotherapy, and telemedicine. Surgical simulation employing virtual reality technology involves training through simulated surgeries combined with 3D virtual models [28-29]. Augmented reality technology is utilized in projecting 3D models of human organs formedical education [30]. Viewing FMRI's 3D images with virtual glasses has been shown to enhance clinical training and surgical skills [31].

Since the 1990s, several special issues on Augmented Reality have been published in journals including Communications of the ACM, Presence: Teleoperators and Virtual Environments, Computers and Graphics, and International Journal ofHuman-Computer Interaction. The Horizon Report highlights Augmented Reality (AR)for enhancing perception by overlaying information on

3D spaces, providing unique experiences [32]. Combining computer-generated models of anatomical structures with specialized software introduces new ways of interacting with anatomy, beyond traditional cadaver dissection or static image methods [33]. Cheng and Tsai [32] analyze AR's role in science education through a review of articles from the Web of Knowledge and Scopus databases spanning 2004 to 2023, identifying 12 significant studies [32]. They explore AR's features, educational applications, participant demographics, and effectiveness in science education. Additionally, Ibáñez and Carlos conduct a systematic review on AR's support for STEM education. A specific study on AR and VR notes that text usage in these technologies can impact reading speed, suggesting users may need an additional 10% interaction time with text in VR and AR applications [34]. Augmented Reality (AR) systems offer the advantage of embedding or superimposing information onto reality, facilitating the presentation of medical knowledge that closely mirrors reality and provides avenues for innovative and interactive learning environments. Users can spatially correlate virtual objects with their surroundings [35].

Text learning is a reader-dependent and it offers just text information. Multimedia learning can offer instructional message containing textual and pictorial information. However, the multimedia learning is in a sequenced order. The processes can link the organized informationto prior knowledge. The VR environment has a low-cost advantage and it has good feedback with users. Augmented reality-based simulation, enhanced with feedback, enables more realistic interactions without relying on costly and often insufficient models. Mixed reality technology has attracted considerable attention. They deliver immersive and interactive experiences via head-mounted devices [36]. Applications of mixed reality include autonomous driving [37], displaying clothing collections in museums with specific constraints and requirements [38], and providing visual real-time feedback in golf [39]. While most immersive learning research has focused on outcomes, fewer studies have addressed the educational practices and strategies essential for providing a theoretical and pedagogicalframework. This framework is necessary to contextualize outcomes where technology aligns with educational methods. Thus, this research incorporates mixed reality in nuclear energy education to enhance learning.

3. Research Architecture

The use of nuclear energy is indeed a highly controversial issue, with both positive and negative impacts, affecting the global environment and every living being. Therefore, the implementation of nuclear energy education is crucial, enabling every citizen to have sufficient knowledge of nuclear energy, radiation protection awareness, and the ability tomake informed decisions on whether to use nuclear energy.

In this regard, designing an augmented reality (AR) app for nuclear energy education is ahighly innovative approach. AR technology can allow learners to understand relevant knowledge about nuclear energy more intuitively and interactively, enhancing the funand effectiveness of learning. Here are some suggestions and key points for the design of a nuclear energy education AR app. This chapter summarize the main findings of this study, discuss the theoretical and practical implications, and propose suggestions for future research.

In research conclusions, regarding the impact of mixed reality technology on learning outcomes, this study found that the experimental group using mixed reality technology significantly outperformed the control group using traditional teaching methods. The average post-test scores of the experimental group were significantly higher than those of the control group, indicating that mixed reality technology helps improve learning outcomes. In learning satisfaction and interaction experience, questionnaire survey results showed that the experimental group scored higher in both learning satisfaction and interaction experience compared to the control group. Students generally believed that mixed reality technology made the learning process more interesting and interactive, which helped to increase learning motivation and engagement. In technology acceptance, the research results indicated that bothstudents and teachers had a high acceptance of mixed reality technology, considering it easy to operate and significantly enhancing classroom teaching effectiveness.

In theoretical implications， the research confirmed the potential of mixed reality technology in education, supporting the theory of technology-assisted teaching, and demonstrating that advanced technological tools can promote active learning and deep learning among students.

About Practical Implications, Teachers should actively explore and use mixed reality technology, integrating it into classroom teaching to enhance classroom interactivity and student learning outcomes. Teachers should also receive relevant technical training to master the operation and application of mixed reality technology proficiently. For Educational Institutions: Educational institutions should strengthen investment in mixed reality technology, equip schools with related equipment and software, and provide professional development opportunities for teachers to improve overall teaching quality.

In Research Limitations, the research has some limitations. First, the subjects were limited to students from a single university, making the sample scope narrow, and the results might not be generalizable. Secondly, the study duration was short, preventing observation of the long-term impact of mixed reality technology on learning outcomes.

In suggestions for future research, future research can expand the sample range toinclude students of different ages and disciplines to validate the findings of this study.Additionally, long-term follow-up studies are recommended to observe the long-term effects of mixed reality technology on student learning outcomes. Moreover, the application of other advanced technologies in education, such as artificial intelligence and augmented reality, can also be explored.

In summary, this chapter has summarized the main findings of this study, discussed the theoretical and practical implications, made recommendations for teachers and educational institutions, and highlighted the limitations of the research and future research directions. Thisstudy demonstrates the significant role of mixed reality technology in enhancing learning outcomes and learning satisfaction, providing empirical support for the application of educational technology.

1. **Core Knowledge Modules**: Including basic knowledge of nuclear energy, the working principles of nuclear reactors, and the nuclear fuel cycle.
2. **Radiation Protection**: Explaining types of radiation, their effects on the human body, and how to effectively protect against radiation.
3. **Applications and Controversies of Nuclear Energy**: Introducing various applications of nuclear energy, such as power generation and medical uses, while also discussing the risks and

controversies, including nuclear waste disposal and nuclear accidents.

4. **Interactive Simulations**: Using AR technology to allow users to simulate the operation of a nuclear reactor, understanding the actual process of nuclear energy.
5. **Case Studies**: Presenting historical nuclear accidents and successful applications ofnuclear energy, helping users to comprehensively understand the pros and cons of nuclear energy.
6. **Tests and Evaluations**: Designing tests and evaluation mechanisms to assess users' mastery of nuclear energy knowledge, and providing feedback and suggestions.

Through these features and modules, this app can help users gain a comprehensive understanding of nuclear energy, enhance radiation protection awareness, and rationally consider the issue of using nuclear energy. The objective of the education on nuclear energy isto offer user interfaces that foster inclusive design, aiming to enhance the interactive experience for users as depicted in Figure 1.

Figure 1. THOR in Real-World Applications

This study comprises four modules. The system encompasses the History of THOR, nuclear theory, an overview of the THOR structure, and the applications of THOR, asillustrated in Figure 2.

1. History of THOR (Since 1961~): This module offers a comprehensive examination of THOR's historical development, current status, significant achievements, and its wide range of applications.
2. Nuclear Theory: This module delves into complex subjects such as nuclear fissionreactions, different types of neutron-involved reactions, and the practical uses and significance of nuclear reactors, specifically THOR.
3. **THOR Structure**: Using AR technology to allow users to simulate the operation of a nuclear reactor, understanding the actual process of nuclear energy. This section details the key components of THOR, including basic knowledge of nuclear energy, the working principles of nuclear reactors, and the nuclear fuel cycle.
4. **Applications**: This part emphasizes the main uses of THOR, including boron-neutroncapture therapy (BNCT), and neutron radiography. Presenting historical nuclear accidentsand successful applications of nuclear energy, helping users to comprehensively understand the pros and cons of nuclear energy.

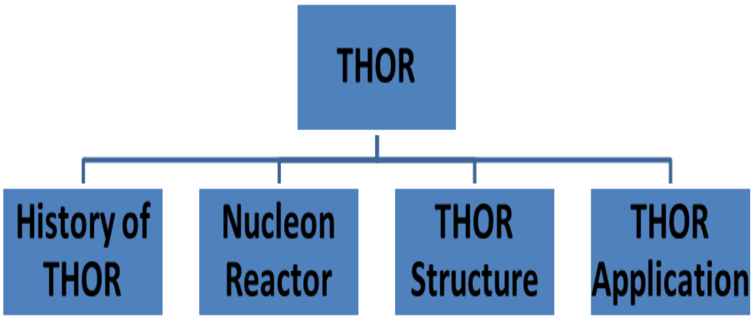

Figure 2. The nuclear energy education design.

THOR APP was deployed to assist students in monitoring their study habits related to specific questions. The user interface features four key conceptual areas alongside ten questions. Within the app, students can explore content and maneuver through pages pertinentto the subject matter. The app meticulously logs each user's search history, including visited pages, to facilitate further analysis, as illustrated in Figure 3.

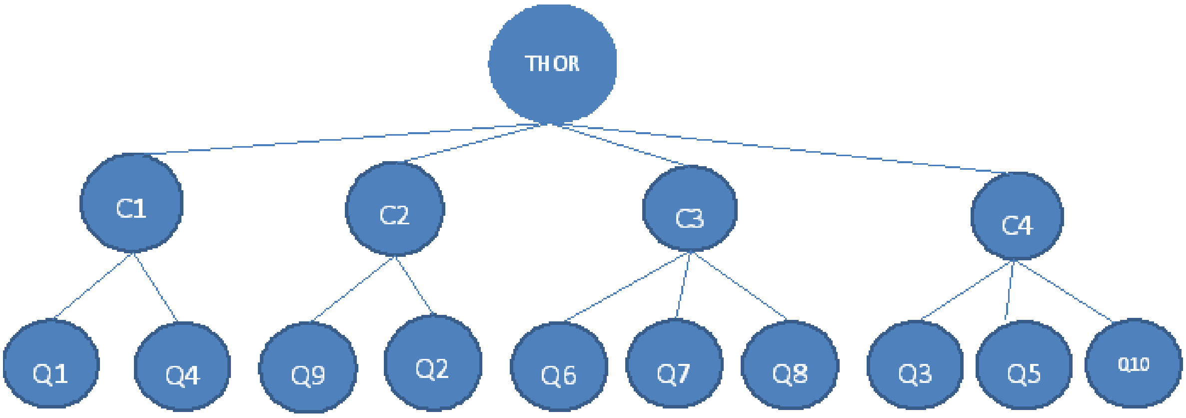

Figure3. The nuclear energy quiz’s map modules design.

4. Experimental Evaluation

The system architecture is built using Maya, Java, OpenGL, and Android 4.2. This part details the system’s framework and its operational setting. The application of AR and APPtechnologies in this project fulfills two main objectives:

1. AR is used not for simulation purposes but for its capacity to integrate with various media types. Although frequently confused with simulation due to similar features, itstrue function is focused on media integration.
2. The implementation of "Adaptive" technology in AR development is crucial due to thecomplexity of AR systems, which involves advanced tracking methods, visual simulation, digital synthesis, and interface management.

Using AR technology to allow users to simulate the operation of a nuclear reactor, understanding the actual process of nuclear energy and figure 4 illustrates the operational results. An ID card is used to activate the nuclear energy 3D eBook. Furthermore, Figure 5 demonstrates the deployment of the nuclear energy 3D eBook on a mobile platform using AR technology, featuring video content, 3D models, and animations.

Figure 4. The nuclear energy 3D eBook.

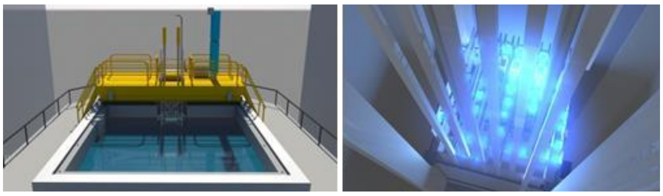

Figure5. UsingARtechnologyin nuclear energy

4. Experiments and Discussion

This study utilized a quasi-experimental research method. Our goal is to achieve a deeperinsight into specific learning styles and forms of participation that could improve learning performance, thereby assisting in the creation of future programming language learning environments.

For consistency in the study, both the experimental and control groups were instructedby the same teacher. Table 1 presents the mean and standard deviation (SD) values ofpre-tests and post-tests for the experimental group. A homogeneity test of within-class regression was conducted for a nuclear energy course, revealing pre-test and post-test mean values (standard deviation) of 31.8 (23.878) and 66.4 (23.969), respectively.

Table 1. Mean (standard deviation) values of pre-test and post-test scores.

	Pretest Mean(SD)	Posttest Mean(SD)
Experimental Somatosensory Technology Group	31.8(23.878)	66.4(23.969)
ChatGPT		

The impact of using printed textbooks on programming comprehension scores in the posttest was analyzed using a one-way ANCOVA, with adjustments made for variations inthe pretest scores. Assumptions were verified before conducting the ANCOVA. A significantinteraction was observed between programming comprehension in the pre-test (used as the covariate) and the use of the printed textbook method (independent variable) (F = 4.793, *p* = .013). Table 2 illustrates the impact of the THOR APP method on post-test scores, analyzing the interaction effect with gender.

Table 2 displays the ANCOVA results pertaining to the interaction effect.

Source of variance	Type III SS	df	MS	F	*p*
Corrected model	4769.226[a]	2	2384.613	4.793	.013
Intercept	54417.315	1	54417.315	109.380	.000
Pretest	1657.443	1	1657.443	3.332	.074
Gender	2811.971	1	2811.971	5.652	.022
Error	23382.774	47	497.506		
Total	248600.000	50			
Corrected total	28152.000	49			

* $p<0.05$; R^2 =.169

5. Conclusions and Future Work

This chapter summarize the main findings of this study, discuss the theoretical and practical implications, and propose suggestions for future research. In research conclusions, regarding the impact of mixed reality technology on learning outcomes, this study found that the experimental group using mixed reality technology significantly outperformed the control group using traditional teaching methods. The average post-test scores of the experimental group were significantly higher than those of the control group, indicating that mixed reality technology helps improve learning outcomes.

While recent research has significantly focused on nuclear safety, there remains a widespread lack of in-depth understanding of nuclear energy among users. To bridge this knowledge gap and enhance understanding of nuclear education, we created A integrative environment on Nuclear Energy by integrating eBook technology with mobile platforms, withthe THOR research reactor serving as a primary example. This initiative is particularlybeneficial due to its introduction of 3D eBook features and the integration of mixed reality technology. The study details the creation of the nuclear energy 3D eBook, with a strong emphasis on incorporating mixed reality to enrich the educational experience. The applicationoffers detailed insights into the history of THOR, nuclear theory, the structure of THOR, and its diverse applications. It also offers essential knowledge about nuclear energy and enhances the ability to produce 3D multimedia digital content. An interactive feature uses paper cardsto depict real-life scenarios or elements related to THOR and the nuclear energy 3D eBook. This research lays the groundwork for establishing standardized methods and data control services for digital storage systems, focusing on the development of service systems and prioritizing data management, stability, and security.

In learning satisfaction and interaction experience, questionnaire survey results showed that the experimental group scored higher in both learning satisfaction and interaction experience compared to the control group. Students generally believed that mixed reality technology made the learning process more interesting and interactive, which helped to increase learning motivation and engagement. In technology acceptance, the research results indicated that both students and teachers had a high acceptance of mixed reality technology, considering it easy to operate and significantly enhancing classroom teaching effectiveness. Intheoretical implications, the research confirmed the potential of mixed reality technology in education, supporting the theory of technology-assisted teaching, and demonstrating thatadvanced technological tools can promote active learning and deep learning among students.

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