Embodied Learning in Virtual Reality: Comparing Direct and Indirect Interaction Effects on Educational Outcomes

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***Abstract*— This paper is based on a case study that examined two types of interaction methods in Virtual Reality (VR) through observation. Participants were assigned to complete a design task using VR, where they engaged in either direct or indirect interaction methods. The direct interaction mimicked real-world actions, while the indirect interaction involved using a mediating user interface. Using the 'Immersive Framework for UX and Learning in Immersive Technology for Learner Engagement' as the theoretical foundation, this study analyzed how these two interaction methods influenced user experience, engagement, and educational outcomes. Participants were divided into two groups, each experiencing one of the interaction methods while designing an office space in VR. While direct interaction mimics real-world activities, enhanced physical engagement, and potentially intrinsic motivation, indirect interactions provide greater precision through a user interface, require more cognitive effort and affect usability and motivation differently. Based on these observations, the authors suggest that a combination of both interaction methods can create a balanced and effective learning environment. This approach supports hands-on learning in the initial stages and precision tasks in more advanced stages. The study offers insights aimed at guiding educators in selecting appropriate VR interaction methods to optimize educational content development and improve learner engagement and outcomes.**

Keywords*— *Virtual Reality; Educational Technology; User Experience; Sense of Agency; Virtual Embodiment

I. INTRODUCTION

Virtual Reality (VR) technologies have gained significant traction in educational contexts over recent years due to advancements in hardware affordability and accessibility. In engineering education, VR offers unique opportunities to enhance student engagement and understanding, particularly in areas requiring spatial reasoning and complex problem-solving. Engineering disciplines, often focused on abstract concepts and intricate systems, benefit from VR's ability to transform theoretical knowledge into practical, experiential learning. For instance, VR enables students to visualize and interact with three-dimensional models of engineering systems, such as circuit designs, mechanical structures, or architectural layouts, providing a deeper understanding that surpasses traditional two-dimensional representations.

The development and integration of VR into education have been driven by its potential to create immersive and engaging learning environments that surpass traditional methods in terms of experiential learning. This potential is further supported by embodied cognition theory, which posits that cognitive processes are deeply rooted in the body's interactions with the physical world. In engineering education, this theory underscores the importance of hands-on experience, as students often better understand complex concepts when they can physically engage with materials and systems. VR amplifies this by providing an immersive environment where learners can directly interact with virtual objects and simulations, fostering deeper comprehension through embodied experiences that mirror real-world engineering tasks.

Many researchers have claimed that the effectiveness of such learning experiences is tightly linked to the design of these environments, as they provide unique affordances. In engineering education, this design must carefully balance realism with pedagogical goals, ensuring that the virtual experiences are not only engaging but also educationally valuable. Advancements in immersive technologies have led to the development of various methods for creating a sense of immersion, ranging from mobile VR to Head-Mounted Display systems (HMD) and projection-based systems (e.g., CAVE systems), which can offer multimodal interaction and manipulation capabilities.

There is a growing effort to understand the technical foundations of VR to develop effective educational applications, particularly in software engineering [1], civil and architecture engineering [2, 3], industrial engineering [4], and others where precision and accuracy are paramount. The success of these efforts depends on the type of systems and platforms used, which must provide the necessary technological infrastructure to support immersive educational experiences [5]. Additionally, factors such as User Experience (UX) and interaction design can significantly improve learning, especially learning pertaining to spatial cognition and problem-solving in engineering disciplines. In this article, the authors report their findings from a case study that focused on two different interaction methods in VR, and further discuss the importance of each approach - namely 'direct' and 'indirect interaction'.

II. BACKGROUND

Research has shown that VR can effectively support various instructional design methods, particularly in higher education settings. In engineering education, this support translates into significant learning outcomes, as VR serves as a powerful pedagogical tool. Specifically, VR can lead to skill-based, cognitive, and affective outcomes. Skill-based outcomes involve the enhancement of technical or motor skills, thereby improving students' practical performance and academic grades [5]. Cognitive outcomes contribute to better knowledge retention and a deeper understanding of complex concepts, enabling students to apply theoretical knowledge in real-world situations. Additionally, affective outcomes focus on the development of positive attitudes, motivations, and 'soft' skills, creating a more engaging and motivating learning environment that benefits both professional and personal growth.

These outcomes are closely tied to the immersive nature of VR, which allows students to explore complex concepts in a three-dimensional space with high-fidelity interaction, fostering deeper understanding and knowledge retention. However, achieving these outcomes depends on various factors related to VR software and hardware, which can significantly impact the learning experience.

Oprean and Balakrishnan [6] introduce the immersive framework, which highlights the importance of UX factors that influence learning through the degree of students' engagement. This framework, which focuses on representational abstraction and interactivity as key components, is particularly relevant in understanding how VR can enhance learning outcomes in engineering education. Representational abstraction involves combining technological attributes, such as field of view and level of detail, with the learning content to create an immersive environment. Interactivity, on the other hand, involves the user's ability to act within the virtual space, facilitated by features like motion tracking and feedback mechanisms. The framework emphasizes that factors like *presence*, *embodiment*, *enjoyment*, and *novelty* are crucial in sustaining learner engagement and improving educational outcomes, thereby directly influencing the effectiveness of VR as a pedagogical tool in engineering education.

A. Engagement

Engagement is essential to the learning process, particularly in active learning [7]. However, engagement is a complex term with varied interpretations [8]. It is often associated with concepts such as motivation [9], interest, involvement, immersion, and user experience [10]. While these terms are related, they each have distinct meanings. Oprean and Balakrishnan [6] use the term 'learner engagement' instead of simply 'engagement' to capture these nuances. Learner engagement arises from a joyful experience supported by the novelty of the experience and involvement.

Enjoyable experiences in education lead to improved outcomes. The roles of fun and play have long been established as motivators for sustained learning [11]. However, the nuances of fun and the subjectivity of what motivates a learner can cause variation in how well enjoyment enhances learning. Increased motivation through fun and play can heighten learning challenges, encouraging learners to engage with content through higher-order thinking skills. Nonetheless, there are downsides to enjoyment in learning: (a) the experience may be so enjoyable that it never increases the challenge, leading to boredom, and (b) the challenge may increase too quickly, causing frustration. Focusing solely on enjoyment can also result in poor learning outcomes; hence, it should be balanced with other factors related to learning content [12]. Optimal enjoyment of learning content requires aligning the challenge with the learner's skill level and providing constant feedback. Learners should be aware of their capabilities at any given time and receive timely assistance when their capabilities fall short to enhance enjoyment.

A completely new experience can significantly boost initial satisfaction, leading users to overlook usability issues or content [13]. Novelty in UX, while unique, fades over time, sometimes seen as a drawback for effective learning [14]. Despite this, novelty remains important with new devices and applications. First-time immersive technology users may feel curiosity and awe, which can have mixed effects [15]. Although novelty generates high engagement, this can quickly wane, creating a false sense of success [16]. To effectively integrate novelty in education, continually introducing new elements is crucial to sustain engagement. Consistently novel experiences help learners adapt and apply knowledge, much like virtual simulations distract patients from pain [17]. Sustaining novelty can develop higher-order thinking skills and maintain long-term engagement in immersive technology.

B. Presence

The concept of "presence" or the sensation of "being there" in a virtual environment is fundamental to User Experience (UX) in immersive technology. In fields related to space, this sensation is often referred to as "spatial presence," or "being within a space." Presence is a multi-dimensional concept involving various subjective and interrelated factors [18]. According to Lee [19], factors influencing presence can be classified as technology-based and user-based [20]. IJsselsteijn et al. [21] propose four broad categories of variables affecting presence: the extent and fidelity of sensory information, the match between sensors and the display, content factors, and user characteristics.

Research in immersive technology indicates that presence plays a crucial role in understanding and perceiving virtual environments. Spatial elements in presence help anchor references between objects and content, mimicking real-world scenarios where navigation, scale, distance, and structure influence how users interpret and recall events [10]. For example, navigating a new environment involves using familiar navigation skills and adapting based on new experiences. From a UX perspective, the intensity of presence fluctuates throughout an experience, suggesting its dependence on other UX factors to sustain immersion. Therefore, maintaining ongoing engagement is essential, requiring the introduction of varied elements.

C. Virtual Embodiment

Advances in VR technology have enhanced the experience of having a self-avatar, by mapping users' physical movements onto their virtual avatars, increasing the sense of virtual embodiment, which in return can improve their sense of spatial awareness [22]. The concept of virtual embodiment was central to the design of the interactions discussed in this study.

Virtual embodiment in media technology refers to a user's graphic representation within a virtual environment. Kilteni et al. [22] defining a 'sense of embodiment' as the sensations felt when a user 1) has a body, 2) is inside the body, and 3) controls the body in VR. Kilteni's [22] definition includes the sense of self-location (feeling inside a spatial volume), body-ownership (feeling self-attribution towards a body), and agency (feeling of generating actions). Sense of self-location is influenced by vision, vestibular signals, and tactile inputs. Sense of body-ownership is formed by sensorimotor systems, visual, and tactile inputs. Sense of agency (SOA) is the sensation of causing an action, active only when the sensorimotor system is engaged. Actions with high agency, according to Murray [23], are autonomous, chosen from many possibilities, and able to control the experience.

In VR, users gain SOA by interacting with the environment and its objects, making interaction design crucial for forming a sense of virtual embodiment. Researchers define interactivity as the degree and manner of user interaction with a VR system, often measured by active participation in virtual environments [24]. The operationalization of interactivity varies widely, ranging from involvement levels [25] to navigability [26]. The direct and indirect interaction discussed in this paper are viewed as a function of technology affordance related to the user's sense of agency (SOA). In the real world, individuals naturally engage with their surroundings, comparing anticipated visual responses from their actions to the actual movements observed. Mismatches or delays in this comparison can reduce or nullify SOA.

Direct interaction involves minimal time for users to select and manipulate objects, like moving furniture to rearrange a room, closely resembling real-world interactions and enhancing the sense of presence. Indirect interaction uses a mediating interface to control objects, requiring more time but offering greater accuracy in executing commands to move, rotate, or control objects in the virtual environment. Figure 1, shows the direct and indirect interaction conditions. The commands in the 'direct interaction' get executed immediately after selecting the desired option; whereas, in the 'indirect' condition, once a command is executed, the user should 'confirm' the action to finalize the command.

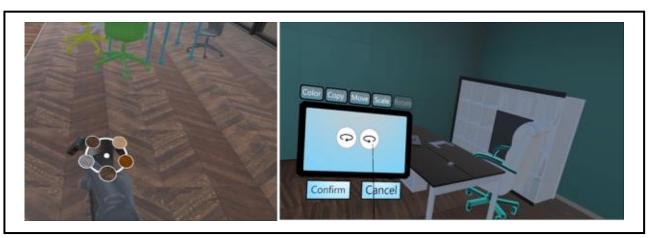

Fig. 1. The left image, changing material of the floor in the 'direct interaction'. The right image, rotating a chair in the 'indirect interaction'.

In the 'indirect interaction' mode, the control interface moves gently as the user navigates through the space until the command is confirmed or canceled. Additionally, a snapping feature is defined with a preset value. For example, when using the 'rotate' command, objects snap to 15-degree increments. To rotate an object by 90 degrees, the user can either click the rotate button six times or click and hold the button until the object reaches the desired orientation, with the rotation pausing briefly after each 15-degree increment.

Direct and indirect interaction in VR contribute to the sense of agency by allowing users to feel in control of their actions within the virtual environment. Direct interaction enhances the sense of agency by enabling users to perform intuitive, real-world-like movements to manipulate virtual objects, providing immediate feedback that aligns closely with their physical actions. This alignment between action and response reinforces the user's perception of being the initiator of those actions, thus strengthening the sense of control and presence [27]. Conversely, indirect interaction, though mediated by interface elements like buttons and menus, fosters a sense of agency by allowing precise control over virtual objects and actions. This precision, while cognitively demanding, enables users to make deliberate and accurate adjustments, which can enhance their confidence in their ability to affect the virtual environment. By offering clear and responsive feedback to these interactions, indirect methods can similarly reinforce users' perception of control and intentionality in their actions [27]. Both interaction methods, through their unique mechanisms, contribute to a robust sense of agency by ensuring that users perceive a direct correlation between their inputs and the resulting changes in the virtual world.

III. THEORETICAL FRAMEWORK

Oprean and Balakrishnan [6] introduce the concept of 'attention allocation' as one of the main contributors to achieve 'presence', 'virtual embodiment', 'enjoyment', and 'novelty', which are the driving force for enhanced learner's engagement.

Attention is critical for the effectiveness of representational abstraction and interactivity in influencing UX and learning. It helps maintain a learner's focus on an activity or experience [28]. Initially, learners allocate a certain amount of attention, which can vary based on UX and individual factors. As the sense of presence increases, more attention is directed toward the experience, minimizing external distractions, similar to the concept of flow [29]. Technological factors, such as headsets and headphones, can enhance attention by blocking external stimuli. However, isolating features of technology might be less effective in collaborative settings where ambient noise is beneficial. Understanding the immersive attributes of each technology is essential for aligning it with specific learning scenarios. Like UX, the learner experience relies on focused attention towards the learning content, aiming to reduce split-attention and improve information processing [30]. Attention is often achieved through a mix of learning strategies linked to UX principles: involvement, motivation, and usability. Figure 2, below demonstrates the immersive framework for UX and learning in immersive technology for learner engagement by Oprean and Balakrishnan [6].

A. *Involvement*

Involvement refers to the extent of user participation in an activity [31]. In learning, it involves external factors that provide cognitive stimulation, physical interaction, control, potential exploration, and varying challenges [32]. Cognitively, learners challenge existing mental models to form new ones through active learning. Physical interaction engages learners' bodies, making the learning activity more immersive. Immersive technology enhances involvement by providing a greater sense of agency, resulting in better interactivity. This allows learners to situate their mental models physically and mentally within a real-world context, which is more engaging compared to abstract information. For example, giving directions using landmarks (landmark knowledge) is easier than using cardinal directions (survey knowledge) without the proper mental models and context.

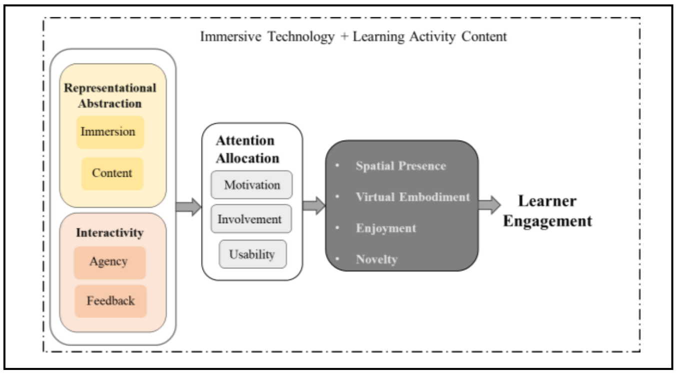

Fig. 2. Based on Immersive Framework for UX and Learning in Immersive Technology for Learner Engagement by Oprean and Balakrishnan [1].

B. Motivation

Ryan and Deci [33] suggest that learning incentives can be internal or external. Internal motivation drives a learner to focus solely on the learning goal, ignoring distractions. UX factors like affect and enjoyment directly impact internal motivation, helping learners stay invested in an experience. Enjoyment increases investment, enabling learners to overlook inconsistencies or poor interface design. External motivators, common in traditional learning environments, include rewards like grades, which encourage participation and success despite design issues. Active learning uses extrinsic motivation to create positive experiences, correlating with UX enjoyment factors [34]. A balance of challenge and reward is crucial for maintaining motivation [35]. Overall, motivation engages and sustains students in learning activities. UX leverages motivation through novelty and sensory involvement, enhancing learner engagement. Understanding the relationship between UX and motivation is key to designing engaging activities that foster involvement and enjoyment.

C. Usability

Usability is crucial in influencing the user experience. While often tied to satisfaction, other usability aspects can also impact satisfaction negatively. In this study, satisfaction is defined by usability ratings, affecting engagement with technology. There are similarities and differences between usability in learning (pedagogical usability) and HCI. Pedagogical usability includes content, interface, and tasks, focusing on meeting learning objectives [36]. Usability issues in UX fall under pedagogical usability but must relate to learning objectives. Poor UI is akin to weak instructional guidance, obstructing learning objectives and decreasing engagement. Good usability in immersive technology should blend seamlessly into the experience, allowing learners to focus on the task. Proper technical usability combined with well-designed activities frees mental resources for constructing new knowledge. However, poorly designed aspects can hinder learners from fully engaging with the content, impacting their ability to meet learning objectives.

IV. A CASE STUDY

The current report is part of a comprehensive study on how virtual embodiment affects users' understanding and comprehension of space in VR. This paper focuses on observations of subjects participating on the two conditions of direct and indirect interaction. The objective was to explore the differences between the use of direct and indirect interaction and how it impacts students' performance in design tasks.

A. Research Method

The research method employed in this study involved a combination of observational techniques and analysis of participants' design outcomes. A total of 122 participants were divided into two groups, each experiencing different interaction methods—direct and indirect interaction—in a VR environment. Half of participants identified as female and half as male, with majority of subjects (66%) as undergraduate students and the rest as graduate students majoring in different disciplines. While the main study also investigated the difference between participants with architecture and non-architecture background, the current study only reports the results of data analyzed inn the conditions where 'interaction' as an independent variable was systematically manipulated.

Participants, introduced a role-playing scenario where they are employees of a real estate company, were tasked with designing a new office space with some given consideration. After a brief training session and subjects' familiarization with the VR space and controllers, participants had up to 25 minutes to complete their designs. The brief included detailed information influencing the design, such as daily tasks, communication needs, and spatial requirements. Participants navigated the virtual office space to familiarize themselves with the layout and available commands. The scenario simulated a realistic design challenge, incorporating workflow optimization, ergonomic considerations, and collaborative spaces. Participant's interactions within the VR environment were recorded and analyzed, focusing on how participants used direct and indirect methods to copy, rotate, move, and scale objects. The virtual environment was modeled using 3ds Max and implemented with the Unity Game Engine for the HTC VIVE Pro 2 headset.

B. Data Collection and Analysis

Data were collected through direct observation, screen capture, and the screenshots of participants' design outcome, allowing for a detailed examination of participants' interactions within the VR environment. Observers noted the frequency and type of actions performed by participants, such as object manipulation (e.g., moving, rotating, and scaling), the use of the VR controllers, and the physical movement of participants while engaged in the design tasks. Additionally, screen recordings were analyzed to assess the efficiency and accuracy of the design tasks, with a particular focus on how participants used the direct and indirect interaction methods to achieve their design goals.

Finally, participants' design outcomes were evaluated based on several criteria, including the spatial organization of the office space, the alignment and placement of furniture, and the overall aesthetic quality of the design. The precision of object manipulation, especially in tasks requiring high accuracy, was of particular interest, as this directly related to the effectiveness of the interaction methods used.

C. *Results*

The results from observational notes indicate that in the direct interaction mode, users exhibited higher physical body movement compared to the indirect mode. This difference is because direct interaction allowed users to manipulate objects directly, as if they are using their hands, while indirect interaction required users to interact with a mediating User Interface (UI) through the VR controller. For instance, to rotate an object in direct interaction, users moved their hand and wrist as if they were physically holding the object and rotating it. In indirect interaction, users selected rotation options via a button press, leading to less physical body movement. Additionally, users having to 'confirm' their actions in order to *apply* the new changes meant participants in the indirect interaction mode had to use the controllers more by clicking more buttons. Consequently, it took participants in the 'indirect interaction' condition longer time to complete their design tasks, as evidenced by screen recordings. It was also observed that users periodically rested their hands due to holding the controllers in an upright position, though it was unclear which interaction mode was more ergonomically comfortable. Individual differences in design preferences and precision of command execution also influenced user interactions. Some participants preferred a casual approach to placing and manipulating objects, while others were more precise and meticulous. For example, when arranging chairs around a table, some participants preferred to place the chairs in the correct corresponding positions so that they all face each other; whereas others only placed chairs without paying attention to their orientation (see figure 3). Given that the 'indirect interaction' mode provided more precise and accurate object manipulation compared to the 'direct interaction', it was more convenient to align objects using the 'indirect interaction'. For users in the 'direct interaction' who preferred to align objects, the experience became more inconvenient both ergonomically and mentally.

Direct interaction in VR involves users interacting with the virtual environment and objects in a way that mimics real-world actions. This high degree of physical involvement enhances the user's sense of presence and agency, as they see immediate results of their actions in the virtual world. In contrast, indirect interaction involves a mediating interface where users control objects through commands executed via a menu. This method requires less physical engagement as users primarily interact with the UI using VR controllers. The indirect method, while less physically immersive, provides precise control over object manipulation, which can be beneficial in tasks requiring high accuracy. However, this reduced physical involvement might decrease the user's sense of presence and agency, making the interaction feel less intuitive and more detached from real-world experiences.

Fig. 3. The right image, shows furniture placed casually throguh direct interaction. The left image, shows well aligned furniture placement.

Motivation, both internal and external, plays a critical role in sustaining user engagement. Direct interaction in VR aligns closely with the concept of internal motivation, where users are driven by the enjoyment and affective engagement of performing realistic tasks in a virtual environment. The immediate feedback and intuitive nature of direct interaction can enhance user enjoyment, leading to higher investment in the task and a stronger sense of agency. This heightened motivation is crucial for maintaining user engagement, especially in learning scenarios where intrinsic interest and enjoyment significantly impact outcomes. Indirect interaction, on the other hand, might rely more on external motivation. The precision and control offered by the interface can be seen as external incentives for users who prioritize accuracy and efficiency in their tasks. However, the indirect method's slower and more cognitive-demanding nature might reduce the user's intrinsic motivation, as it can feel more cumbersome and less engaging. Balancing the need for precision with the desire for an enjoyable and immersive experience is essential to maintaining motivation in indirect interaction scenarios.

Usability, a key component of UX, significantly influences how effectively users can interact with VR technology. The results from the usability testing and comparison between the two interaction conditions suggest that background knowledge and experience also impacted users' perceived ease of use and task performance [37]. In this paper, however, the authors have discussed some potential explanations for the differences between the two interaction conditions by relying on the observational data.

Direct interaction in VR is generally more user-friendly, as it mimics natural interactions and provides immediate, intuitive feedback. Users can quickly learn and adapt to the direct interaction method, enhancing their overall satisfaction and engagement. The seamless integration of physical movements with virtual actions reduces cognitive load, allowing users to focus on the task rather than the interface. Indirect interaction, while offering precise control, presents more usability challenges. The reliance on a mediating interface and the need for multiple steps to execute commands can increase cognitive load and reduce overall satisfaction. Users may find the indirect method less intuitive, requiring more time and effort to complete tasks. However, the design of the interface, with features like snap-to-grid for rotation and movement, can mitigate some usability issues by providing clear and precise control mechanisms. Ensuring that the interface is user-friendly and minimizing the steps required to execute commands are critical for improving usability in indirect interaction methods.

V. CONCLUSION AND RECOMMENDATIONS

The results of this study underscore the significant role that VR systems can play in achieving diverse learning outcomes within engineering education. The distinct differences observed between direct and indirect interaction methods are closely aligned with the principles of Edgar Dale's Cone of Experience [38] and Bloom's Taxonomy [39], which offer valuable frameworks for understanding the cognitive and experiential dimensions of learning.

When developing educational content, especially in engineering, it is essential to select the appropriate interaction method to optimize these learning outcomes. Edgar Dale's Cone of Experience visualizes different types of learning experiences, ranging from the most concrete and direct to the most abstract and indirect. Meanwhile, Bloom's Taxonomy categorizes cognitive skills into hierarchical levels, from basic recall of facts to higher-order thinking skills such as creating and evaluating. Integrating these frameworks helps educators design effective learning activities by considering both the type of experience and the cognitive complexity involved.

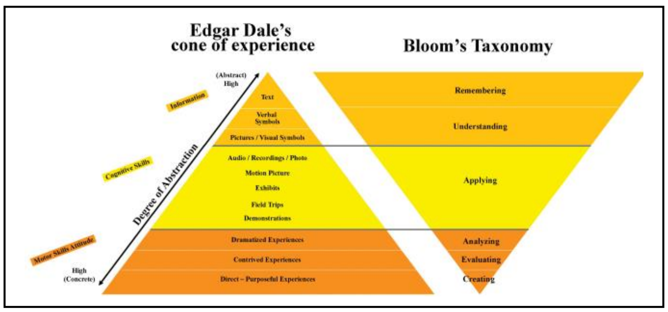

Fig. 4. Edgar Dale’s cone of experience (left) and Blooms’ taxonomy (right).

In terms of *skill-based outcomes*, direct interaction in VR, characterized by high physical engagement and immediate feedback, aligns with the lower levels of Dale’s Cone of Experience, such as direct, purposeful experiences. These experiences are highly concrete and involve active participation, which is crucial for developing technical and motor skills in engineering students. For instance, in mechanical engineering, students could use VR to interact directly with virtual components of machinery, allowing them to understand the assembly process through hands-on manipulation. This method allows students to engage physically with the material, leading to improved practical performance and academic grades. Within Bloom’s Taxonomy, these interactions correspond to the lower cognitive levels of Remembering and Understanding, as students gain foundational knowledge through hands-on activities.

For *cognitive outcomes*, the study's findings demonstrate that both interaction methods contribute to knowledge retention and a deeper understanding of complex concepts. Direct interaction supports embodied learning, allowing students to grasp spatial and design-related tasks intuitively, which enhances their ability to *Apply* and *Analyze* information—levels that lie in the middle of Bloom's Taxonomy. For example, civil engineering students might use VR to explore the structural integrity of buildings by manipulating different load conditions in real-time. Indirect interaction, which requires precision and detailed manipulation, aligns with higher levels of abstraction in Dale’s Cone, such as visual and verbal symbols. This method supports higher-order cognitive tasks like *Evaluating* and *Creating*, as outlined in Bloom’s Taxonomy, enabling students to apply theoretical knowledge in real-world situations with greater precision and control. In fields like electrical engineering, indirect interaction might involve the detailed design and analysis of circuit layouts, where accuracy is paramount.

The *affective outcomes* observed in this study, such as the development of positive attitudes, motivation, and 'soft' skills, are also reflective of the educational principles embodied in both Dale's Cone and Bloom's Taxonomy. Direct interaction, by fostering engagement through realistic and immersive experiences, enhances intrinsic motivation and contributes to the development of professional and personal skills. This is particularly relevant in disciplines like environmental engineering, where VR can simulate complex ecosystems, allowing students to engage with environmental management scenarios that cultivate critical thinking and ethical considerations. This aligns with the motivational aspects necessary for sustaining higher levels of cognitive engagement and the effective use of abstract learning experiences. Indirect interaction, while more cognitively demanding, provides external motivation through the precision and control it offers, which is particularly relevant for tasks that require critical thinking and the synthesis of new ideas, as described in the higher levels of Bloom’s Taxonomy.

For a well-rounded educational experience, it is often beneficial to combine both direct and indirect interactions, leveraging the strengths of each method. Early stages of learning can employ direct interactions to build foundational knowledge and engagement through hands-on activities, especially in problem-based learning curricula such as architectural engineering or engineering design. As learners progress and tasks become more complex, transitioning to indirect interactions can help them refine their skills and apply their knowledge in precise, controlled ways. For example, a course in environmental science might begin with direct interactions where students explore a virtual ecosystem, identifying species and their interactions. As they advance, they might use indirect interactions to model and simulate environmental changes, analyzing the impact of various factors with precision.

The integration of Edgar Dale's Cone of Experience and Bloom's Taxonomy into the design of VR-based educational content provides a comprehensive framework for selecting the appropriate interaction methods to optimize learning outcomes. By thoughtfully combining both direct and indirect interactions, educators can craft a more engaging and effective learning environment. This approach not only helps students develop technical skills, but also deepens their understanding and fosters positive attitudes, leading to richer learning experiences and higher levels of engagement in engineering education.

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