BOON OR BANE: A SYSTEMATIC REVIEW OF VIRTUAL REALITY APPLICATION IN LANDSCAPE ARCHITECTURE DESIGN STAGE

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Abstract
The application of Virtual Reality (VR) in the design process has gained growing attention as the technology accelerates the potential of designing spaces in the landscape architecture field, particularly for educational purposes. As VR can be described as a computer-generated environment that closely resembles reality, its application may expand the visual sense and comprehension in promoting natural interaction between humans and the environment. However, the potential and limitations of integrating VR applications in landscape architecture design are still being determined. Therefore, the study aims to evaluate the potentials and limitations of VR application in the landscape architecture design stage where VR technology is currently applied. Forty (40) papers were thoroughly reviewed using PRISMA as a systematic literature review tool. The study found that VR enhances visualisation, immersion, interactivity, and spatial thinking in the landscape design process. However, the application appears challenging due to limited research and funds, limited resources, high cost and more learning time, limited collaboration, and cybersickness cause. Interestingly, VR applications have been used extensively in early and later stages, particularly for presentation and detail drawing. Furthermore, the design development stage and design concept have also been applied.
Keywords: Boon, Bane, Virtual Reality (VR), Application, Landscape Architecture Design Stage

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1. INTRODUCTION

In the ever-evolving design-based discipline, particularly landscape architecture design, integrating Virtual Reality technology has become a growing interest and innovation subject. As the field of landscape architecture grapples with the challenges of translating conceptual ideas into tangible and immersive experiences, the potential of VR to revolutionise the design process has captured users' attention (Cai, 2020; Wu et al., 2021).

The application of VR in landscape architecture design has been explored in various contexts, each highlighting its unique advantages and limitations. Researchers have found that VR can enhance users' visualisation and simulation capabilities, enabling them to "walk into" their design spaces and experience the nuances of scale, lighting, and environmental factors in real-time (Liu et al., 2020; D. Z. Yu, 2020). This interactive engagement has been praised for stimulating creativity and fostering a deeper understanding of the design, ultimately leading to more informed and refined outcomes (Yu, 2020).

However, the adoption of VR in landscape architecture design has its challenges. Studies have indicated that while VR tools are perceived as attractive and original, they may fall short regarding pragmatic qualities such as perspicuity, efficiency, and dependability (Aydin & Aktaş, 2020). Integrating VR workflows into existing design processes can also present logistical and technical hurdles, requiring careful planning and investment in infrastructure development.

As the field of landscape architecture continues to evolve, the integration of VR technology has emerged as a critical area of inquiry. Through systematic analysis and exploration, researchers aim to uncover the true potential of this innovative approach, balancing the transformative capabilities of VR with the practical considerations of its implementation within the landscape architecture design process. (Wu et al., 2021; Yu, 2020; Aydın & Aktaş, 2020; Cai, 2020). This exploration of VR in landscape architecture seeks to assess its potential and limitations, providing a balanced understanding of how this technology can be effectively integrated into the design process while acknowledging the challenges that must be addressed to realise its benefits fully.

2. LITERATURE REVIEW

2.1 Virtual Reality (VR) Application in Education Field

The demand for enjoying 3D experience beyond the usage of a monitor has made Virtual Reality (VR) overwhelmingly popular in the current decade. The first VR machine was patented in 1962 when Cinematographer Morton Heilig created Sesorama, a multi-sensory simulator as the first approach to

create a virtual reality with full-color 3D video, audio, vibrations, smell, and atmospheric effects such as wind (Dom Barnad, 2024; Howard & Gaborit, 2007; Kim et al., 2009). Heilig has also patented Telesphere Mask as the first head-mounted display (HMD) with broad vision, stereo sound, and no motion tracking in the headset. Then, Ivan Sutherland proposed the ultimate solution of virtual reality as an artificial world construction including interactive graphics and force-feedback in 1965. This concept featured computer hardware to form and keep the virtual world in real time (Dom Barnad, 2024; Tomasz Mazuryk, 1996).

In the 1990s, virtual reality was widely discussed in consumerism and academia. While VR offers stimulating engagement, promotes special memory, and extends distance learning, many teaching and learning methods use VR in various modes to enhance pedagogical effectiveness (Lege & Bonner, 2020). According to Yildirim et al., (2018) Figure 1, the application of VR in the education discipline can be classified into diverse areas.

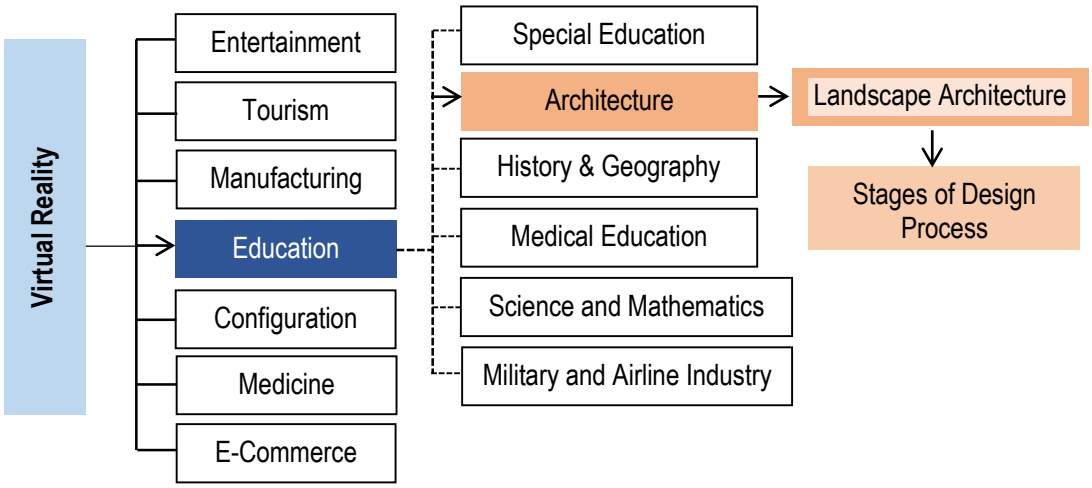

FIGURE 1 - VIRTUAL REALITY APPLICATION IN THE EDUCATION FIELD, PARTICULARLY IN LANDSCAPE ARCHITECTURE
Source: Hill et al., 2019; Yildirim et al., 2018

Virtual Reality (VR) application spans various industries, including entertainment, tourism, manufacturing, education, configuration, medicine, and e-commerce. Meanwhile, VR plays a significant role in education across multiple fields, such as special education, architecture, history, geography, medical education, science, mathematics, and the military/airline industry. However, this study focuses specifically on VR's application in architecture education, particularly within landscape architecture. The study examines how VR supports the landscape architecture design process. It emphasises the various stages of design—conceptualisation, visualisation, design development, and presentation—where VR enhances creativity, engagement, and design accuracy.

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Recent studies revealed that VR immersive technology has been expanded to extended reality and olfactory engineering. Scientists have been working for decades to figure out how to design beyond visuals such as scent and sound. Details such as the volume and concentration of each scent emitted by a system, timing, and refresh rates all affect the user's perception and immersion. Design engineers have been investigating the possibility of combining many senses to replicate a real-world scent experience and detecting soundscape as virtual technologies have advanced over the past few years (Corning, 2020). Thus, those who are blind and visually impaired can also experience virtual reality (Luoma et al., 2023). For that reason, everyone would find VR applications in education to be extensively immersive and inclusive.

2.2 Potential and Limitation of Virtual Reality (VR) Application in Landscape Architecture Design Process

Virtual Reality (VR) has emerged as a transformative tool in various design disciplines, including landscape architecture. As the field evolves, landscape architecture increasingly adopts VR to enhance visualisation, collaboration, and spatial engagement. VR presents a distinctive capability of thoroughly engrossing users in interactive, three-dimensional settings, enabling them to investigate and modify virtual landscapes before realising the tangible world (Kourtesis & MacPherson, 2021; Radianti et al., 2020; Sleipness & George, 2017). Hence, with 3D visualisation, users can improve their spatial thinking and awareness, especially when grasping complex concepts (Andalib & Monsur, 2024; Hill et al., 2019; Horne & Thompson, 2008). Additionally, VR applications help users perceive and portray architectural forms, which improves design outcomes. This is because the cognitive mapping used in virtual reality experiences allows for the simulation of the environment and the experimental investigation of complex environmental analysis (Horne & Thompson, 2008; Loukas et al., 2015).

Besides, VR also enables user interaction (Kavanagh et al., 2017; Loukas et al., 2015) through stereoscopic displays of the perception of reality (Drew Hill et al., 2019). In this regard, as the intuitive design process is developed, the users are immersed (George et al., 2017). This potential has led to a surge in the use of VR for landscape architecture design processes such as site inventory and analysis, design development, and presentations. According to specific research, VR application shows a positive outlook at an earlier stage as it stimulates design creation (Hill et al., 2019; Rafi et al., 2008). Students' comprehension of their design is enhanced, and their ability to articulate ideas is developed when they use VR for site inventory, analysis, and conceptual design creation (Portman et al., 2015). However, employing VR later in the design is also beneficial (Hill et al., 2019).

Virtual reality (VR) in landscape design has many benefits, but there are also drawbacks. These include the high cost of VR technology, the steep learning curve for users, and the possibility of oversimplifying or distorting complicated environmental data. Research indicates that VR significantly impacts cue conflict and the intensity of motion sickness. Nevertheless, it appears to differ according to each person's level of perceptual sensitivity (Fulvio et al., 2021). Numerous elements, including exposure duration, usability concerns, technical system, and user characteristics, contribute to simulator sickness (Stanney et al., 1997).

In addition, VR restricts accuracy and refinement by making it challenging to achieve the proper scale and proportion in a virtual environment (Rafi et al., 2008). Besides, verbal communication has limitations since it makes it difficult for users to have group discussions, which can impede productive collaboration, particularly in large-scale projects (Sleipness & George, 2017). Users would also face technical challenges when utilising VR, such as setting up equipment, installing other applications, and requiring appropriate space. Issues with accessibility, expense, and programming difficulty for inexperienced users also beset the use of VR in education (George et al., 2017; Horne & Thompson, 2008). Several research indicates that as VR application improves individual design experience, they should be used for visualisation rather than active design production (Sleipness & George, 2017).

As a cutting-edge technological system, VR can leverage the effectiveness of the teaching and learning process today, notwithstanding its potential limitations. The potential of VR recognises sound as a crucial virtual immersive design component in landscape architecture and a means of capturing and interpreting soundscape data to connect it to the visible landscape (Louma et al., 2023). Due to its adaptability and ability to be integrated with various teaching techniques, 3D modeling visualization and the placement of VR at various points in the learning framework have the potential to boost student engagement and elevate pedagogical efficacy (Andalib S.Y, 2024)

3. RESEARCH METHODOLOGY

A comprehensive literature search was performed using three academic search engines, Google Scholar, Scopus, and ScienceDirect, to identify relevant studies on applying Virtual Reality (VR) in the landscape architecture design process. The search targeted articles published between 2000 and 2024 to capture the most recent and significant research.

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3.1. Search Strategy

The search strategy used a combination of keywords like "Virtual Reality (VR) Application," "Landscape Architecture Design Process," and "Potential and Limitation of VR." Boolean operators (AND, OR) were applied to refine results, and only articles published in English were considered.

3.2. Screening Process

To systematically identify and screen relevant studies, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. The PRISMA flow diagram documented the selection process, detailing each step involved.

- **Identification**: All articles retrieved from the databases were imported into reference management software through Mendeley, where duplicates were removed.
- **Screening**: The remaining studies' titles and abstracts were screened for relevance. Articles not meeting the eligibility criteria based on title and abstract were excluded from further analysis.
- **Eligibility**: The full texts of the articles that passed the screening stage were assessed for eligibility. Studies that did not provide significant evidence or were not directly related to the application of VR in landscape architecture were excluded.
- **Inclusion**: Finally, the studies that met all the eligibility criteria were included in the systematic review. The included studies were then analysed to extract data relevant to the research objectives.

3.3. Eligibility

To determine the relevance of the studies, the following eligibility criteria were established:

- **Publication Date:** Only articles published between 2000 and 2024 were included.
- **Language:** Only studies published in English were considered.
- **Relevance:** Studies had to focus explicitly on the application of VR in the landscape architecture design process, discussing its potential, limitations, or both.
- **Study Type:** Both qualitative and quantitative studies were included, provided they offered empirical evidence or theoretical analysis relevant to the research objective.

3.4. Data Extraction and Synthesis

Data from the included studies were extracted and synthesised to ensure significant evidence aligned with the research objectives. Following PRISMA guidelines and strict inclusion criteria, forty (40) papers were identified as most relevant to the study.

4. RESEARCH RESULTS AND DISCUSSIONS

The forty (40) selected articles were analysed (Figure 1) and categorised into themes like VR applications, stages in the Landscape Architecture design process, and VR's potentials and limitations (Table 1). Each theme will be explained in the next section.

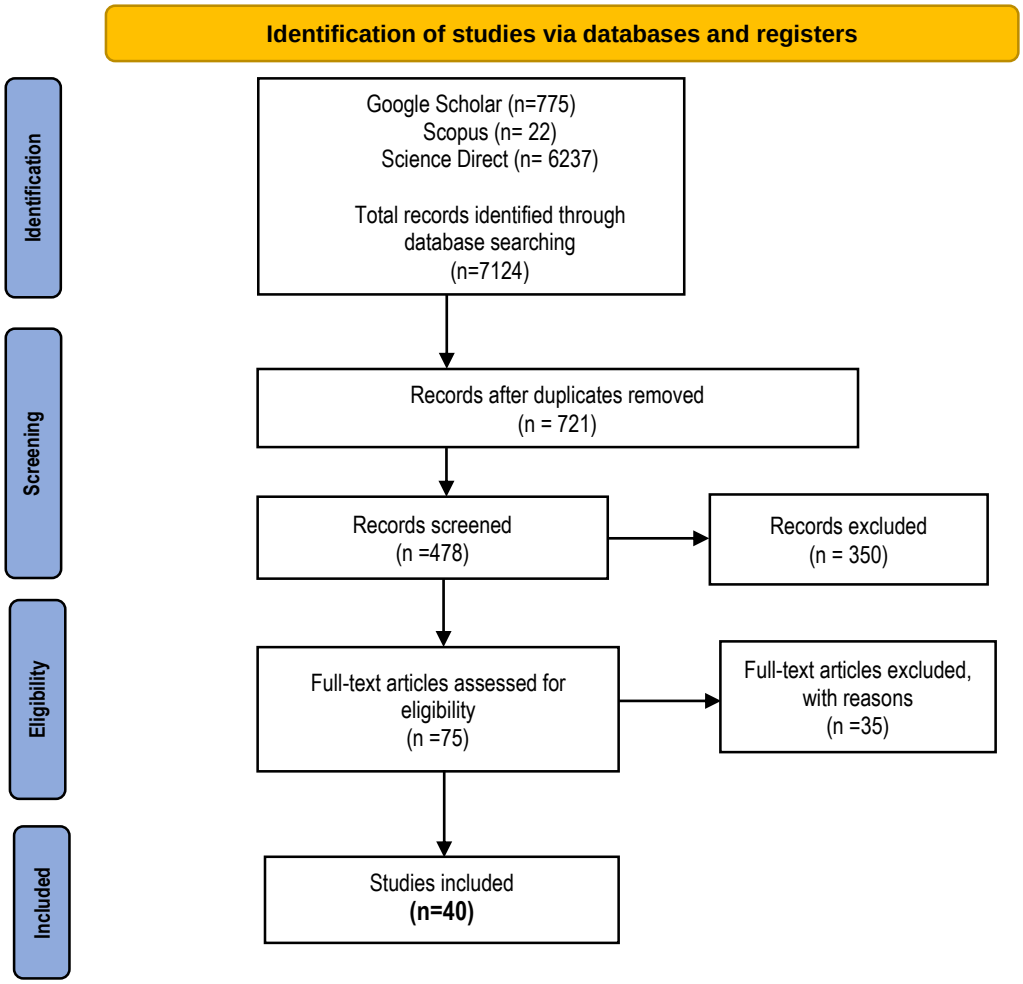

FIGURE 1 – THE FLOW CHART OF PRISMA
Adapted from Trifu et al., 2022

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TABLE 2 - THE POTENTIALS AND LIMITATIONS OF VIRTUAL REALITY APPLICATION IN LANDSCAPE ARCHITECTURE DESIGN PROCESS

No	Sources	Application Characteristics	Potentials	Limitations	Stages in the Landscape Design Process
1	Andalib, S.Y; Monsur (2024)	Immersive Visualizations	Enhance learning experience and engagement, bridge the gap between theory and practical application	VR faces hurdles in navigation resource availability and accessibility	
2	Ha et al., (2024)	A tool visualizes, manipulates, and interacts with complex computer systems and data.	Refining design details by offering a clearer understanding of the model's spatial characteristics, learning about design concepts, and real-time experiences. Improve spatial understanding of 3D spaces, and develop students' understanding of scale.	The current VR head-mounted displays (HMDs) face certain technological limitations. Some participants experience cybersickness due to sensory mismatch.	Later stage and detail design stages
3	Chen (2024)	Immersive experience	Provide an immersive platform that enables designers to visualize, and evaluate the implications of design decisions in real-time	Demands a commitment to continuous research, innovation, and substantial investment in both technological infrastructure and specialized expertise	Design concept and Design development process
4	A. Yu & Z.Xu. (2024)	Enhance spatial thinking, and immersive, interactive learning environments.	Enhancing cognitive abilities, emotional skills, and creative thinking	High costs and technical demand	
5	Luo. W & Kim.S (2024)	Interactive, 3D environment and modified landscape intuitively	Improve visualization, cost-effectiveness and enhance user engagement with design concept		
6	Luoma et al., (2023)	Sound as an immersive design parameter	Immersive to store and perceive sound information	The unity of visual and aural perception in experiencing a landscape is not deeply a part of the practice of landscape architecture.	
7	S. Li &Peng (2023)	3D graphics processing	Interactivity-interaction between users and input/output tool to achieve a relatively real simulation effect.		
8	Wu et al., (2021)	Immersion and presence by simulating real environments in 3D and its interactive, 360-degree experience virtual and the real world.	VR immersive technology transforms students' learning experiences by deepening engagement, sparking creativity, and encouraging dynamic collaboration, making education more interactive.	VR offers more complexity which requires time to learn, is high cost, and is time-consuming as some said VR is difficult to implement (difficult to prepare VR teaching material). May have effects on physiological conditions such as dizziness, vertigo, etc. The scarcity of VR equipment and the time required to develop VR learning models.	
9	Yanrong Bai (2020)	3D Visualisation, Immersive experience, interactivity and autonomy	VR aids in the seamless execution of landscape design. Integrate various landscape elements, and provide different landscape design angles. It is a powerful tool for decision-making and providing insightful references to guide the design process	The vast amount of data required by Virtual Reality can pose challenges in landscape architecture design and may impact the final design outcomes	Design development process

No	Sources	Application Characteristics	Potentials	Limitations	Stages in the Landscape Design Process
10	Lang & Guo (2021)	Multi-sensory, Immersion, Interactivity, Imagination	Improving the design process by providing a more interactive and immediate way to perceive the spatial concepts.	Limited application in landscape design	Design concept
11	Song & Huang (2018)	Immersive	Offers users interaction with the virtual world in various directions and different angles (create different landscape modes through the perception of different the direction of energy).	Tend to be somewhat cumbersome to wear, and are relatively costly for users. Lacking of output and processing data that leads to mismatched loading speeds with user movements, low equipment resolution, and dizziness after device use.	Design development process and later stage of the design process
12	George & Summerlin (2018)	Tool for visualization and presentation	82% of firms have adopted or intend to adopt VR soon		Late stages of the design process.
13	Wang (2018)	Visualization	50% used VR to solely visualize the design proposals	most studies are still in computer science and there is a lack of motivation and funds for applied research	
14	Z.Li et al., (2018).	Multi-view, real-time, and 3D. Imaginary creation Immersive	Enhance immersive experience Improve teaching quality		
15	Lee & Lu (2017)	Immersion, interaction, and imagination)	Immersive, offers real-time 3D interaction and offers robust technical support for implementing design ideas and corresponding performance.	It requires support from other software such as GIS, particularly at an early stage.	Presentation stage
16	Sleipness & George (2017)	VR as an effective tool for developing design concepts on a small site	Attentive to the spatial impacts of their decisions		
17	George, Sleipness & Quebbeman (2017)	Immersion and interaction	emphasis on the value of immersion and interaction in VR	Its usage in the earlier design stages is still underutilized. Difficulty in collaborating in VR as students outside of VR experienced the design differently	The majority of applications have been used in later design process stages
18	Ying Zhang (2016).	3D virtual environment	the users can experience the interactive virtual world		
19	George (2016)	Spatial understanding	Immersive in 3D from the initial phases of design at a human scale	Small details were hardly identified and discover	Earlier stage of the Landscape Architecture design
20	Portman et al., (2015)	VR as a largely passive viewing platform	Contributes to a new design guideline	Lack of research on the VR application	
21	Chamberlain (2015)	Spatial thinking	Spatial thinking is critical: scale and complex problems		
22	Hu H (2015)	3D visualisation	To determine the scope and details of landscape construction and its 3D form.		The construction drawings
23	Jiayuan Lu. (2013)	Immersion, Interaction, and Imagination	VR via intuitive and natural means of real-time interaction, immersion, and imagination		
24	De Freitas & Ruschel (2013)	Spatial visualisation and communication	Visual evaluation mechanism particularly in design ideas understanding and communication.	Virtual environments and the availability of high-bandwidth networks	Early stage-design ideas

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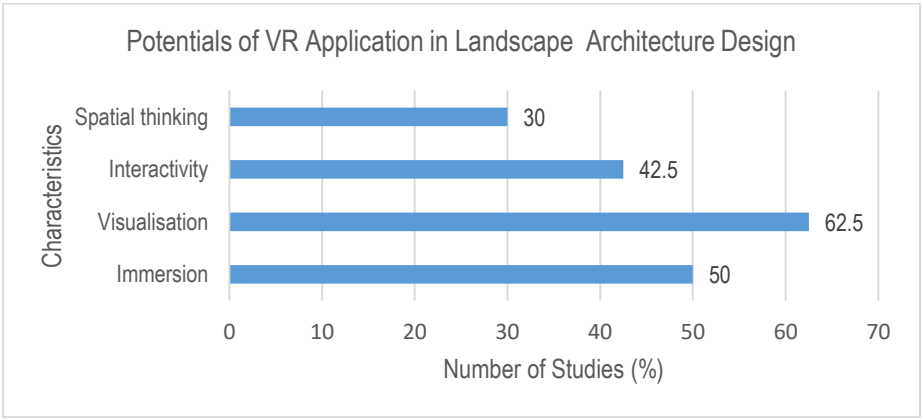
No	Sources	Application Characteristics	Potentials	Limitations	Stages in the Landscape Design Process
25	Castronovo et al., (2013)	Immersive	Immersive to evaluate designs as it offers a more realistic viewing experience Enhances the spatial awareness	Separates the designer from the physical site, the immersive nature of VR may cause the viewer to make incorrect conclusions about the site Verbal team collaboration proved to be hindered by using VR.	Site Visit
26	Hansen & Machin (2013)	A tool for spatial visualization and communication	Visualization helps to expand the visual sense and incorporate all types of images across different fields and disciplines		
27	Yuan K, Yang D (2012)	3D Visualisation	The VR technology helps to generate various construction schemes and procedures on the spot using 3D landscape planning and design		Simulation can regulate the precise construction plan and safeguards in the construction projects.
28	Rahimian & Ibrahim (2011)	VR utilization in the design process	Enhance their understanding of complex issues and relationships. Helps to improve spatial understanding and awareness	Insufficient data on those early stage particularly on the benefits of VR, VR usage limitation and project scale. Verbal team collaboration proved to be hindered by using VR.	Earlier stages such as analysis and concept development site inventory and basic analysis.
29	Lange, E. (2011)	Adaptation of 3D simulation	Time efficiency & economically feasible		
30	Ma, J., Li, G., & Liu (2011)	3D Visualisation	Focuses more on the multi-dimensional space of landscape architecture design		
31	Koh (2010)	Site analysis & Conceptual design.	user able to easily attach to their design intuitively in the interactive designing environment by virtual reality technology.		To facilitate users for quick landscape site analysis and conceptual design.
32	Pfeiffer (2010)	Promote continuous creativity	The VR technology is used to analyze landscape foundations and evaluate the direction and quality of the landscape.		At the early preliminary stage of landscape projects
33	Ghadirian & Bishop (2008)	Realistic visualizations	Exploration with real-time movement and experience at multiple scales.		
34	Horne & Thompson (2008)	Visualization	Visualisation provides a mechanism to more closely represent and understand the complexities of the landscape concept		
35	Gersmehl & Gersmehl (2007)	Spatial ability and visual sensory	Spatial ability and visual sensory to successfully present their ideas, particularly in design communication		
36	Eastgate et al., (2006)	Simulation	Therefore, virtual reality (VR) technology is a technology that encourages natural interaction between humans and the environment.		
37	Forlizzi & Battarbee (2004)	An effective approach for designing a virtual world, particularly in a problem-based learning environment.	The interactive concept within the virtual world design, developing skills in spatial relationship dimension and scale proportion	Restricts the students to rely on a combination of sketching and modeling for the conceptualization stage.	Design development and Schematic design stage

No	Sources	Application Characteristics	Potentials	Limitations	Stages in the Landscape Design Process
38	Grau, O. (2003)	Immersive	Immersive VR is an active experience, that can make users able to manipulate the virtual environment		
39	Kalisperis et al., (2002)	3D Visualisation	The development of VR is quite fast	Limited utilization the design was developed primarily using 3D software tools such as 3D Studio Max and Maya based on sketches, physical modeling, and drawings.	In the early stage
40	Lyons et al., (2000)	Immersive	Computer technology can help landscape design with the highest degree of accuracy and, efficiency offering an immersive experience		Computer aide Computer-aided.

Four (4) overarching themes emerged from the investigation, as indicated by Table 1: immersion, visualisation, interaction, and spatial thinking. Meanwhile, four (4) primary themes—restricted research and resources, expensive and time-consuming, cyber sickness, and limited verbal collaboration—can be used to describe the constraints of the VR application in landscape architecture. Additionally, virtual reality has been used in four (4) primary stages of the landscape design process: the conceptual stage, the early stage, the later stage, and the detail design stage. Based on Table 2, each of these themes has been carefully examined.

The percentage of research that meets the chosen significant topics has been analysed based on Table 2. The potential of virtual reality (VR) use in landscape architecture is represented by four (4) primary themes among the forty (40) reviewed research, including visualisation, immersion, interactivity, and spatial thinking. According to Graph 1, the most common VR application characteristics are visualisation (62.5%), followed by immersion purpose (50.5%), interactivity (42.5%), and spatial thinking (30%) across the reviewed research.



GRAPH 3 – PERCENTAGE OF REVIEWED STUDIES FOR POTENTIALS OF VR APPLICATION IN LANDSCAPE ARCHITECTURE DESIGN

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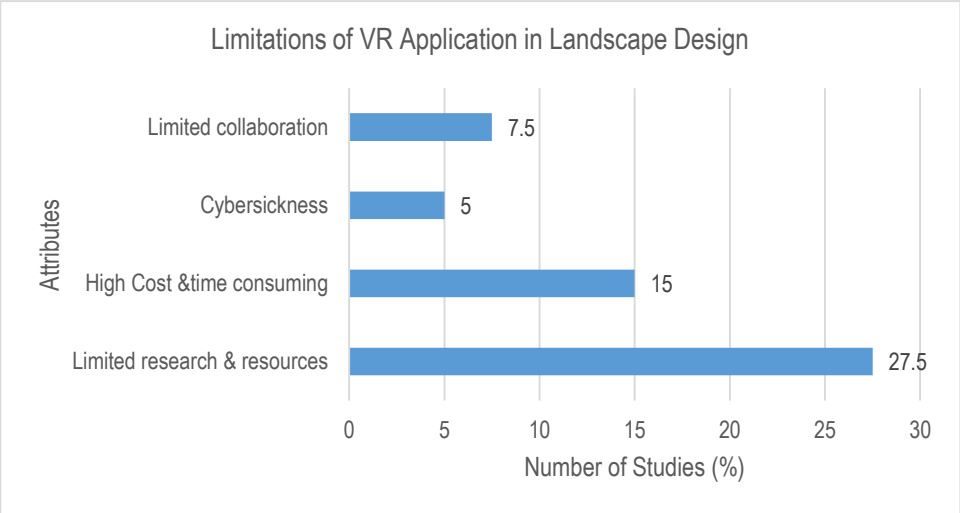
TABLE 2 – ANALYSIS PROCESS OF SUBTHEMES IN THE 40 SOURCES OF REVIEWS

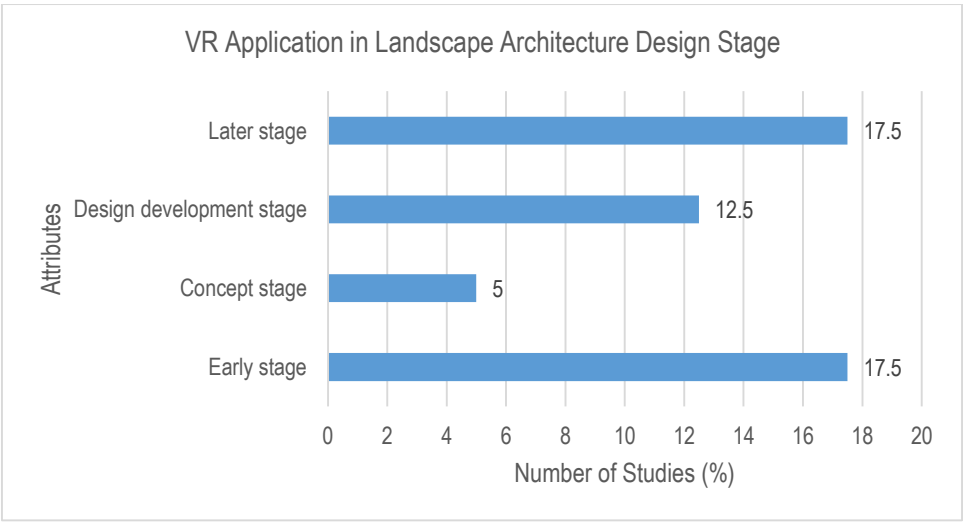
No	Sources	Potentials				Limitations				Stages in Landscape Design			
		Immersion	Visualization	Interactivity	Spatial Thinking	Limited Research & Resources	High Cost & Time-Consuming	Cybersickness	Limited Verbal Calibration	Early Stage	Conceptual Development	Design Development Process	Later Stage & detail design
1	Andalib, S.Y; Monsur. (2024)	/	/			/							
2	Ha et al., (2024)		/	/	/		/	/					/
3	Chen (2024)	/	/			/	/				/	/	
4	A. Yu & Z.Xu. (2024)	/		/	/	/	/						
5	Luo.W & Ki m.S (2024)		/	/									
6	Luoma et al., (2023)	/											
7	S. Li & Peng (2023)	/	/	/									
8	Wu et al, (2021).			/		/							
9	Yanrong Bai (2020)	/	/	/		/	/					/	
10	L.Wang & Guo (2021)	/		/		/		/				/	/
11	Song & Huang (2018)	/		/	/	/	/	/				/	/
12	George & Summerlin (2018),		/										/
13	Wang (2018),		/			/							
14	Z.Li et al., (2018).	/		/									
15	Lee & Lu (2017)	/	/	/		/							/
16	Sleipness & George (2017)		/		/								
17	George, Sleipness & Quebbeman (2017	/		/					/				/
18	Ying Zhang (2016).		/	/									
19	George (2016)	/			/					/			
20	Portman et al., (2015)		/				/						
21	Chamberlain (2015)				/								
22	Hu H. (2015)		/	/									/
23	Jiayuan Lu (2013)	/		/									
24	De Freitas & Ruschel (2013)		/		/	/				/			
25	Castronovo et al., (2013)	/			/				/	/			
26	Hansen & Machin (2013)		/										
27	Yuan K, Yang D (2012)		/										
28	Rahimian & Ibrahim (2011)		/		/	/			/	/			
29	Lange, E. (2011)	/	/										
30	Ma, J., Li, G., & Liu (2011)		/		/								
31	Koh (2010)		/	/						/	/		
32	Pfeiffer (2010)		/							/			
33	Ghadirian & Bishop (2008)		/	/									
34	Horne & Thompson (2008)		/										
35	Gersmehl & Gersmehl (2007)	/	/		/								
36	Eastgate et al., (2006)	/											
37	Forlizzi & Battarbee (2004)			/	/							/	
38	Grau, O. (2003)	/											
39	Kalisperis et al., (2002)		/			/				/			
40	Lyons et al., (2000)	/											/

The data in Graph 2 reveal that four (4) significant themes have developed as the VR application's limitations. The most significant number (27.5%) can be attributed to inadequate resources and research, followed by high costs and time-consuming (15%), limited collaboration (7.5%), and cybersickness (5%), which has the fewest studies.



GRAPH 2 – PERCENTAGE OF REVIEWED STUDIES FOR THE POTENTIAL OF VR APPLICATION IN LANDSCAPE ARCHITECTURE DESIGN

The percentage of research that offers VR application in the landscape architecture design stage is depicted in Graph 3. Early and later stages were given equal percentages, with (17.5%) of the total presented. The design development process comes in second with (12.5%), followed by the design concept with (5%).



GRAPH 3 – VR APPLICATION IN LANDSCAPE ARCHITECTURE DESIGN STAGE

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4.1. Potentials of VR Application in Landscape Architecture Design

The study's findings suggest four (4) primary themes: immersion, visualisation, interactivity, and spatial thinking. These themes highlight the potential of VR applications for landscape architecture design. It is interesting to note that these four main themes have been inextricably intertwined. As a visual visualisation, the sense immersion of VR application (Castronovo et al., 2013; Eastgate et al., 2006; Grau, 2003; Lyons et al., 2000; Sleipness & George, 2017) is the interaction of a complex computer system with the natural environments (Ha et al., 2024; Hansen & Machin, 2013) through three-dimensional (3D) representation (Gersmehl & Gersmehl, 2007). In this sense, multiple viewing experiences (Z. Li et al., 2018; Ma, J., Li, G., & Liu, 2011; Song & Huang, 2018) are essential to enhance user engagement with the design process, particularly in design concept comprehension (Weian L. & Soobong K., 2024), mainly on a small-scale site (Sleipness & George, 2017). Due to the interactivity that helps to enhance the spatial understanding of the design, users can improve the teaching and learning experience and engagement. As a result, the users can enhance the teaching and learning experience and engagement (Andalib & Monsur, 2024; Z. Li et al., 2018; Weian Luo & Soobong Kim, 2024) through interactivity, improving the design's spatial understanding (Chamberlain, 2015; George, 2016). Therefore, it develops creative thinking, intuitive skills, and imagination (Chen, 2024; Jiayuan Lu., 2013; Koh, 2010; Wu et al., 2021).

Surprisingly, some research noted that users may use VR applications to assess the extent and specifics of landscape creations on multiple scales (Hu H, 2015; Yuan K, Yang D, 2012). Because of its realistic simulation effects, VR thus enables the evaluation of design decisions in real-time (Chen, 2024; Li S. & Peng, 2023; Wu et al., 2021). These findings provide additional credence to the understanding of scale theory (Chamberlain, 2015; Forlizzi & Battarbee, 2004; Ghadirian & Bishop, 2008) , according to which VR applications illuminate how to direct the design process at the human scale (George, 2016), particularly during the initial stages of conceptualising landscape design and ideas (De Freitas & Ruschel, 2013; Horne & Thompson, 2008).

These findings suggest an association between visualisation, immersion, interactivity, spatial thinking, cognitive skill enhancement, and creative thinking (Pfeiffer, 2010; Wang et al., 2018; Yu & Xu, 2024) , facilitating and supporting problem-based learning (Forlizzi & Battarbee, 2004). Thus far, the findings provide evidence that visualisation immersion has been identified as the most promising characteristic of VR applications. In the meantime, interactivity and spatial thinking have also backed the notion of a natural relationship between humans and technology.

4.2. Limitations of VR Application in Landscape Architecture Design

Despite the boon of VR applications, their bane has made it difficult to utilise them fully. The four (4) significant factors that have arisen from the literature are the following: a lack of research and resources, cybersickness cause, high cost and time commitments, and limited user collaboration. Due to a lack of funding and research, virtual reality applications appear to remain in their infancy, particularly in the context of teaching and learning (Chen, 2024; Portman et al., 2015; P. Wang et al., 2018). Specific difficulties associated with this restricted use in landscape design (Kalisperis et al., 2002; Wang & Guo, 2021) include scarce resources, accessibility issues (Andalib & Monsur, 2024), and technical demand (Ha et al., 2024; Song & Huang, 2018; Yu & Xu, 2024). Some studies revealed that VR applications also need high bandwidth (De Freitas & Ruschel, 2013) , and specific head-mounted devices (HMDs) have handling limitations (Ha et al., 2024).

Some studies present that VR application needs a significant financial investment (Song & Huang, 2018; Yu & Xu, 2024) and a time-consuming learning curve (Wu et al., 2021). It sometimes demands some complex software to be embedded (Chen, 2024) to create natural visual interaction, particularly at an early stage of the process (Lee & Lu, 2017). As such, managing it requires specialised expertise to handle (Chen, 2024). Apart from that, a fully immersive experience limits students to using a combination of sketching and 3D representation (Forlizzi & Battarbee, 2004). This is because certain features were barely noticed and found during the process (George, 2016). This view is supported by Luoma (2023) those who note that the theories of visual and aural perception in experiencing simulation are not intensely practised as the immersive experience also demands the other senses, mainly sound, as the parameter.

VR also has difficulties with collaboration, particularly in group discussions, even with realistic simulation (Castronovo et al., 2013; Rahimian & Ibrahim, 2011). As a passive individual viewing platform (Portman et al., 2015), it separates users outside the VR experience (George et al., 2017). This account also supports the idea that VR applications keep users apart from the actual location (Castronovo et al., 2013). Besides, VR applications may have some effect on cybersickness (Ha et al., 2024), dizziness, and vertigo due to sensory mismatch (Song & Huang, 2018; Wu et al., 2021). Some users experience discomfort after using the device.

Collectively, these findings outline a critical concern about the limitation of research and resources, and the challenges of time and cost have been highlighted. However, the challenges have also been outlined concerning limited collaboration and the need for concern for the source of cyber sickness. All these adverse effects will eventually be lessened as technology advances.

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4.3. VR Application in Landscape Architecture Design Stages

There are four (4) primary stages of the landscape design process- the early stage, design concept, design development process, and the last stage – are those that are frequently simulated using virtual reality. Fascinatingly, the findings indicate that VR applications are commonly used in the early (Castronovo et al., 2013; De Freitas & Ruschel, 2013; George, 2016; Kalisperis et al., 2002) and later stages (George & Summerlin, 2018; Ha et al., 2024; Sleipness & George, 2017b; Song & Huang, 2018) of the design process. Some studies revealed that VR applications are also utilised during the presentation stage.

Meanwhile, the design development stage is also used, particularly for schematic design (Bai, 2020; Chen, 2024; Forlizzi & Battarbee, 2004; Song & Huang, 2018). Specifically for the concept (Wang & Guo, 2021), VR application has been applied the least. Early in the site inventory and analysis stage, VR immersion helps experience the natural interaction (Koh, 2010; Rahimian & Ibrahim, 2011). Besides, the VR application has also been facilitated with detailed construction drawings (Hu H, 2015; Lyons et al., 2000).

The findings of these reviews support the idea that VR applications are being employed as platforms for visualisation visualisations late in the process. On the other hand, hand-drawn sketches are required to develop and create design ideas that challenge VR immersion.

5. CONCLUSIONS

This study aimed to understand better the potential and limitations of VR applications in the landscape architecture design stage. The findings offer valuable perspectives for assessing the boon and bane of utilising VR in the design process and enhancing teaching and learning engagement. This approach will help expand our understanding of how VR applications would be beneficial and challenge the design process, particularly in landscape architecture design. To optimise the benefits of VR immersion, it will be crucial to investigate the possible applications of all sensory components in the future. Thus, gaining a grasp of its benefits and drawbacks would enable future VR research in various design fields and allow users to inspire innovative ideas and efficient design processes.

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