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Design and Usability Evaluation of a Virtual Reality–Based Information System for Solar Photovoltaic Awareness

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ABSTRACT

Virtual reality (VR) has increasingly been adopted as a platform for interactive information systems that support user engagement and system understanding through immersive interaction. This paper presents the design, implementation, and usability evaluation of PV Gallery, a VR–based information system developed to support user awareness and system-level understanding of solar photovoltaic (PV) systems. The system integrates structured onboarding, interactive informational modules, and a task-based component placement mechanism within a unified VR environment. A usability evaluation was conducted with 21 participants using a structured questionnaire assessing system usefulness, ease of use, ease of learning, user satisfaction, and perceived understanding. Descriptive statistics, reliability analysis using Cronbach's alpha, and independent-samples t-tests were employed to examine system usability and user perception differences. The results indicate high user satisfaction and interaction intuitiveness, with strong internal consistency observed across most usability dimensions. Differences related to comfort and perceived usefulness highlight the importance of ergonomic and inclusive design considerations in VR-based information systems. The findings demonstrate the feasibility of VR as an interactive information system for presenting multi-component technological systems and provide practical insights for the design and evaluation of user-centered VR systems in engineering and management contexts.

Keywords: virtual reality; solar photovoltaic; green technology; usability test; user experience evaluation

INTRODUCTION

Virtual reality (VR) has steadily evolved into a mature interactive medium capable of supporting immersive digital experiences [1-5]. Advances in hardware, rendering performance, and interaction techniques have enabled VR systems to move beyond experimental prototypes toward deployable platforms that support meaningful user interaction. By allowing users to explore virtual environments through spatial navigation and direct manipulation, VR offers unique opportunities to design experiences that emphasize engagement, presence, and interaction quality [6-8]. These characteristics distinguish VR from conventional desktop-based interfaces and make it particularly suitable for applications where understanding spatial relationships and system structure is important.

As a result, VR has gained attention as a platform for interactive information systems in which user experience plays a central role [6, 9-12]. In such systems, information is not only presented visually but is embedded within an interactive environment that users can navigate and explore. From an information systems perspective, the effectiveness of VR-based systems depends on factors such as usability, interaction clarity, system responsiveness, and user comfort. Poorly designed interaction flows or insufficient onboarding can undermine system usefulness, regardless of the quality of the underlying content. Consequently, careful system design and systematic usability evaluation are essential to ensure that VR-based information systems meet user needs and support effective interaction.

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In recent years, VR has gained attention as a platform for communicating sustainability-related topics, including renewable energy and environmental awareness [13, 14]. Solar photovoltaic (PV) systems represent a relevant example in this context, as they consist of multiple interconnected components and operational processes that are often unfamiliar to general users. These systems are commonly introduced using diagrams, videos, or textual explanations. While such representations are informative, they typically present system elements in a static or fragmented manner, which may limit users' ability to form an integrated understanding of component relationships and system workflows. Immersive virtual environments offer an alternative approach by enabling users to explore system layouts, observe relationships between components, and interact directly with virtual representations in a spatial context [15].

Within the field of entertainment computing, many VR applications adopt interaction patterns inspired by games and interactive media, including task-based challenges, guided progression, and real-time feedback mechanism [16, 17]. These design strategies aim to sustain user engagement while supporting intuitive interaction and reducing cognitive and physical strain. Prior studies have shown that factors such as onboarding design, navigation clarity, interaction responsiveness, and physical comfort play a critical role in shaping how users perceive and experience immersive VR systems [18, 19]. From a system design perspective, these factors influence not only user satisfaction but also overall system acceptance and continued use.

Motivated by these considerations, this study introduces PV Gallery, an interactive VR application designed to present solar PV systems through immersive exploration and hands-on interaction. The application integrates a structured onboarding process, interactive informational scenes, and a pick-and-place activity that simulates PV system configuration. Rather than presenting information in isolation, the experience is organized as a coherent sequence of interactions that guide users through the virtual environment in a controlled and engaging manner.

Rather than focusing on formal learning outcomes, this work examines user experience aspects of the PV Gallery application, including perceived usefulness, ease of use, ease of learning, satisfaction, comfort, and perceived understanding of the presented content. A usability evaluation was conducted to assess these dimensions and to explore potential differences in user experience across gender groups. By presenting both the design and evaluation of an interactive VR experience centered on renewable energy awareness, this study contributes design-oriented insights into how immersive VR systems can balance engagement, usability, and clarity when presenting multi-component real-world systems within the scope of interactive information systems.

OBJECTIVES

While VR has been widely used to create immersive experiences related to sustainability and renewable energy, many existing applications place primary emphasis on visualization or information presentation. Less attention has been given to how interaction structure, progression design, and feedback mechanisms collectively influence user experience in awareness-oriented VR environments. In particular, the integration of onboarding, guided exploration, and hands-on interaction within a single, continuous experience is not always examined from a user experience perspective. As a result, aspects such as interaction learnability, comfort, and consistency of engagement across different user groups are often reported only implicitly or remain underexplored.

This study addresses these gaps through the design and evaluation of PV Gallery, an interactive VR application developed with a structured, scene-based interaction flow. The novelty of this work lies in its experience-driven design, which emphasizes controlled progression, immediate visual feedback, and interaction clarity across multiple stages of the VR experience. In addition, the study provides empirical insights through a usability evaluation that examines multiple dimensions of user experience, including usefulness, satisfaction, perceived understanding, and comfort-related differences across users. Together, these contributions offer practical guidance for designing and evaluating interactive VR experiences within interactive information system contexts.

PV GALLERY VR APPLICATION DESIGN AND DEVELOPMENT

The PV Gallery VR application was developed as an interactive virtual reality system intended to engage users with solar PV systems through immersive navigation and task-based interaction. The application was implemented using the Unity game engine and deployed on a standalone VR headset device, enabling users to experience the system

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without reliance on external computing hardware. Throughout the development process, particular attention was given to interaction clarity, system responsiveness, and user comfort, ensuring that the experience remained accessible to users with varying levels of familiarity with VR technology.

Rather than focusing solely on content presentation, the design of PV Gallery emphasizes interaction flow, scene-based progression, and real-time system feedback. These elements were intentionally integrated to support intuitive exploration and consistent interaction across users. The system was structured to guide users through a sequence of experiences that gradually increase in interaction complexity, allowing them to build confidence before engaging with more demanding tasks. This section describes the experience structure, interaction logic, and implementation considerations that define the PV Gallery VR application as an interactive information system.

Experience Structure and Scene Flow

The PV Gallery experience is organized into five sequential scenes that together form a structured and coherent interaction flow. This sequence was defined during the design phase to support gradual user acclimatization to the virtual environment while introducing interaction complexity in a stepwise manner. The progression from one scene to the next is governed by explicit system conditions, such as task completion or interaction triggers, ensuring a predictable and consistent experience for all users.

Figure 1 illustrates the storyboard used during development, mapping user actions, interaction points, and scene transitions. The storyboard served as a design reference to align system behavior with intended user actions, minimize cognitive load, and avoid abrupt transitions. The five scenes include: (1) an entry interface with language selection, (2) an onboarding environment for controller familiarization, (3) an exterior navigation scene, (4) interior informational spaces, and (5) a task-based interactive scene. Each scene plays a distinct role within the overall interaction flow, contributing to a cohesive and structured user experience.

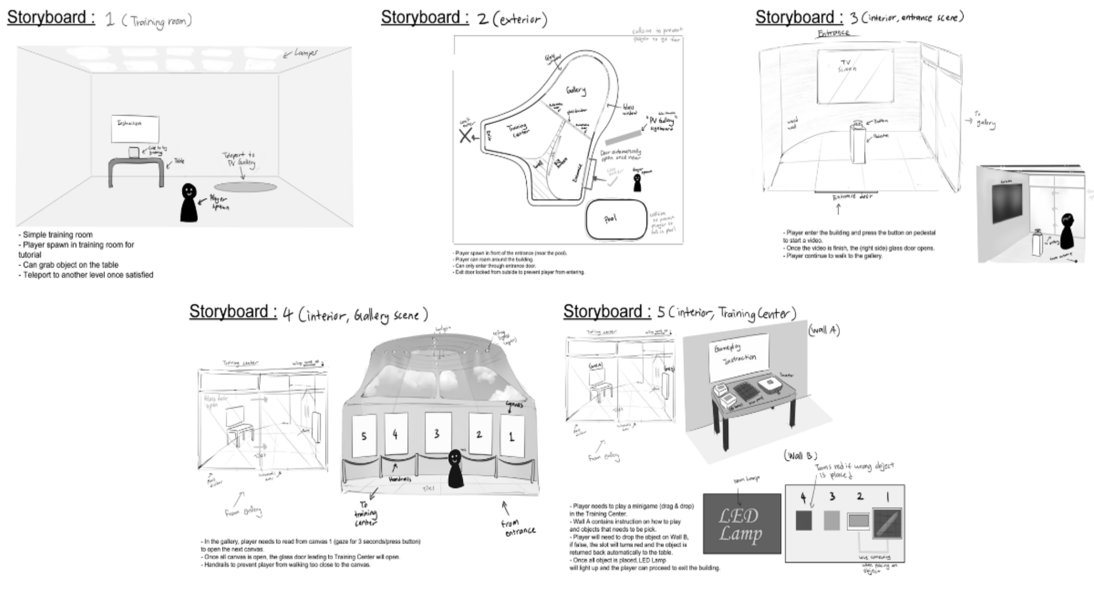

Figure 1. Storyboard or system architecture of PV Gallery VR application.

System Interaction Flow and User Interface Design

To support accessibility for local users, the PV Gallery system incorporates a bilingual interface that allows users to select either English or Malay at the start of the experience. The application begins with a splash screen displaying the PV Gallery identity, followed by a language selection interface that enables users to choose their preferred language before proceeding. This initial step ensures that users can engage with the system content in a language that is comfortable and familiar to them.

After language selection, users enter Scene 01, an onboarding environment designed to familiarize them with fundamental VR interactions. This scene introduces essential interaction mechanics, including movement, object

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manipulation, and camera orientation using handheld controllers. Interaction guidance is embedded directly within the virtual environment through visual cues and spatial prompts rather than external instructions, allowing users to learn through exploration (Figure 2a). A simple object interaction task encourages users to practice grabbing and manipulating a virtual object, helping them gain confidence before progressing further.

Once the onboarding interactions are completed, users are guided toward a clearly marked teleportation zone that transitions them into the main gallery environment. This transition mechanism ensures a clear and intuitive shift between scenes while maintaining immersion. Users then arrive at Scene 02, an exterior gallery environment that establishes spatial context and visually introduces the PV Gallery structure. Navigation within this scene is supported by collision boundaries that restrict unintended movement while preserving a sense of openness and orientation (Figure 2b). These boundaries help guide users toward the intended entry point without disrupting immersion.

Users subsequently proceed to Scene 03, the Entrance Room, where an audiovisual presentation introduces solar energy–related content through a video display. Video playback is initiated by user interaction, requiring the user to press a designated button to begin the presentation (Figure 2c). To ensure consistent exposure to the content, system progression is temporarily restricted until the video concludes. Once playback is complete, an automatic glass door opens, allowing users to move forward in the experience.

Following the entrance presentation, users enter Scene 04, which contains multiple interactive panels presenting information related to PV system components, system operation, policy context, and practical applications (Figure 2d). Each panel is activated either through direct button interaction or sustained viewing, allowing users flexibility in how they engage with the information. To maintain a structured interaction sequence, progression to the final scene is enabled only after all panels have been completed, ensuring that users encounter the full set of informational content.

The final stage of the experience, Scene 05, introduces a task-based interaction focused on component placement and feedback-driven exploration. In this scene, users are presented with a set of virtual PV system components arranged on a table (Figure 2e). A visual guide indicates the interaction goal and expected placement sequence. Users pick up individual components and place them into designated slots on a wall-mounted layout board (Figure 2f). Immediate visual feedback is provided to indicate correct or incorrect placement. Incorrect actions cause the component to return to its original position, encouraging exploration without penalty. Upon successful completion of the placement sequence, a visual indicator is activated, and the exit pathway is unlocked, signaling the conclusion of the experience.

Throughout the application, interaction design prioritized consistency, responsiveness, and user comfort. Teleport-based navigation was adopted to reduce motion discomfort, and interactive elements were designed with uniform affordances and clear visual feedback. Scene transitions were explicit and predictable, supporting a smooth and intuitive experience flow. Overall, the PV Gallery VR application was implemented as a structured interactive system that balances immersion, usability, and engagement. The modular scene-based design and controlled interaction logic provide a suitable platform for evaluating user experience in immersive virtual environments within the scope of interactive information systems.

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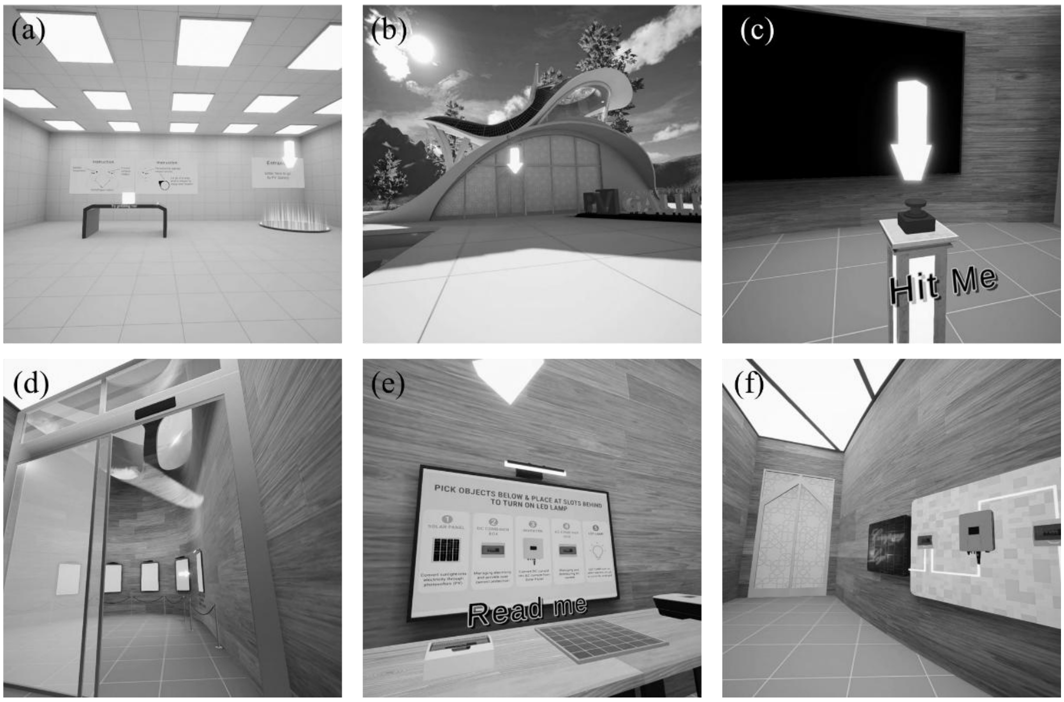

Figure 2. (a) Overview of Scene 01: Training Room, designed to familiarize users with VR controls, Interactive tutorial table with a glowing cube for user interaction, Visual guide explaining controller inputs for movement, object manipulation, and camera rotation and Teleportation portal marked as "Entrance" used to transition into the main PV Gallery. (b) Exterior view of the PV Gallery, where users arrive after training completion. (c) Pressing the button activates a video presentation on solar energy. (d) Users enter the Gallery Room with informative panels; panels are activated by reading for a minimum duration or pressing a button. (e) Instructional panel and table displaying solar PV components. (f) Components must be arranged in the correct sequence, a visual activation indicator confirms successful system configuration and completion of the task opens the exit door, marking the end of the VR experience.

METHODS

Study Design

This study employed a cross-sectional survey design to assess user perceptions of the PV Gallery VR application. The objective was to evaluate key usability and experience-related constructs, including usefulness, ease of use, ease of learning, satisfaction, and knowledge and understanding. Data were collected using a structured post-experience questionnaire administered immediately after participants completed the full VR session, which included a training scene, interactive learning modules, and a hands-on assembly challenge.

Participants

A total of 21 participants were recruited through convenience sampling from a university setting. Eligible participants were required to be at least 18 years of age and fluent in either English or Malay. Participants were intentionally selected from groups without prior knowledge of solar PV systems to ensure that the VR experience served as their first structured exposure to the topic. Demographic information such as gender and age group was collected to support subgroup analysis. Prior to participation, all individuals provided written informed consent by signing a Testing Consent & Non-Disclosure Form, which outlined the purpose of the study, ensured confidentiality, and emphasized the voluntary nature of participation.

Survey Development

To evaluate usability and perceived understanding within an interactive VR experience, a structured questionnaire was developed based on the validated USE Questionnaire (Lund, 2001). This instrument was chosen for its comprehensive assessment of user interaction with digital applications and was adapted to suit the context of a VR

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learning environment. The original dimensions which are usefulness, ease of use, ease of learning, and satisfaction were retained. A fifth dimension, knowledge & understanding, was added to capture the perceived learning outcomes specifically related to solar energy. The final instrument consisted of 20 questions, divided evenly across the five subscales. In addition, two demographic questions (gender and age group) were included. To enhance accessibility and cultural relevance, the survey was made available in both English and Malay, allowing respondents to choose their preferred language and reducing potential bias from language barriers. This bilingual, context-specific adaptation ensures that feedback from participants is both relevant and meaningful, supporting targeted improvements in system design. A summary of the questionnaire structure is presented in Table 1.

Table 1. Usability and learning survey questions adapted from the USE questionnaire.

Subscale	No.	Statements
Usefulness	1	PV Gallery VR helps me complete learning activities effectively
	2	PV Gallery VR meets my needs for this type of VR training
Ease of Use	3	The PV Gallery VR experience is easy to use
	4	It is simple to navigate through the scenes
	5	The 'Pick and Place' game does not require a lot of steps to complete
	6	I can play PV Gallery VR without referring to written instructions
	7	I did not notice any inconsistencies while using PV Gallery VR
	8	Both first-time and frequent users would enjoy using PV Gallery VR
Ease of Learning	9	I learned to use the VR controller quickly
	10	I easily remember how to navigate after the training scene
Satisfaction	11	I am satisfied with the PV Gallery VR experience
	12	I would recommend PV Gallery VR to others
	13	PV Gallery VR is enjoyable to use
	14	I felt comfortable using PV Gallery VR without experiencing dizziness
	15	The VR experience did not cause nausea or discomfort
Knowledge & Understanding	16	PV Gallery VR helps me to better understand solar energy
	17	I gained new knowledge about solar energy that I did not know before
	18	The 'Pick and Place' game deepened my knowledge of solar energy concepts
	19	I can explain how a solar panel system generates electricity after using PV Gallery VR
	20	Using VR made learning about solar energy more engaging compared to traditional methods (e.g., reading or lecture)

Instrument

The finalized questionnaire comprised 20 Likert-scale items, grouped under five subscales: Usefulness (2 items), Ease of Use (6 items), Ease of Learning (2 items), Satisfaction (5 items), and Knowledge & Understanding (5 items). Items were rated on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The survey was administered immediately following the VR session to capture fresh impressions and ensure accurate reflections of user experience. The structured design of the instrument facilitated a comprehensive assessment of both usability and engagement, while also enabling informed design iteration prior to broader deployment.

Data Analysis

Quantitative data were analyzed using standard statistical techniques. Descriptive statistics (mean, median, standard deviation, and frequency distributions) were calculated for all questionnaire items. Internal consistency for each subscale was evaluated using Cronbach's alpha. To examine group differences, particularly by gender, independent-samples t-tests were conducted on the mean scores of each subscale.

RESULTS & DISCUSSION

Overview of User Experience Evaluation

This section presents the results of the user experience evaluation conducted on the PV Gallery VR application and discusses the findings in relation to system usability, interaction quality, user engagement, and physical comfort.

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The evaluation focuses on five experience-related dimensions: usefulness, ease of use, ease of learning, satisfaction, and perceived knowledge and understanding. These dimensions were selected to capture how users perceived and interacted with the system as an immersive interactive information platform.

Rather than measuring objective learning performance, the analysis emphasizes subjective user experience indicators, which are particularly relevant for evaluating immersive systems where engagement, clarity of interaction, and comfort strongly influence overall system acceptance. From an information systems perspective, these measures provide insight into whether the system design effectively supports user interaction, facilitates exploration, and maintains a positive experiential flow throughout the VR session.

Descriptive Statistics of Usability Questions

Descriptive statistics were computed for all 20 questionnaire items spanning the five core usability domains: Usefulness, Ease of Use, Ease of Learning, Satisfaction, and Knowledge & Understanding. Overall, participant responses indicated consistently positive perceptions of the PV Gallery VR application. Most items yielded median scores of 4 or 5 on a five-point Likert scale, reflecting strong agreement with favorable usability statements. Figure 3 presents the mean and standard deviation for each survey item, offering a detailed view of response distribution across the questionnaire.

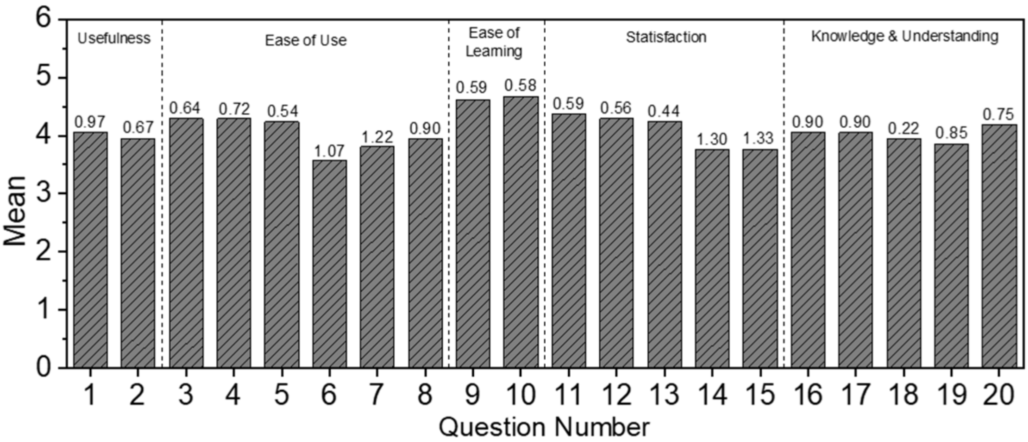

Figure 3. Mean and standard variation scores for usability survey questions.

Descriptive statistics were computed for all 20 questionnaire items spanning the five core usability domains: Usefulness, Ease of Use, Ease of Learning, Satisfaction, and Knowledge & Understanding. Overall, participant responses indicated consistently positive perceptions of the PV Gallery VR application. Most items yielded median scores of 4 or 5 on a five-point Likert scale, reflecting strong agreement with favorable usability statements. Figure 3 presents the mean and standard deviation for each survey item, offering a detailed view of response distribution across the questionnaire.

Among the five subscales, Ease of Learning achieved the highest average ratings. Question 10 ("I easily remember how to navigate after the training scene") recorded the highest mean score (M = 4.67), followed closely by Question 9 ("I learned to use the VR controller quickly") with a mean of M = 4.62. These findings indicate that the onboarding and interaction familiarization components were effective in preparing users to navigate and interact within the VR environment independently. This result aligns with prior research highlighting the importance of structured onboarding in immersive systems, particularly for users with limited prior VR experience.

High scores were also observed in the Ease of Use and Usefulness domains. Participants expressed strong agreement regarding the simplicity of navigation, clarity of interaction mechanisms, and the perceived relevance of the application for understanding solar energy systems. These results suggest that the interface design and interaction logic supported efficient system use without imposing unnecessary cognitive or physical effort. From a system engineering perspective, this reflects successful alignment between system functionality and user expectations.

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The Satisfaction subscale similarly reflected favorable evaluations, with most participants reporting enjoyment and general comfort during the VR session. However, Items 14 and 15 addressing physical comfort, dizziness, and nausea showed slightly lower mean scores (M = 3.76) and greater variability. While these values remain within an acceptable range, they indicate that a subset of users experienced mild discomfort. Such variation is not uncommon in immersive VR environments and highlights an important area for system refinement, particularly given the influence of physical comfort on sustained user engagement.

The Knowledge & Understanding subscale also demonstrated strong performance, with participants reporting improved comprehension of solar energy concepts following the VR experience. This suggests that the combination of immersive storytelling, interactive exploration, and task-based interaction contributed to a clear and engaging system experience. Taken together, the descriptive results indicate that PV Gallery functioned effectively not only as an interactive system but also as a meaningful experiential platform for presenting multi-component technical information.

Reliability of Usability Subscales

To assess the internal consistency of the usability constructs measured in the survey, Cronbach's alpha was calculated for each of the five subscales: Usefulness, Ease of Use, Ease of Learning, Satisfaction, and Knowledge & Understanding. Table 2 summarizes the reliability coefficients for each domain based on responses from the 21 participants who completed the post-VR usability questionnaire.

Table 2. Reliability Analysis of Usability Subscales Measured by Cronbach's Alpha

Subscale	Number of questions	Cronbach's Alpha
Usefulness	2	0.84
Ease of Use	6	0.30
Ease of Learning	2	0.73
Satisfaction	5	0.88
Knowledge & Understanding	5	0.88

The analysis revealed strong internal consistency for most subscales. Satisfaction (α = 0.88) and Knowledge & Understanding (α = 0.88) demonstrated excellent reliability, indicating that the items within these domains consistently captured participants' affective responses and perceived understanding. The Usefulness subscale also showed good reliability (α = 0.84), despite consisting of only two items, suggesting a strong conceptual alignment between perceived task relevance and system utility.

Ease of Learning yielded an acceptable reliability coefficient (α = 0.73), which is reasonable given its two-item structure. This result indicates that participants responded consistently to questions related to interaction memorability and controller familiarity following the onboarding phase. Collectively, these findings support the suitability of the instrument for assessing user experience dimensions in immersive VR systems.

In contrast, the Ease of Use subscale exhibited a low reliability coefficient (α = 0.30), falling below the commonly accepted threshold of 0.70. This suggests that the six items within this domain may not have measured a single, cohesive construct. One possible explanation is that the Ease of Use items captured multiple aspects of usability, including navigation, interaction steps, system consistency, and game mechanics, which may not be internally homogeneous. Additionally, certain negatively phrased items may have introduced interpretation variability among participants.

Despite this limitation, the overall reliability profile of the instrument remains robust. The findings indicate that the questionnaire is effective for evaluating most experiential dimensions of the system, while also highlighting areas for refinement. Future iterations of the survey could improve the Ease of Use subscale by separating distinct usability facets or simplifying item phrasing to enhance psychometric coherence.

Gender Differences in Perceived Usability

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To examine whether perceived usability differed between male and female users, independent-samples t-tests were conducted on the five usability subscales: Usefulness, Ease of Use, Ease of Learning, Satisfaction, and Knowledge & Understanding. Composite scores for each subscale were calculated by averaging participant responses to the corresponding items. Results are presented in Table 3, which reports the mean scores and standard deviations for male and female participants, t-value statistics, degrees of freedom (df), significance levels (p-value), and effect sizes (Cohen's d) for each comparison.

Table 3. Gender-Based Differences in Usability Perceptions

Subscale	Male (M±SD)	Female (M±SD)	t-value	df	p-value	Cohen's d
Usefulness	4.29	3.61	2.17	19	0.043	0.96
Ease of Use	4.14	3.87	1.65	19	0.115	0.73
Ease of Learning	4.75	4.50	1.20	19	0.245	0.53
Satisfaction	4.47	3.58	2.95	19	0.008	1.30
Knowledge & understanding	4.03	4.00	0.11	19	0.912	0.05

The analysis of gender-based differences in usability perceptions revealed significant variations in participants' affective responses to the PV Gallery VR application. Male participants reported notably higher scores in the subscales of Usefulness ($t(19) = 2.17$, $p = .043$, $d = 0.96$) and Satisfaction ($t(19) = 2.95$, $p = .008$, $d = 1.30$), indicating that they found the application more effective for achieving learning objectives and reported greater overall enjoyment. These differences were supported by large effect sizes, highlighting substantial practical differences in user experience between genders.

The Satisfaction subscale, in particular, showed the largest gender gap. Further examination identified Questions 14 and 15, which addressed physical comfort such as dizziness and nausea as key contributors to this disparity. Female participants gave lower ratings to these items, suggesting greater susceptibility to VR-induced discomfort. This is consistent with prior VR research, which has shown that women are more likely to experience motion sickness [20]. Additionally, VR hardware is often optimized for average male anthropometrics, potentially disadvantaging female users in terms of comfort and fit.

While gender differences in Ease of Use were not statistically significant ($p = .115$), the moderate-to-large effect size ($d = 0.73$) suggests a meaningful trend that may become significant with a larger sample size. No significant differences were found for Ease of Learning or Knowledge & Understanding, suggesting that both male and female participants were equally successful in navigating the application and grasping the solar energy concepts presented. This finding affirms the educational efficacy of the PV Gallery VR experience across genders, even if satisfaction and comfort levels differed.

These results underscore the importance of inclusive design in immersive educational systems. Female participants' relatively lower satisfaction scores, especially concerning physical comfort, highlight the need for personalized onboarding strategies, adjustable motion and camera settings, and ergonomic calibration options. Simple interventions, such as offering teleportation-based movement, customizing user height and IPD settings, and including voice-guided tutorials, may significantly improve the affective experience for underrepresented user groups.

In sum, the gender-based differences observed in this study reflect not only physiological and ergonomic factors but potentially also differences in prior exposure to interactive digital technologies. Addressing these issues through thoughtful, user-centered design could help reduce affective usability gaps and broaden the reach and impact of VR applications in education. Future research employing qualitative methods, such as think-aloud protocols or semi-structured interviews, may provide deeper insights into the specific barriers faced by female users and inform strategies for fostering more inclusive and equitable learning environments in VR.

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CONCLUSION

This paper presented PV Gallery, an interactive virtual reality application designed to engage users with solar photovoltaic systems through a carefully structured immersive experience. The application combines bilingual onboarding, guided navigation, interactive informational spaces, and a task-based component placement activity to create a coherent interaction flow that supports exploration, engagement, and user comfort. A usability evaluation involving university participants examined multiple dimensions of user experience, including perceived usefulness, ease of use, ease of learning, satisfaction, comfort, and perceived understanding. The results indicate that users generally found the application intuitive and engaging, with high satisfaction and interaction learnability, while also highlighting the influence of comfort-related factors on overall experience. Differences observed across user groups further emphasize the importance of inclusive and ergonomically informed interaction design in immersive environments. Collectively, these findings demonstrate how interactive VR experiences can be effectively designed and evaluated to engage users with sustainability-related themes, offering practical insights for the development of user-centered VR applications within the context of interactive information system engineering.

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