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Analysing the Elements of 3D Design in Semi Immersive Virtual Reality Digital Learning

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ABSTRACT
This study explores the role of 3D design features in semi-immersive virtual reality (VR) and their potential to enhance digital learning experiences. Given the growing integration of VR in education, understanding key design elements—such as space, form, line, plane, texture, colour, and value—is essential for creating immersive and engaging learning environments. Through a qualitative content analysis of four semi-immersive VR teaching videos, this research examines how these elements influence user engagement. The findings highlight that shape, colour, value, and texture each contribute uniquely yet interdependently to the structuring of user experience in semi-immersive VR settings. By offering insights into the strategic application of 3D design principles, this study provides valuable guidance for educators and developers aiming to optimise digital learning environments, thereby advancing the effectiveness of VR-based education.

Keywords: *Element of 3D Design, Semi-Immersive Virtual Reality, Digital Learning.*

1 INTRODUCTION

Digital learning is defined as a learning that is supported by technology (Walker, 2024). The use of digital devices in education, particularly immersive technologies such as virtual reality (VR), has been increasing (Zawacki-Richter & Latchem, 2018). VR offers significant educational potential by enhancing motivation and engagement through immersion, interaction, and user involvement (Freina & Ott, 2015). However, for VR to be effective as a learning tool, it is crucial to design compelling 3D environments that capture students' attention and facilitate focused learning. Integrating 3D design elements such as perspective, shadows, lighting, and texturing is essential to creating immersive settings that aid conceptual understanding.

A key feature of three-dimensional (3D) displays is their ability to present images with depth from various viewing angles, aligning with human visual perception (Zhang et al., 2024). Depth perception is crucial in 3D design to prevent user confusion and discomfort (Fox et al., 2018). Unlike traditional 2D mediums, 3D environments incorporate depth cues, improving user experience by creating interactive and navigable spaces. Without proper depth representation, users may experience disorientation, reduce immersion and potentially cause discomfort. Poorly designed 3D environments in VR can diminish user interest and lead to issues such as eye strain and VR-induced nausea. Therefore, designing immersive 3D user interfaces (UIs) with ergonomic and usability considerations

is critical to maintaining immersion and preventing adverse physiological effects (Zhou et al., 2023).

Despite VR's advantages in education, many VR learning experiences fail to fully engage students due to poorly designed 3D environments, which can lead to cognitive overload, loss of immersion, and physical discomfort. The absence of a strategic approach in integrating key 3D design principles—such as depth, lighting, and texturing—often results in environments that do not effectively support learning. This study aims to explore how semi-immersive VR environments can be designed to enhance user engagement and learning outcomes through the application of 3D design principles. Specifically, this research seeks to identify key 3D design elements that influence user engagement in semi-immersive VR learning environments, examine the impact of these elements on student comprehension and learning experiences, and propose design recommendations for optimizing semi-immersive VR content to maximise engagement and learning effectiveness. By addressing these aspects, this study aims to bridge the gap between VR technology and effective 3D design practices, ultimately contributing to the development of more immersive and impactful digital learning experiences.

2 LITERATURE REVIEWS

Understanding 3D design elements is crucial in shaping immersive virtual environments, where aspects such as space, form, line, plane, texture, colour, and value influence user engagement and learning experiences. The analysis of selected semi-immersive VR teaching videos reveals variations in spatial utilization, with some environments allowing unrestricted movement while others impose limitations. The presence of high-poly and low-poly 3D models affects the realism of objects and characters, while the application of lines and planes contributes to depth perception and environmental structure. Additionally, texture detailing, colour schemes, and lighting values play a significant role in enhancing realism, as seen in the differentiation between vibrant and dimly lit environments, as well as variations in material appearance such as glossy, rough, or plain surfaces. A systematic assessment of these design elements is conducted through a structured qualitative content analysis approach, categorizing the presence and function of each element in the selected VR environments. The findings highlight how design choices, such as spatial openness, textural realism, and effective lighting, contribute to engagement and comprehension in VR-based education. By establishing a clear methodological framework, this research provides insights into optimizing 3D design for enhanced learning experiences, reinforcing the importance of well-structured virtual environments in educational and training contexts.

2.1 Elements of Three-Dimensional (3D) Design

The use of 3D elements in graphic design has grown in popularity because it makes it possible to create dynamic motion graphics and animations that greatly increase audience engagement and visual impact (RedAlkemi, 2023). The essential elements of shape, form, texture, colour, light, and space are all included in the elements of 3D design, and each has a distinct purpose in the production of three-dimensional digital things or settings. Form gives an object volume and mass to give it a sense of solidity and depth, whereas shape determines an object's outline or form. Texture improves realism and visual interest by adding tactile elements and surface details. In addition to adding to the aesthetic appeal, colour also expresses atmosphere, emotion, and visual hierarchy. To define an object's appearance, cast shadows on it, and create highlights on it, light is essential. Space affects composition, perspective, and the sense of depth by defining the spatial connections between objects and elements in a picture. These components work together to create the overall visual experience and story of 3D designs across a variety of applications and industries. There are many uses for 3D graphics, such as in design, teaching, and visual communication. It has been discovered that 3D technology improves students' understanding of 3D visualisation by providing possibilities for hands-on learning and encouraging innovative problem-solving skills (Helena Chivai & Aysegul, 2022).

2.2 Semi-Immersive Virtual Reality (VR)

VR can be classified into three types: non-immersive, semi-immersive, and completely immersive. In semi-immersive VR, users are partially integrated into the 3D virtual environment. Using a computer screen or VR headset, you can move around in a virtual environment, but other than visual experience, you will have no physical sensations. A VR headset can be used, for example, to provide pilots with partial immersion in a flight simulation (Musa M, Rahman P, Dimitrios B, 2022). Semi-immersive virtual reality (VR) is a digital environment that offers users a partially immersive experience, usually through VR headsets or displays that cover the user's field of vision. Unlike fully immersive VR experiences, which completely replace the user's physical surroundings, semi-immersive VR allows users to interact with virtual environments while maintaining some awareness of their real-world surroundings. With better depth perception, spatial awareness, and interactivity than standard 2D interfaces, this partial immersion lets users interact with digital content and simulations in a more immersive way. Virtual Reality (VR) has become popular among individuals of all ages and backgrounds around the world, particularly in educational settings. These findings also align with the suggestions put forth by Pellas et al. (2021), who also support the use of virtual reality (VR) to augment traditional didactic methods or take the place of hands-on exercises that students would normally be unable to complete in laboratories. Because there isn't enough time or technology resources for school- level courses, the same authors have also suggested using stereoscopic 360° VR devices. According to Harada and Ohyama (2022), this technology adds value since it gives students the freedom and security to explore abstract ideas openly. The ability to render virtual scenes from many angles and points of view is an inherent advantage of low-immersion VR technologies, such as the VeeR Mini Goggles. This aids in the growth of spatial awareness, which in turn brings about the sensation of physical presence.

3 METHODOLOGY

This study employs qualitative methods to analyse visual data, as the primary focus is on visual data processing in semi-immersive virtual reality (VR). A visual content analysis of four selected semi- immersive VR teaching videos is conducted, focusing on key 3D design elements such as colour, texture, value, and shape. The objective is to identify the most frequently utilized 3D design components that contribute to the creation of visually engaging VR environments, enhancing student interest and improving their overall learning experience. A structured approach is ensured by applying qualitative content analysis as the data analysis framework, following an established theoretical basis. A systematic coding process categorizes 3D design elements based on their frequency and functional significance in semi-immersive VR environments. The four selected videos align with the criteria for semi-immersive VR, specifically focusing on their 3D environment design. In these environments, users wear headsets that provide a three-dimensional view while maintaining awareness of their real-world surroundings, distinguishing them from fully immersive systems. Additionally, word cloud analysis visually represents the prominence of various 3D design aspects, supported by appropriate references to validate its methodological relevance. Reliability and validity are strengthened through intercoder reliability checks, peer review validation, and triangulation with existing literature, ensuring a rigorous and transparent research process.

4 RESEARCH DESIGN

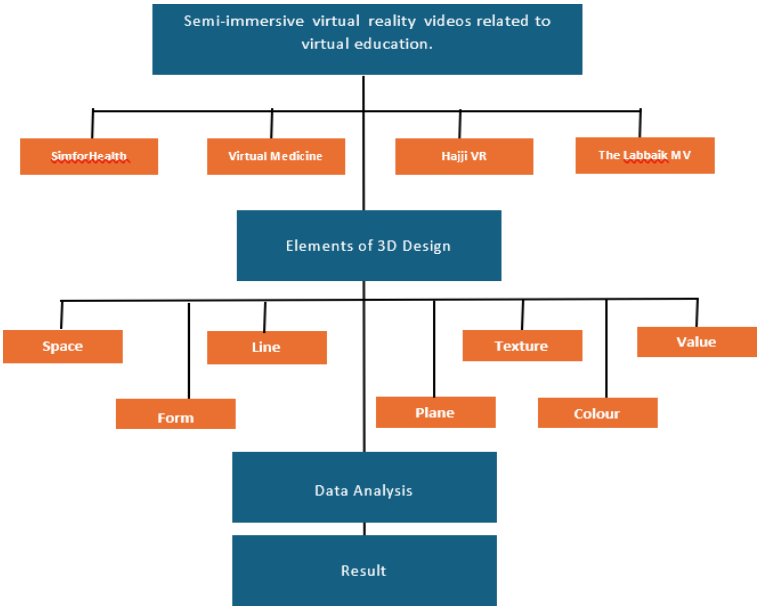


Figure 1 The study flow diagram of the research design.

Table 1 The four chosen semi-immersive virtual reality teaching videos.

No.	Title	Details
1.	SimforHealth. This VR offers an immersive, interactive and collaborative approach to the training of health professionals in line with the principle.	Year published: 2008. Originated: Bordeaux, Aquitaine, France. Developer: Kevin Blanc.
2.	Virtual Medicine. This VR serves the extensive knowledge-based anatomical terminologies for students, medical and nursing schools, universities, healthcare systems, medical associations, and health practitioners.	Year published: 2022. Originated: Bratislava Metropolitan Area, Slovakia. Developer: Michal Tkáč.
3.	Hajji VR. This VR is a virtual reality application for learning and visiting the rites of the sacred pilgrimage and of the small pilgrimage, also called 'Omra.	Year published: 2021. Originated: Canada. Developer: Salam Softwork Studio.
4.	The Labbaik MV. This VR comes with a powerful set of online digital learning tools to enable effective and immersive metaverse Hajj and Umrah training.	Year published: 2022. Originated: United Kingdom. Developer: The LabbaikVR Team.

5 DATA ANALYSIS

Table 2 The presence of the element in the VR

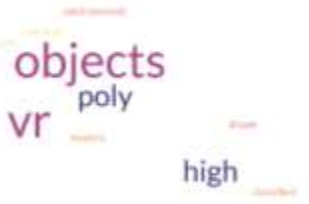
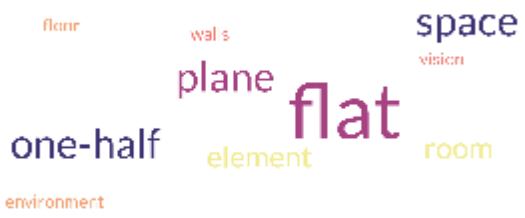
The Elements of 3D Design	Selected Semi-Immersive Virtual Reality Teaching Videos			
	SimforHealth	**Virtual Medicine**	**Hajj VR**	**The Labbaik MV**
Space	• There are two spaces. One is nonfunctional spatial, and the other is functional spatial. • The non-functional area occupied one-fifth of the area. • Half of the sidewalk space can be seen when the user moves towards the patient's room. • The user can rotate 360 around the patient's room. • The space of the patient room took up one-quarter of all the environment space in the VR.	• There is only one room in the 3D environment of the VR. • Space is quite limited because the user can only see one-half of the room. • The user can see one-fifth of the outside space through the window. • The user can rotate 180 degrees to look around the space room.	• The space of the 3D environment in VR is very wide. • Users can move in any direction inside the interior space. • One-half of the user's movement is limited when outside. • The user's vision is unlimited as they can see around the • walking. •	• One-third of the outdoor space was incorporated into the 3D environment. • Half of the 3D environment consists of interior space. • The user can go in any direction in the interior space. • One-half of the user's movement is limited when outside. • The user can rotate 360 degrees to look around the 3D environment.
Form	• Almost one-half of the places the user sees have a Form element. • All 3D objects in the VR are classified as high-poly 3D models. • Users can use a 3D hand controller in VR to lift items. • Medical objects are produced in high poly 3D as they look realistic.	• All the 3D object is designed in a high polygon shape. • The shape of the organs, bones and muscles produced is very similar to the real human anatomy. • Users can use a 3D hand controller in VR to lift items • The form element took up half of the 3D environment space	• One-half of the area is dominated by buildings. • One-third of the 3D objects, such as trees, clocks and books, are classified as low poly 3D models. • One-fifth of the objects in the VR environment are 2D elements, such as screens and information icons.	• One-third of the outside area is dominated by the buildings. • The shape of the human character looks a bit stiff. • All the 3D objects classified as high poly 3D models. • One-half of the user's field of view can perceive form elements in a 3D environment while using VR.
Line	• Most of the Line elements are used for the division of the room. • There are line elements to show shadows on the floor. • Users can see one-quarter of the pattern on the foyer ceiling using line elements. • One-half of the room is filled with line elements as it is	• One-third of the line element is in some organs. • The lines on each organ design on the anatomy help illustrate the size of the organ. • The thickness of the line changes when the organ is enlarged or reduced. • A third of the line elements can be seen in the room area as it	• The lines on the building are not clear and make the depth of the building look unrealistic • Only one-fifth of the line has a thickness to show the depth of the building and the size of the objects. • One-half of the line element is used as the pattern of the ceiling and building's walls.	• One-half of the buildings contain the line element, giving some of the buildings depth and form. • The line on the arrow helps the user know the direction they want to go. • The applied lines help make the building look uniform.

	found on the screen in the room.	is found in the lines on the curtains, patterns on the walls and even the ceiling.		
Plane	• All the room has the plane element. • The flat screen shows information in the plane element. • Most of the plane elements are used to determine the depth and height of the space in the environment. • The depth of the wardroom looks small because the distance between the wall and the floor is quite short.	• The flat surfaces, such as floors and walls, dominated one-half of the user's vision. • One-quarter of the user's vision is filled with flat screens that contain information about the organs. • The flat screens are mostly semi-opaque. • One-fifth of the room area is filled with flat ceiling lights placed on the ceiling of the room.	• One-half of the 3D environment in the VR is dominated by the plane element. • One-third of the space is filled with flat objects such as carpet and ceiling. • The tile floor dominates one-half of the outdoor area • One-half of the interior space contains walls to divide the room	• One-half of the user's vision mostly sees flat surfaces, such as building walls and mosque floors, making the surrounding space appear spacious. • All the outside and interior space contains a plane element, which is the floor. • One-fifth of the 3D environment area contains a flat signboard.
Texture	• One-half of the object in the VR environment has texture. • One-third of the floor of the hospital in the VR has a texture which is smooth and shining. • One-quarter of the medical equipment has texture. • The texture of the clothes and fabric looks rough.	• All the texture on the organ is very realistic, like an organ in the real world. • The texture found on each organ is still clearly visible despite its small size. • One-quarter of the walls in the room can be seen to have a wood-like texture. • One-third of the organ has a smooth and shiny ceramic-like texture. • One-quarter of the organ has a soft texture and looks like real skin.	• One-half of the 3D objects, such as the floor, walls and door, have a plain texture. • One-quarter of the 3D object has no texture. • There is no texture of the leaves, which makes the tree look like a 2D drawing. • Most 3D object textures look like pasted-on patterns, which makes them appear unrealistic even though they use real world patterns.	• The texture of the floor looks glossy and reflects light, making it look realistic. • One-third of the 3D environment contains fabric texture, as it is used on the Kiswa of Kaaba and the fabric of the ihram. • The fabric's texture is not smooth and flowy and looks stiff. • Stone and concrete textures dominate one-third of the 3D environment since they are used on most building walls.
Colour	• All the objects in the VR environment are coloured. • The colour brightness is low, making the 3D environment quite dark. • Greyish white colour dominated half of the room of the 3D environment in the VR. • Blue colour dominates one quarter of the 3D	• One-third of the colour found in the organs matches the colour of the organs in the human body in the real world. • One-fifth of the organs, such as the blood vessels and other small organs, did not match the actual colours in the real world as it used yellow and purple colours. • Half of the room's	• One-half of the colour selection of the pattern looks harmonious. • The bluish-grey sky colour makes the atmosphere of the environment quite gloomy. • The colour brightness of the 3D environment is very vibrant. • White colour dominated half of the	• One-half of the space uses lots of white, making the environment look bright. • The colour of the blue sky outside makes the area appear overcast. • Blue colour dominates one-quarter of the 3D environment as it was used as the sky on the outside space and screens

	environment as it was used on nurses' shirts, sheets, screens and floors. • Yellow colour dominates one-fifth of the 3D environment; it was used on the mattress and dustbin	colour is dominated by blue as it was used as the colour of the screens, ceiling and pattern on the walls. • The selection of blue and brown colours makes the room quite dark.	outside and interior space of the 3D environment in the VR. • The 3D environment room uses earth tones for its colour scheme.	• One-third of the area uses earth tones as the colour palette • One-fifth of the green colour is used as the arrow to show the direction • The selection of colours corresponds to the actual situation
Value	• Lighting coming from different directions makes the shadows of objects look erratic. • Some objects, like the screen, appear shapeless because there is no shadow. • One-half of the objects in the 3D environment have shadows because there are many sources of lighting. • Half the area of the room is refracted with light coming from the ceiling. • One-fifth of the sunlight entering the hospital area can be seen at the beginning of the scene.	• Each 3D item has a clear shadow appearance, which makes it more lifelike and realistic. • The room has dim lighting because the light source only takes up a fifth of the room's space. • One-quarter of the organ has no • appears to be transparent. • One-third of the objects in the 3D environment have shadows because there are few sources of lighting.	• One-half of the space is dominated by natural light, which is sunlight. • Although the brightness of the lighting is high, the shadows of the objects are not visible. • Only one-fifth of the interior space looks dim and shady. • One-half of the 3D environment is filled with light, making the VR environment look wide.	• One-half of the 3D environment is illuminated by multiple light sources scattered throughout the area. • The shadow appearance of each 3D object is clear, making the object • One-third of the interior space appears dim because there is no light source in some areas. • The outside light source is natural sunlight, while the interior light source is the ceiling lights.

6 RESULT

Table 3 Results obtained using Word Cloud

The Elements of 3D Design	Word Cloud Result
Space	
Form	
Line	
Plane	
Texture	

Colour	
Value	
Space	

Table 4 The words obtained are arranged in order of frequency of mention.

The Elements of 3D Design	Selected Semi-Immersive Virtual Reality Teaching Videos
Space	• Space • User • Environment • Room • Around • One • Degrees • Look • Rotate • Area
Form	• Objects • VR • High poly • Environment • One-half • Form • Models • Shape • Classified

Line	• Line • Elements • Room • Building • Ceiling • Depth • One-half • Organ • Element
Plane	• Flat • Plane • Space • One-half • Element • Room • Vision • Walls • Floor • Environment
Texture	• Texture • Organs • One-quarter • One-third • Fabric • Floor • Environment • Smooth • Looks
Colour	• Colour • Environment • Used • Blue • VR • Room • White • Dominates • Organs • Makes
Value	• Light • Objects • Environment • Lighting • Sources • One-half • Spaces • Shadows

7 FINDINGS

The word cloud analysis identified key components of 3D design elements, revealing dominant themes within each category. For space elements, frequently occurring terms include "flat," "plane," "space," "one-half," "element," "room," "vision," "walls," "floor," and "environment," indicating how spatial arrangement influences user perception. In form elements, terms such as "objects," "VR," "high poly," "environment," "one-half," "form," "models," "shape," and "classified" suggest that

model complexity and realism play crucial roles in virtual immersion. Similarly, for line elements, words like "line," "elements," "room," "building," "ceiling," "depth," "one-half," "organ," and "element" highlight the importance of structural definition in virtual spaces. The plane elements share overlapping terms with space elements, emphasizing their role in defining spatial boundaries. Texture elements include "texture," "fabric," "organs," "one-quarter," "one-third," "floor," "environment," "smooth," and "looks," suggesting that surface detailing contributes to visual and tactile realism. For colour, key terms such as "colour," "environment," "used," "blue," "VR," "room," "white," "dominate," "organs," and "makes" highlight how colour choices affect perception and user focus. Lastly, value elements are characterized by words like "light," "objects," "environment," "lighting," "sources," "one-half," "spaces," and "shadows," underscoring the role of illumination in depth perception and realism.

Beyond word frequency, thematic analysis was applied to identify patterns in how these elements contribute to user engagement and immersion. The findings reveal that spatial design and form realism strongly influence environmental perception, while lighting and texture enhance depth and believability. The frequent mention of "one-half" and "one-third" across multiple categories suggests a tendency towards proportional and balanced design in semi-immersive VR environments. These results align with existing studies on 3D design in VR, reinforcing the importance of structured spatial planning and material realism in creating effective educational experiences. Enhancing clarity, the study incorporates word cloud visualizations and frequency tables, offering a more structured representation of key 3D design elements. This integrated approach strengthens the study's reliability and validity, ensuring a rigorous examination of how design elements shape virtual learning environments.

8 CONCLUSION

This study supports the hypothesis that every aspect of 3D design plays a crucial role in determining the appeal and effectiveness of virtual reality (VR) environments. The findings highlight that the optimal use of 3D design elements enhances the attractiveness of VR spaces and promotes a more effective learning experience. Space provides users with an area to move and interact with the environment, while Form shapes 3D objects that serve either decorative or functional purposes. Line structures spatial depth and clarifies the dimensions of 3D shapes, whereas Plane contributes to spatial perception. Texture adds realism and visual appeal, Colour enhances the overall aesthetics, and Value creates depth, conveys spatial openness, sets the mood, and improves both visual appeal and functional clarity in VR.

While this study provides valuable insights into the role of 3D design elements in shaping user experience, some limitations should be considered. The research focuses on four selected VR videos, which, although structured, may not fully represent the diversity of VR design. Future studies should expand the scope by analysing a broader range of VR applications, such as gaming, professional training, and medical simulations, to gain a more comprehensive understanding of 3D design effectiveness. Additionally, incorporating quantitative or experimental methods could provide objective measurements of user engagement and interaction, strengthening the reliability of findings. Practitioners in VR design could benefit from integrating advanced technologies such as eye-tracking to identify which design elements capture users' attention most effectively, enabling the development of more immersive and engaging VR environments.

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new insights into the application of experience design. This research has been approved by the Research Ethics Committee of the College of Creative Arts CCA/GK/05/2024 (EXM02).

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