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AI-Driven Situated Cognition Interaction Design for Immersive Learning in Virtual Space Tourism

Wen Wen[1,a], Yao Liu[2,b], Tianli He[3,c], Wang Ying[4,d,*]

[1]Graduate School, China Architecture Design & Research Group, Beijing, 100044, China
[2]Departmentof Design, Politecnico di Milano, Milan, 20133, Italy
[3]Singapore University of Technology and Design (SUTD), 138682, Singapore
[4]Cultural Development Institute, Yunnan University, Kunming, Yunnan, 650504, China
[a]vinod.wen@gmail.com, [b]yao.liu@mail.polimi.it, [c]tianli_he@mymail.sutd.edu.sg, [d]wangyingynu@163.com
[*]Corresponding author

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Abstract: This study presents an AI-Driven Situated Cognition Interaction Design Model of VR immersive learning context specifically related to virtual space tourism. This research intends to apply to pedagogy through the use of AI-based systems, collaborative engagement, and sustainable learning to close the gap between immersive technology and an educational outcomes. The model proposed emphasizes authentic contexts, real-time interactivity, and self-projection promising a traditional platform for exploiting sustainability challenges of space exploration. The Cabin integrates range sensors, a VR Space Tourism Experience, AI-based life-support systems, high-resolution VR displays, and embodied interaction sensors to create realistic scenarios. User studies showed an increase in users understanding of sustainability concepts, collaborative problem-solving and long-term retention. This study demonstrates how AI can empower designers to imagine and create interactive learning environments that cultivate critical awareness and sustainable behaviors of content for real world challenges.

1. Introduction

Through immersive experiences, virtual space tourism aims to render space travel engaging and attainable. The potential for individuals to engage with space in a virtual setting is not only intellectually stimulating but also serves as an educational instrument as technology advances. Utilizing virtual environments enhances our comprehension of the intricacies of space missions, particularly with sustainability and resource management. This study examines the potential of a Situated Cognition framework to enhance learning in immersive events.

Situated Cognition Theory posits that students acquire knowledge most effectively in authentic surroundings through engagement with tasks relevant to their experiences [1,2]. This method emphasizes the importance of context in learning and understanding, especially in interactive environments. Implementing these concepts in virtual space tourism will facilitate the creation of engaging scenarios that not only captivate users' interest but also enhance understanding of the sustainability challenges associated with space travel.

Furthermore, the potential of Extended Reality (XR) technology to convey concepts of sustainable design is substantial. XR settings enable individuals to engage with eco-friendly scenarios and observe immediate outcomes of their actions [3]. This context-oriented methodology enhances understanding and promotes rational sustainable decision-making [4].

Notwithstanding these advantages, current literature reveals a distinct inconsistency regarding the application of Situated Cognition Theory in virtual space tourism. Most contemporary VR applications prioritize entertainment over teaching, often lacking the necessary depth to effectively convey sustainability principles in conjunction with space science [5]. This study addresses the research vacuum by proposing a Situated Cognition Interaction Design Model tailored for virtual space tourism, highlighting the incorporation of sustainability concepts.

The proposed model utilizes situated cognition concepts to create immersive learning experiences that enable users to engage in contextually rich scenarios simulating real-world issues. This strategy enhances individuals' understanding of sustainability within the realm of space exploration, thereby equipping them for the challenges of real missions. This section will examine the theoretical underpinnings of the concept, its implementation, and evaluation methods, thus providing a comprehensive analysis relevant to educational technology and space education.

2. Literature Review

2.1 The Development of Situated Cognition Theory

Lave and Wenger theory of Situated Cognition indicates that the acquisition of knowledge is contextual, and learning occurs within a task in social interactions of real-world contexts[1]. But over the time this perspective has developed from little more than transfer of knowledge to highly sophisticated learning ecosystem design. Recently, researchers began investigating how it could apply to digital and virtual environments, most notably for training in complex tasks and skills [2]. An example is Barsalou combined situated cognition with cognitive modeling to describe the individual learning, in other words what a person does before and after performing a series of tasks [6].

And as virtual reality (VR) technology has matured, Situated Cognition Theory has seen widespread use in simulation training and medical education. Building on this, Dalgarno and Lee explored how learning could be supported through 3D virtual environments, noting how effectively immersive learning takes place and highlighting the dynamic and interactive nature of such environments [4]. This evolution illustrates that situated cognition had evolved beyond a physical environment and into a virtual/augmented world, while also providing learners with high-fidelity case-based experiences in a technology-rich environment.

2.2 Constructivist Learning in the Contemporary Context

According to the constructivist learning theory, learners construct knowledge actively using exploration and problem-solving [7]. The recent increase of constructivist learning in VR has been quite popular. For example, Shaffer developed an immersive game-based learning environments, which implemented constructivist approaches to the problem: Under their engagement with interactive tasks, students learned even complex problems, while critical thinking and collaboration were activated [8].

From a virtual space tourism context, studies have been conducted to apply constructivist learning approaches. Gee highlighted virtual tasks as a new frontier for both engaging learners and supporting knowledge construction, using examples of complex decision-making (e.g., as found in video game simulations) as a spearhead of the field [9]. However, they are usually limited in the sense that they look at one single task or short-term learning effects with only few studies examining long-term effects and knowledge transfer. Moreover, most of the related constructivist research is designed either for the technological development or entertainment experience [5], although there is an insufficiency in constructivist research specifically for the virtual space tourism.

2.3 Limitations of Existing Studies

VR studies that exist today are largely skewed towards entertainment, with a focus on the visual experience and marketability as opposed to educational merit. Sterman, for instance, found that many virtual games had shallow learning designs and provided limited interactive experiences [10]. This was explored by Slater and Sanchez-Vives for immersion in VR, but they did not discuss its educational relevance [5]. Although some research apply VR in education, for instance, through Clark and Mayer's multimedia learning model, they are not context-rich task design and knowledge-sharing to collaborate with learning, would not produce the expected educational outcome [3].

Furthermore, in the microdomain of virtual space tourism, there is significantly less research on the application of situated cognition and constructivist principles. Most work studied thus far are technical demos or simulations of tasks. For example, while Dalgarno and Lee emphasized the spatial benefits of virtual learning environments, a deeper discussion of the relationship between educational content and technology was absent [4]. Likewise, Sterman indicated that the majority of VR educational applications do not provide an adequate balance between realism and educational value, hindering their effectiveness for deep learning [11].

2.4 Research Innovation

In response to these gaps, this study proposes an educational design framework for virtual space tourism that center on the perspectives of Situated Cognition Theory and constructivist learning. The main innovations of this research, compared to existing studies, include:

Sustainable model Case: The study integrates education with virtual tasks by creating realistic task situations, including resource management task and environmental protection task.

Social Discovery and Searching Based on Play: The research enriches the study with social learning discovery and enhancement by supporting multi-user interaction and collaboration, improving learning outcomes.

Integration of Technology and Theory: This research employs high-resolution VR technology, and orchestrated learning through Situated Cognition Theory to synthesize the components, and to design immersive, interactive, and authentic teaching and learning scenarios.

The development of these innovations not only fills the gap in research on the application of situated cognition in virtual space tourism but also offers theoretical evidence and practical guidance for further educational technology applications.

3. Situated Cognition Interaction Design Model

3.1 Situated Cognition Theory

3.1.1 Authentic Context

Situated Cognition Theory emphasises that learners are dependent on the environment that learning takes place in. Informal learning occurs when learners are placed in larger real-world contexts that enable them to grapple with true problems [1](see Figue 1). This is a principle that educational experiences are more effective when the experiences have a real-world application. In virtual space tourism, such as, immersive experiences are created which emphasizes the the complications surrounding the exploration of space [2].

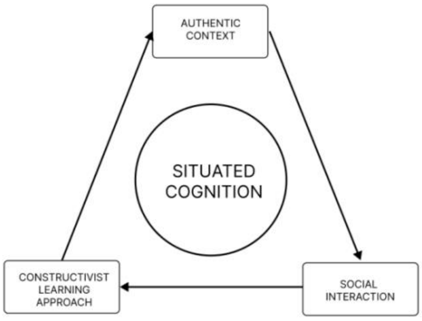

Figure 1: Situated Cognition Model

3.1.2 Constructivist Learning Approach

This is where Situated Cognition goes deeper than constructivist-based learning (which includes approaches like Problem-Based Learning) by stating that the surroundings and context cannot be removed from the act of collaboration or knowledge everybody is generating locally. It highlights the need for members to experiment, reflect, and explore what they do in order to maximize their learning [12]. This is to engage users in immersive virtual environments conducive to the active learning and reasoning. To illustrate, as users now work to relocate or assign resources in completing a mission in a certain area they are constructing the rationale for their sustainability definition [8].

3.1.3 Social Interaction

One connecting thread found in Situated Cognition Theory is social interaction. Social learning is learning by working and communicating with others. This perspective realizes that knowledge is co-created in conversations and shared experiences often. Breaking up opportunities for sharing different perspectives with collaborative tasks, an emphasis on the social negotiation of solutions, and an iterative processing of sustainability challenges in space exploration, through users interacting with a virtual space tourism environment, can support such learning [13].

3.2 Virtual Reality Theory

3.2.1 3D Space

Figure 2 shows the overview of Virtual Reality Theory.3D Space is about providing a space that wraps around the user in a natural immersive way in 3D. It enables people to perceive depth, move through space, and interact with objects in a way that seems realistic. Being able to experience things in 3D allows users to immerse themselves in the virtual world as though they were as real as they are, making it easier for them to comprehend complex ideas such as this. This spatial dimension is important for authentic contexts that support learning [5].

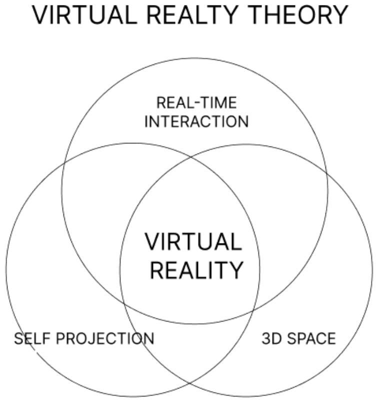

Figure 2: Virtual Reality Model

3.2.2 Real-Time Interactivity

Live interactivity is a central characteristic that enables users to operate freely in a virtual environment and receive instantaneous feedback on their actions. This interactive play allows users to touch objects, make decisions and see immediate consequences of their decisions. Providing users with space for trial-and-error learning allows exploration and experimentation, which is critical to successful learning and knowledge construction [4]. The experience becomes much more immersive, and the learner is given a sense of agency through these interactions.

3.2.3 Self-projection

Self-projection is what happens when users take on virtual avatars, creating a perfect melding between their corporeal selves and the digital landscape within which they reside. That sense of embodiment helps contribute to users feeling like they're within the content they're experiencing. This participatory approach allows users to take on a sense of ownership and agency about their avatar through self-projection, driving them to invest more time and effort in the learning material. In addition, this embodiment enables users to communicate and cooperate with other users in a common virtual space, thus enhancing the experience of learning.

3.3 Situated Cognition Interaction Design Model

Incorporating the principles of Situated Cognition Theory into a Situated Cognition Interaction Design Model, it comprises key aspects of the theory with the necessary components of virtual reality (VR) in order to facilitate the learning process (see Figure 3). Three Components of the Model: it centres around a collaborative engagement, an active learning experience, and an immersive learning environment. These elements are inter-connected and form a coherent structure and framework that enables meaningful learning.

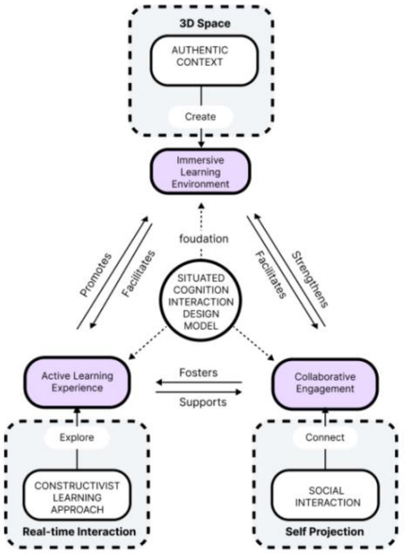

Figure 3: Situated Cognition Interaction Design Model

3.3.1 Collaborative Engagement

Collaborative learning takes a socially oriented approach to the process, examining the importance of social interaction. In a virtual reality (VR) environment, users can inhabit avatars, which allows them to interact effortlessly with one another. This ability to project themselves creates a sense of presence and belonging in the virtual environment. As learners collectively need to accomplish tasks — for example by solving sustainability challenges — they share knowledge, negotiate solutions and construct understanding together. Such interactions contribute to co-construction of knowledge where the heterogeneity of perspectives enriches the learning experience and promote deeper understanding of complex phenomena. The other revolves around leveraging a fundamentally social nature of learning, as collaborative exercises lead to enhanced cognitive engagement and subsequent retention.

3.3.2 Active Learning Experience

In this case, the data is provided by active learning experience, which involves a constructivist interactive approach to learning, where users come into direct contact with the material by exploring and experimenting. In terms uh VR, real-time interactivity enables learners to interact with virtual objects, make choices, and see the consequences of their actions unfold in real time. These concepts highlight active participation, which gives users the opportunity to validate hypotheses and correct all misunderstandings from the feedback they provide. Essentially, it relies on the cyclical action-reflection action process which is fundamental for deep learning. Through the personal involvement in the learning process, users develop themselves, strengthen the critical and analytical thinking and the problem-solving capacity, and the knowledge gained becomes usable in life.

3.3.3 Immersive Learning Environment

An immersive learning environment is defined by authentic contexts that imitate life experiences. With three-dimensional spatiality, learners in VR are able to move around and act within a hotspot full of details and sights, immersing them deeper into what is covered in their learning space. When knowledge is relatable, learning becomes more relatable too. This component works through a mechanism in that the 3D environment provides a sense of presence by allowing the user to see complex systems and relationships within the material. When learners are enmeshed within the context of their learning, the chances of emotional and cognitive investment in the learning process are substantially better, resulting in better understanding and retention of knowledge.

3.4 Design Steps and Framework

To ensure the effective application of the Situated Cognition Interaction Design Model in virtual reality, the following design steps and framework were adopted in table 1 below.

Table 1: Situated Cognition Interaction Design Framework

Category	Design Element	Keywords
Collaborative Engagement Design	Self-Embodiment	Users embody virtual avatars via 3D modeling to enhance presence.
	Collaborative Tasks	Team tasks like resource allocation foster collaboration and shared problem-solving.
Active Learning Experience Design	Real-Time Interaction	Real-time feedback helps users adjust strategies and decisions.
	Exploration and Experimentation	Open-ended tasks promote exploration, strategy experimentation, and critical thinking.
Immersive Learning Environment Design	3D Spaces	Realistic 3D environments enable navigation and interaction, boosting immersion.
	Realism	Simulated real-world scenarios, like resource management, make learning relevant.

By following these design steps, we ensure that the virtual reality experience is not only technologically advanced but also pedagogically effective. The model ensures that users can engage meaningfully with the content, collaborate with peers, and apply their learning in practical, real-world contexts.

4. VR Space Tourism Experience Cabin Design

The VR Space Tourism Experience Cabin is designed for a Situated Cognition Interaction Design Model Approach for the Development of an Educational VR Experience. All of these elements are incorporated into the cabin’s design so that space exploration and sustainability become more tangible. But the technical cost and challenges of implementing such a VR experience must be closely examined. From the hardware technical specifications required to pursue the software development complexity, and user adaptability concerns to provide a good experience for diverse audiences.

4.1 Collaborative Engagement

Collaborative engagement is a fundamental aspect of the cabin's design, emphasizing social interaction among users. In this VR setting, participants embody avatars, which allows for seamless interaction with one another within the virtual space. This self-projection enhances users' sense of presence and belonging, which is crucial for effective learning.

4.1.1 Social Interaction and Knowledge Sharing

Features encourage cooperation, like tasks that tackle sustainability challenges through resource management or expedition planning. Travelers must combine efforts, instilling an appreciation for diverse input in solving complex issues. Co-constructing knowledge yields richer exchanges and deeper insights than solitary study.

4.1.2 Negotiation and Understanding

As users engage in collaborative tasks, they negotiate solutions, enhancing their understanding of sustainability issues in space tourism. This process not only improves cognitive engagement but also reinforces the importance of teamwork in addressing real-world challenges [2].

4.1.3 Technical Challenges and Solutions

As collaborators negotiate answers, comprehending sustainability's role in space tourism grows. Beyond boosting cognitive involvement, the process underscores teamwork's importance addressing real problems, just as in the real world.

4.2 Active Learning Experience

The design of the VR cabin prioritizes an active learning experience, grounded in constructivist principles. Users engage directly with the material through hands-on exploration and experimentation.

4.2.1 Real-Time Interactivity

The cabin incorporates realistic interactive elements that permit learners to manipulate digital objects, make conclusions, and observe the prompt consequences of their deeds. For instance, individuals can alter the cabin’s life-support systems or resource distributions, testing theories regarding sustainability practices promptly [9].

4.2.2 Iterative Learning Process

This hands-on participation supports an iterative process of movement and reflection. As users engage in various scenarios, they get feedback that prompts them to refine their comprehension and strategies. This active involvement cultivates critical thinking and problem-solving abilities, rendering the information achieved more relevant to real world situations [7].

4.2.3 Technical Challenges and Solutions

The integration of realistic interactivity presents substantial technological difficulties, particularly in upholding high-quality graphics and processing power for prompt simulations. To address this, the cabin uses high-performance GPUs (Graphics Processing Units) for rendering complex simulations, confirming realistic environments without lag. Additionally, the software architecture incorporates modular design principles, allowing developers to optimize and update individual components (such as life-support system simulations) without disrupting the entire VR experience. Adaptation to different user skill levels is supported through customizable interfaces and difficulty settings, ensuring accessibility for both novice and expert users.

4.3 Immersive Learning Environment

The cabin replicates an authentic space station environment that immerses learners in realistic scenarios relating to sustainability challenges in space exploration.

4.3.1 Three-Dimensional Spatiality

Through virtual reality technologies, learners navigate and interact within a vivid 3D reconstruction of a space station. This spatiality stimulates engagement by making the remote setting feel immediately present and applicable to their studies.

4.3.2 Sense of Presence

The cabin's design transports users perceptually and cognitively into the virtual space station. Within this setting, learners gain insight into complex operational systems and their interdependencies for sustainable missions. Feeling fully situated contributes to investment in learning, ultimately facilitating comprehension and retention [4].

4.3.3 Technical Challenges and Solutions

To achieve convincing immersion, the cabin integrates high-performance hardware and software seamlessly. Precision headsets and tracking allow natural perception of depth and movement within the reconstructed space. Adaptive rendering prevents discomfort, adjusting frame rates to users' positions and motions. Haptics also introduce "touch" feedback from virtual objects. Advanced lighting realistically models the station's various environments, pushing graphics and rendering capabilities.

4.4 VR Space Tourism Experience Cabin Design

While leveraging cutting-edge VR, the cabin faces substantial technical hurdles. Surmounting limits of equipment, integration complexities, network requirements, and user adaptation is critical to delivering engaging education. Through innovative solutions and state-of-the-art VR integration, the cabin fosters interactive, collaborative learning about sustainability in unprecedented ways(see Figure 4).

Figure 4: Situated Cognition Interaction Design Model

5. Results

5.1 User Research Methods

User research uses qualitative and quantitative user research. Surveys, interviews, and observations are used to collect data and compare the experimental and control groups. Members took pre and post-tests assessing both their sustainability knowledge and interaction with the VR experience. Interviews were also conducted to solicit user feedback on their perception of the virtual space tourism experience in learning challenges, engagement and outcomes.

5.2 Sample and Context Selection

The user sample included individuals from diverse backgrounds, selected based on their familiarity with VR, interest in learning, and level of engagement. The sample consisted of university students, space enthusiasts, and the general public with varying levels of VR experience. The research controlled for VR familiarity by using surveys to assess participants' comfort with VR technology, ensuring that the sample was representative and aligned with the research goals.

5.3 Data Analysis Methods

Data were analyzed by pre-test and post-test comparison, using statistical methods (e.g. t-test) to check for learning outcomes. Outcomes reflected substantial gains in participants' knowledge of sustainability — particularly around challenges beyond the realm of space. Results of the experimental and control groups were compared, revealing that this virtual space tourism experience positively impacted learning, providing deeper understanding and more durable memory retention than traditional learning approaches.

The design and development of the VR Space Tourism Experience Cabin, informed by the Situated Cognition Interaction Design Model, represents a noteworthy advancement in applying immersive technologies for educational objectives. By emphasizing cooperative engagement in an immersive setting that encourages active learning, the cabin enhances user involvement while cultivating a deeper comprehension of the complexities associated with space exploration and sustainability. Initial study results are promising, indicating this VR experience's potential to bolster instruction in space tourism and sustainability. The key findings summarized below distill the outcomes:

6. Discussion

The VR space tourism cabin has good potential as an educational tool, but also introduces challenges that need addressing before wider application can be considered. The engaging design so clearly presents abstract themes of sustainability and cosmic exploration, it raises awareness of both the environmental challenges we face and of the possibilities of sustainable living. More research is necessary to assess the long-term effects on users' retention of information and behaviors related to sustainability.

Some of the major hurdles are the cost of providing advanced VR hardware and time to set up the device which isn't very accessible. Another big concern is the balance between entertainment and education, as 30% of users then asked for more educational content to be meaningful. Fifteen percent of participants reported suffering from physical discomfort like motion sickness during prolonged sessions. Adaptive technology, shorter sessions, and user on boarding can all improve comfort and accessibility, especially for beginners who may not be familiar with VR.

The future research is to investigate the long-term learning impact of the VR, global from the worldwide multi-user collaboration, and adapt to learning technologies. Overall, these developments will help to ensure that VR becomes an even more effective and engaging method of education, particularly in teaching key concepts around sustainability and space exploration.

7. Conclusion

To conclude, the VR Space Tourism Experience cabin is a successful educational tool and as such, able and accessible to a wide range of learners in learning about insustainability as part of space exploration. Despite the related difficulties of technical limitation, physical discomfort, and the contradiction between entertainment and education, there is indeed room for greater achievement in educational outcomes with immersive technologies. As technology advances, more work can for further improvement on creating a more available and practical user experience.

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