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Design and Development of an AR System for Learning 3D Perspective Rendering

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Abstract: *Augmented Reality (AR) has emerged as a promising technology for enhancing learning experiences, particularly in fields that require spatial thinking and visualization, such as product design and other design fields. This study presents the design and development of an AR learning system that aims to facilitate the learning of 3D perspective rendering, a fundamental design course for product design students to demonstrate their ideas. The proposed AR system combines AR capabilities with Alessi and Trollip's Instructional Design model to create an immersive and interactive environment, which allows students to intuitively practice and master the principles of 3D perspective drawing. Through the AR system, students are able to view 3D models of different products superimposed on their physical workspace and provides step-by-step instructions for accurately rendering these models from various perspectives. This study demonstrated the design and development of the AR system and examines the impact of AR on student engagement and learning outcomes. The research findings indicate a significant improvement in both learning outcomes and student engagement.*

Keywords: Augmented Reality, 3D Perspective Rendering, Design Education, Student Engagement

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1. Introduction

With rapid advancements in hardware performance and the widespread availability of 3D content creation tools, 3D computer graphics have become ubiquitous across the web, social media platforms, personal computers, and mobile devices. 3D computer graphics are extensively used across various fields, including marketing, advertising, entertainment, architecture, education, and product design. However, most of the computer graphics content is fixed, with rendering typically following camera paths meticulously defined by 3D graphic artists. The process requires a deep understanding of 3D geometry and for beginners can be challenging and time-consuming (Besançon et al., 2021). On the other hand, 3D perspective rendering—a fundamental skill for product design students — converts 3D objects into visual representations from a specific viewpoint, closely mimicking how the human eye perceives them in real-world perspective. During the rendering creation, students must assess the spatial relationship between three-dimensional objects. This involves determining the scale of objects, their appearance from certain angles, and their interaction with surrounding environmental elements. As a result, product design students often face significant challenges in understanding and mastering 3D perspective rendering.

In addition, students often face numerous challenges when acquiring knowledge through traditional methods like PowerPoint. The challenges presented include, firstly, the abstract nature of projection theory which is difficult to comprehend; secondly, the unclear relationship between 3D object images and their real-world entities; thirdly, the absence of authentic depth perception; and fourthly, the constraints and obstacles in demonstrations and visual representations (Gobert, 2005). Therefore, it is essential to integrate more advanced tools into the teaching processes to assist these students in their 3D drawing learning process such as augmented reality (AR).

Two cutting-edge technologies, virtual reality (VR) and augmented reality (AR), have been developed to allow simulations of experiments or situation that are abstract or complex to facilitate educational activities (Hartman & Bertoline, 2005). AR technology, which enables virtual and real objects to be co-existed, can be used more efficiently in the education and training processes (Matcha & Rambli, 2013). In contrast, VR is created in a completely virtual environment, which means that people need to interact in a virtual environment through VR devices, that lacks the element of physical interaction. The AR technology in mobile applications further advances learning, providing 3D models, videos, and interactive components that make it more engaging for students (Nazeer & Roobini, 2023).

Others than that, today's modern students are the product of a generation that grew up alongside the advancement of information and communication technologies (ICTs) (Salmee & Abd Majid, 2022). AR technology is the tool that can gives them an expectation of a learning experience that is personalized, interactive and engaging. By integrating AR technology into higher education, students will have the ability to keep up with the demands of a technology-driven world, ensuring they have a positive educational experience (D'Angelo, 2018). A deeper understanding and retention of the material, therefore, can be facilitated through hands-on experiences.

Align with, a number of studies have shown the benefits of AR in education realm (Jeffrey & Irizarry, 2020; Feld, 2021; Levy et al., 2024; Li et al., 2024). Despite its potential benefits, AR technology also poses the risk of distraction and cognitive overload. To address this, AR applications must be thoughtfully designed with suitable pedagogical strategies that reduce the chances of overstimulation and cognitive strain (Mohamad Rasli & Rasalingam, 2024). It is crucial to use AR technology responsibly and under the guidance of lecturers to balance its complexity and cognitive demands, ensuring that it enhances the learning experience rather than hindering it.

Objectives

In view of the challenges mentioned above, it is imperative to provide students with necessary resources and tools to practice 3D perspective rendering. The objectives of this study are twofold: first, to design and develop an AR system based on Alessi and Trollip's Instructional Design model, aiming to bridge the gap between theoretical knowledge and practical application by offering students immersive experiences that enhance their understanding of complex 3D concepts; second, to examine the system's impact on student engagement and learning outcomes, providing insights into how AR technology influences student involvement and performance.

2. Method

The Alessi and Trollip's Instructional Design model is a well-established framework that guides the systematic development of instructional materials (Rosmani, Mutalib & Sarif, 2018; Ayuriyanti & Surjono, 2023). Based on the instructional design model developed by Alessi and Trollip (2001), the AR system was designed and developed. It consists of three essential stages: the planning phase, the design phase, and the development phase. In each of these phases, the importance of understanding learners' needs and the context in which they will engage with instructional materials is emphasized as it ensures the quality and effectiveness of instructional content in the learning system, as shown in Figure 1. By applying this framework, the AR system that was developed in this study not only supports the learning of 3D perspective rendering but also enhances user engagement and interaction.

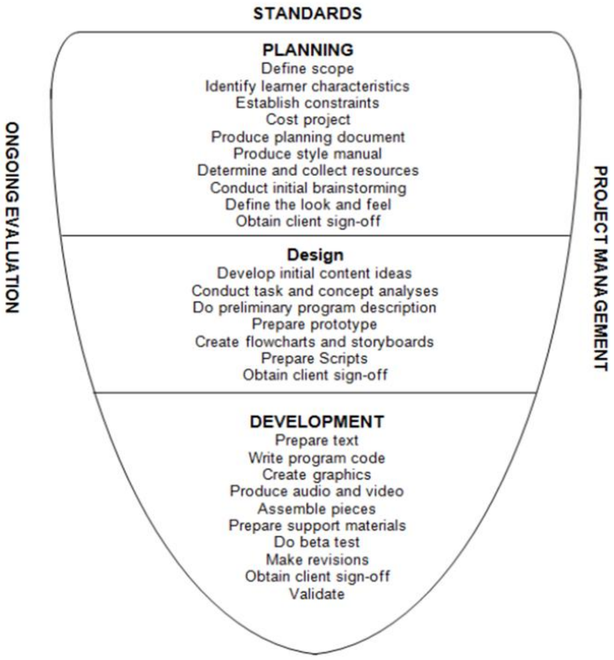

Figure 1: The instructional design model developed by Alessi and Trollip (2001).

Planning

The adapted steps derived from the Alessi and Trollip model that were incorporated during the planning phase comprised the following elements: (1) Clearly outlining the study's scope, (2) Recognizing the characteristics of the students involved, (3) Establishing any constraints that may impact the project, (4) Developing a comprehensive style manual, (5) Specifying and gathering the necessary resources, (6) Engaging in preliminary brainstorming sessions, and (7) Articulating the project's visual aesthetics and overall ambiance.

Based on the 3D perspective rendering subject's course learning outcomes (CLO), the study's initial scope was established. Through observation and student interviews, characteristics of the students were determined. The limitations for the development of the AR system design, including time constraints, technical difficulties, budgetary considerations, and the target audience's prior knowledge, learning preferences, and any unique needs or difficulties they might have comprehending the complexities of 3D perspective rendering, were determined following a thorough investigation. Considering creating a style manual was essential to influencing the AR system's design afterwards, one was established. Following a brainstorming session with subject matter experts, instructional designer, and researcher, the system's appearance and feel were established upon.

Design

The design phase concentrated on formulating the instructional approach and the user interface for the AR learning system. Consequently, the adapted steps included: (1) pinpointing initial content concepts, (2) performing analyses of concepts and tasks, (3) establishing a preliminary description of the program, (4) devising a prototype, and (5) constructing storyboards and flowcharts. The content ideas originated from a detailed examination of the subject syllabus. Following this, comprehensive analyses of tasks and concepts were conducted in collaboration with subject matter experts, aimed at enhancing understanding and bridging the divide between researchers and practitioners in the field of education. Before moving on to the prototype development, an initial outline of the program was crafted. In the final stage of the design process, researchers created storyboards and flowcharts of the system, which served as visual tools to facilitate a clearer comprehension of the system's objectives and functionalities.

Development

The process undertaken during the development phase encompassed several key steps: (1) preparation of the text, (2) writing of the program code, (3) creation of graphic art, (4) assembly of components, (5) development of support materials, (6) execution of an alpha test, (7) implementation of revisions, (8) conduction of a beta test, and (9) further revisions were applied.

Based on the flowcharts developed in the earlier stage, corresponding text was thoroughly crafted and scripted to align with various scenarios, aimed at facilitating the coding process. The visual elements implemented in the system were designed using Autodesk Maya, ensuring a high-quality graphical representation, as illustrated in Figure 2. Once all individual components were completed, a process of assembly commenced, bringing together all elements within the Unity platform, as illustrated in Figure 2. Following the completion of the initial version of the augmented reality system, an alpha test was conducted with the lecturers in charge of the subject to evaluate its functionality. A beta test was then conducted after the review version of the system with 10 industrial design students from the college. The purpose of this beta test was to gather feedback on the user experience and functionality of the augmented reality system from the targeted user. Students were asked to complete a series of tasks that evaluated their understanding of 3D perspective rendering.

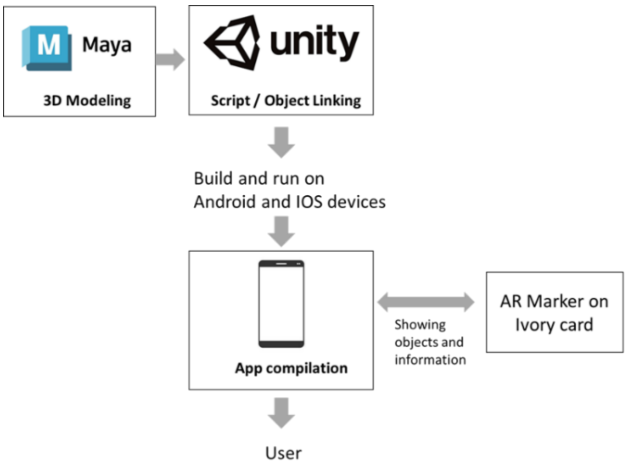

Figure 2: The process of assembly using Unity platform.

3. Finding

Observation and interview were conducted in the planning phase to identify the students' characteristics and problems faced in the class. The findings from the observations indicate several issues that need addressing: 1) there is an insufficient use of learning media to enhance the educational experience, 2) the approach to learning remains predominantly traditional, and 3) the knowledge and skills of students in 3D perspective rendering design courses are notably inadequate. A thorough analysis of these challenges reveals a pressing need for innovative learning methods that can effectively facilitate student learning.

An AR system utilizing Alessi and Trollip's Instructional Design model was developed in this research to bridge the gap between theoretical knowledge and practical application by providing students with immersive experiences that facilitate the comprehension of complex 3D concepts in 3D perspective rendering. The proposed AR system in this research features a variety of products (e.g., kitchen appliances, furniture, personal devices) and spaces (e.g., table, living room, kitchen, office) in multiple design styles, as shown in Figure 3 and Figure 4.

Figure 3: The 3D product model in the proposed AR system (A Blender).

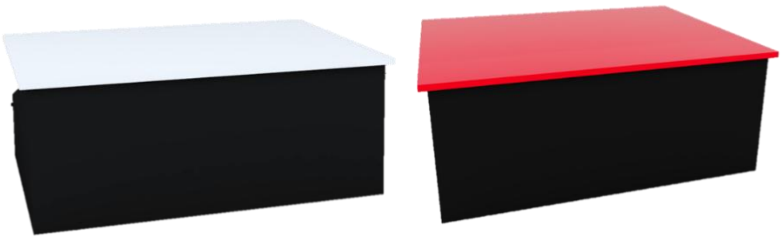

Figure 4: Different design styles of tables were developed in the system.

With this approach, students are able to visualize different interior environments and interact with them, enabling them to gain a deeper understanding of spatial relationships and design principles. As a result, students can find it easier to understand the scale and proportions of the product by viewing it from various perspectives and understanding it in 3D environment, as illustrated in Figure 5. It also enhances their spatial awareness and fosters critical thinking when students analyze how different angles affect product visualization in 3D. Students will be better equipped to understand the principles of perspective after engaging with these complex visualizations, ultimately leading to improved academic performance.

Figure 5: Exploring product in different environment and viewing it from various perspectives.

A beta test was conducted with 10 industrial design students from the college after the review version of the system was completed. The results show that the students made significant improvements in terms of the quality of the learning outcomes, as shown in Figure 6. In contrast to artwork created before the AR system was used, the artwork produced by students after learning with the AR system looks more realistic and viewed correctly. This is because AR technology allows them to accurately visualize the artwork and make adjustments in real-time. This makes the design process more efficient and enjoyable for the students. They were also satisfied with the user experience, which improved their engagement. Overall, the study results indicate that the AR system designed positively impacts student engagement and learning.

(a) (b)

Figure 6: The final artwork illustrated by student. (a) Before using the AR learning system (b) After using the AR learning system.

4. Discussion

Using augmented reality (AR) technology in 3D perspective rendering subjects can provide interactive and immersive environments for students that help them better comprehend complex spatial concepts. The findings align seamlessly with those from other research, indicating that Augmented Reality provides students with the opportunity to see and engage with three-dimensional models, animations, and simulations (Ibáñez & Kloos, 2018; Li et al., 2024; Mohamad Rasli & Rasalingam, 2024). This interactive experience significantly enhances their cognitive abilities and enriches their understanding of complex concepts. As students interact with virtual products in the AR system, they gain insights into the principles of perspective, lighting, and shading, thus being more attentive to the parts that interest them and preparing them for real-world applications in design industries. This hands-on experience fosters a deeper understanding of spatial relationships, which is crucial for mastering 3D modeling techniques.

In accordance with the present results, previous studies have demonstrated that AR can improve engagement and motivation (Jeffrey & Irizarry, 2020; Li et al., 2024). By allowing students to actively manipulate viewpoints and rotate the product in various directions on the surfaces of a 3D environment which they cannot create in the classroom in real time, they gain a deeper comprehension of the complexities of three-dimensional space. The immersive experience provided by the AR environment allowed students to visualize complex 3D perspectives more effectively, leading to a better understanding of the subject matter and enhancing their overall learning outcomes. Therefore, the improvement in students' rendering skills in this study is attributed to the interactive nature of the augmented reality (AR) system, which facilitated deeper engagement with the material.

5. Conclusion

The main goal of the current study was to design and develop an AR system to facilitate the learning of 3D perspective rendering and evaluate the impact of the AR system on student engagement and learning outcome. By adapting the Alessi and Trollip's Instructional Design model, the present study contributes to the growing body of knowledge on the design and development of AR systems for enhancing the understanding of 3D, particularly in 3D perspective rendering. A limitation of this study is that the numbers of students were relatively small. More research is required to assess the effectiveness of the AR system proposed in this study in different learning areas or different courses in the future.

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