

Sustainable Innovation in the Creative Industry: A Participatory Mobile Methodology for Interior Design Spatial Representation

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Abstract. Spatial representation is a cornerstone of the creative interior design industry, yet traditional static mediums often result in material waste and significant miscommunication between designers and occupants. This paper proposes an empirical evaluation framework that utilizes a user-centered mobile application prototype as a proof-of-concept to foster methodological dialogue through participatory design. Grounded in the emerging framework of Human-Building Interaction (HBI), the study evaluates how interactive digital tools can reduce cognitive load and enhance decision-making accuracy. Following an expert heuristic evaluation ($N=3$) that demonstrated substantial agreement ($K=0.578$), usability testing ($N=10$) based on ISO 9241-11 standards showed high effectiveness (90.2%) and efficiency (89.85%). A comparative pilot study indicated that mobile interactivity can enhance spatial comprehension and user agency within exploratory consultation settings compared to traditional static methods. By providing rigorous metrics for engagement, this research presents a scalable prototype that highlights both the potentials and accessibility barriers of digital-first workflows as digital catalysts in design practice.

Keywords: Human-Building Interaction (HBI), Participatory Design, Mobile Augmented Reality, User Experience (UX), Sustainable Design Practices

1 Introduction

1.1 The Sustainability Crisis in Creative Representation

Spatial representation tools are integral to the practice of interior design, acting as channels for conveying intricate spatial concepts to clients and users [1]. Historically, these tools have comprised physical models, hand-drawn sketches,

and both 2D and 3D renderings. While these traditional approaches allowed users to visualize design elements within structured layouts, their static nature often limits user interaction, failing to deliver a comprehensive experience of spatial arrangements [1]. In the contemporary global economy, this limitation precipitates a sustainability crisis. Traditional representation methods—such as non-recyclable physical models and large-format paper prints—are resource-heavy practices [2]. Misunderstandings caused by these static tools frequently result in "spatial waste": the unnecessary consumption of energy and materials due to post-occupancy modifications or the disposal of non-recyclable physical prototypes [3].

1.2 Methodological Innovation as a Catalyst for Change

To address these challenges, we must move beyond viewing digital tools merely as presentation artifacts. Advances in digital technology, including Augmented Reality (AR) and Virtual Reality (VR), have revolutionized these tools, enabling designers to create immersive and interactive experiences [3]. This digital evolution has shifted the user's role from passive observer to active participant, fostering deeper engagement and more informed decision-making [5]. The transition aligns with user-centered design (UCD) principles, emphasizing adaptability, accessibility, and personalized interaction [6]. Integrating user experience (UX) and user interface (UI) design into these tools opens new possibilities for enhancing usability and interaction quality in interior design practices [7]. As highlighted in the discourse on sustainable interaction design, methodological rigor is fundamental to mainstreaming sustainability within creative industries [8].

1.3 Towards "Sustainment" in Design

We adopt the notion of "Sustainment"—a proactive work of becoming futural rather than merely sustaining current systems [9]. This requires a temporal shift where designers use technology to rehearse non-existent realities, making them assessable and malleable for the end-user. The mobile application prototype developed in this study serves as a "boundary object" that facilitates this rehearsal, transforming the designer-client interaction into a collaborative, discursive dialogue for spatial alignment [4].

2 Theoretical Framework: Marrying the Past with Future Solutions

The theoretical foundation of this study is built upon three pillars: Human-Building Interaction (HBI), Sustainable Design Thinking, and Democratic Technology Design.

2.1 Human-Building Interaction (HBI) and Digital Ecosystems

Human-Building Interaction (HBI) scales interaction up to the built environment level, addressing the physical, spatial, and social facets of interaction [1].

- *The Physical Facet:* Relates to the tangible materials and textures. Digital tools allow for "material exploration" without the extraction costs [11].
- *The Spatial Facet:* Concerns the volume and flow. Interactive environments enable users to explore spatial layouts and adjust elements in real time [12].
- *The Social Facet:* Buildings mediate human behavior. A sustainable design must ensure that the social interactions supported by the space are inclusive and functional [1].

Future digital design lies in simulations that support natural, cultural, and social ecosystems [13]. Our prototype aligns with this vision by creating a "playable user experience" that yields real-world impact in spatial decision-making [14]. This integration builds upon the foundational vision of ubiquitous computing introduced by Weiser [23], where digital layers seamlessly blend into the physical built environment to form responsive, human-centered spaces. Expanding on this trajectory, Alavi et al. [27] formally establish Human-Building Interaction (HBI) as a critical domain interfacing computing with architecture, emphasizing that modern digital environments must adapt dynamically to occupant behaviors and spatial experiences.

2.2 Socially Driven Character of Sustainability

Sustainability is more than a technical requirement; it is a social process that shapes the nature, form, and function of the built environment [15]. Traditional architecture can provide principles revitalized in contemporary design through a marrying of the "lessons of the past" with the "technological solutions of the future". This research applies this by reclaiming "organic growth"; the interactive app allows the design masses to evolve based on community needs rather than rigid modules.

2.3 Participatory Design and Democratic Technology

Designing for democracy is a critical challenge requiring crossing disciplinary boundaries, bringing together HCI, participatory design, and political theory. Participatory design serves as a "glue" between technical and social sciences, developing methods to engage people in the design process [17]. By involving users in the design of their own environments, we foster "creative confidence"—the belief in one's ability to use design to effect change [13]. This shift requires adopting structured co-creation frameworks that define the evolving landscapes of participatory design, effectively changing the user's role from a passive consumer to an active co-designer [24]. Furthermore, as highlighted by Ceschin and Gaziulusoy [28], the evolution of design for sustainability requires moving beyond isolated product improvements toward system-level innovations, where participatory methodologies act as crucial transition paths for large-scale socio-technical change.

3 Methodology: Empirical Evaluation and Clinical Pilot Design

This study adopts an empirical evaluation approach structured as a clinical pilot study, where the developed artifact (the mobile application) serves as a proof-of-concept vehicle for generating insights into user interaction patterns. Rather than positioning this work as a broad Research through Design (RtD) investigation, it functions as a targeted clinical assessment of user-centered mobile tools within interior architectural representations. While traditional Research through Design (RtD) emphasizes the artifact as the primary driver of open-ended design knowledge [25], transitioning towards a clinical pilot framework allows for a structured, empirical evaluation of usability metrics and interaction patterns as outlined in classic human-computer interaction evaluation models [26].

3.1 Interaction-Focused Design Model

We utilized Forlizzi and Battarbee's (2004) interaction-focused design model, where the product acts as a bridge between the designer and the user [5]. This model categorizes experience into three types:

1. *Fluent*: Automatic and unreflective interaction.
2. *Cognitive*: Interaction resulting in a new understanding or meaning.
3. *Expressive*: Interaction that allows for individual self-expression.

3.2 Prototyping and Technical Development

Figma was used for prototyping due to its compatibility with all platforms, cloud-based nature, and ability to test on smartphones via an educational license. The development lifecycle involved four iterative stages: Conceptualization, Design & Development, Expert Assessment, and Usability Testing (**Errore. L'origine riferimento non è stata trovata.**).



Fig. 1. Stages of the study

3.3 Comparative Pilot Study Design

To evaluate the application's effectiveness as a professional spatial representation tool, a qualitative comparative pilot study was conducted with a representative user (42-year-old female, merchant, university educated). The study was structured in two stages:

- *Method A (Traditional)*: The participant reviewed 3D renderings on a designer's computer screen for 20 minutes, with the designer providing verbal explanations and mouse-guided indications.
- *Method B (Interactive)*: Immediately following Method A, the participant explored the same project using the mobile application prototype for 35 minutes, receiving only occasional guidance from the researcher. A semi-structured interview followed to compare spatial comprehension, detail retention, and decision-making confidence between the two tools.

4 The Mobile Application: A Tool for Collaborative Spatial Alignment

The application is primarily designed as a presentation and spatial alignment platform to streamline the communication between the interior architect and the client during the design and visualization phases. Rather than functioning as an open-ended digital modeling workspace where the client generates graphics from scratch, the tool aims to democratize the design dialogue. Here, "democratic co-creation" is defined not as autonomous visual production by the user, but as a dynamic, interactive exchange of opinions driven by the occupant's exploration of the designer's curated spatial proposals.

4.1 Interface Architecture and Navigation

Applying UX/UI principles ensures the tool remains accessible and intuitive [4]. Simplified navigation and clear visual hierarchies reduce cognitive load, enhancing user comprehension [16].

- *Home and Login*: The main screen features "Designer Portal" and "User Portal" buttons to separate professional management from client exploration (Fig. 1) [1].
- *Visual Hierarchy*: Icons were grouped based on importance (Materials, Lighting, Furniture) to guide the user's attention naturally, reducing cognitive load [6].



Fig. 1. Home and Login pages of the mobile application prototype

4.2 User Experience Flow and Interactive Simulation

The most critical phase occurs when the user interacts with the virtual space (Fig. 2).

- *Material Toggling:* Users can instantly view changes in flooring, textiles, and fixtures organized by the designer. This "digital sample board" minimizes material waste associated with physical models.
- *Lighting Module:* Tapping on a specific item allows users to view alterations to only that selected element within the image, fostering a better understanding of spatial flow and atmosphere.

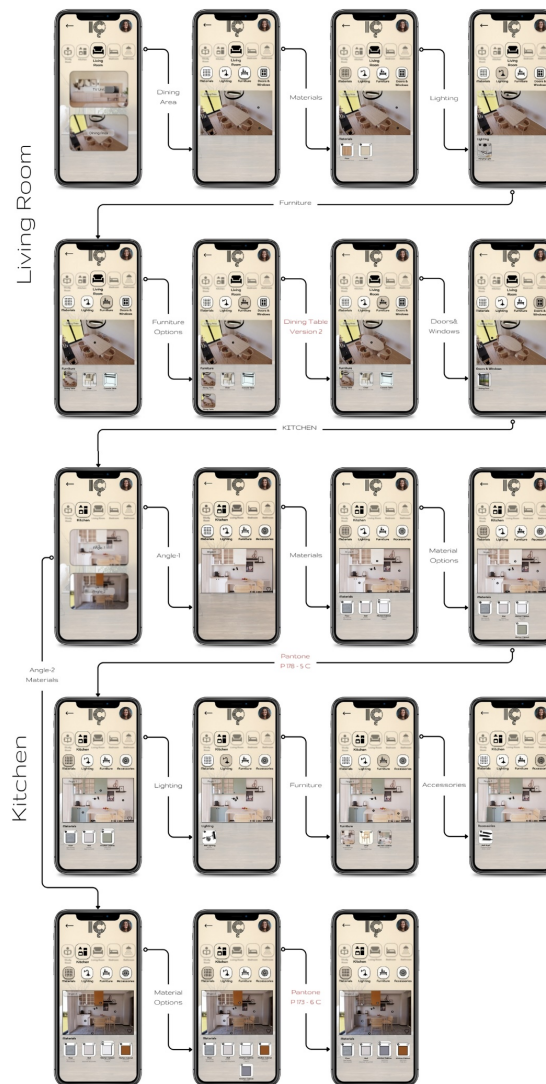


Fig. 2. User experience flow - from category selection to visual interaction

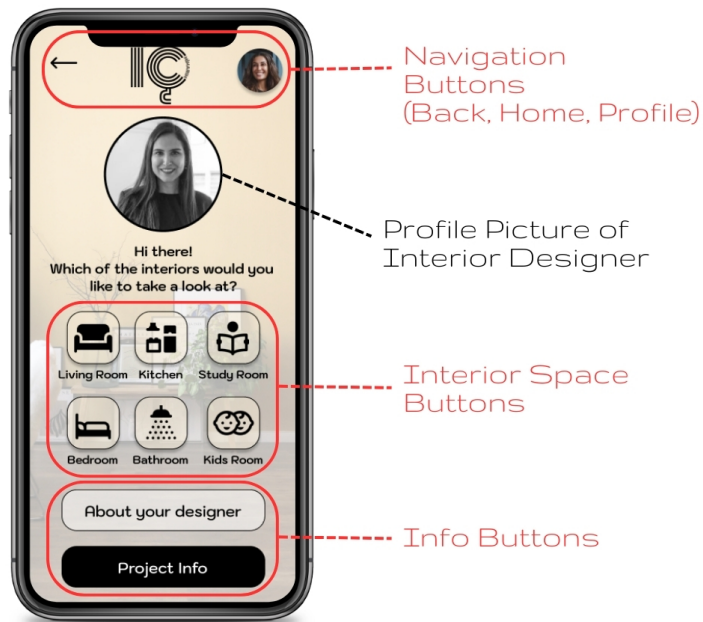


Fig. 4. User interface design of the project main page

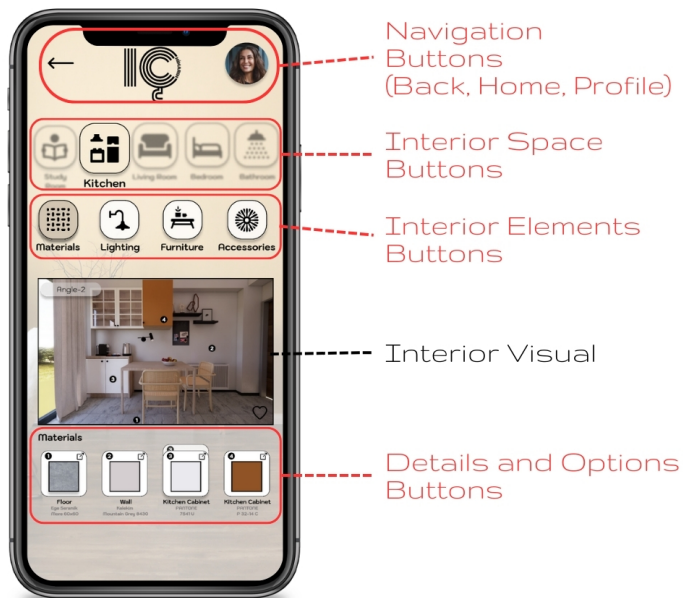


Fig. 3. User interface design of an interior page

5 Results and Statistical Validation

5.1 Expert Assessment: Heuristic Validation

A group of three experts (UX designer and two academics) evaluated the application against a 19-item questionnaire.

Table 1. Expert assessment survey criteria

Articles	Expert-1	Expert-2	Expert-3
Graphical User Interface Design			
1. The graphical user interface of the application is suitable for users aged 18-55.	3	3	3
2. Navigation buttons are always present and accessible.	3	3	3
3. On-screen elements are distinguishable in size.		3	
4. On-screen elements are simple to distinguish.	3	3	3
5. Page designs, including colors and elements, are consistent.	3	3	3
6. Transition animations are simple and guiding.	3	3	3
7. Numbering within the space visuals is guiding.	2	2	3
8. Space visuals are large enough to provide sufficient details.	2	3	2
9. The design is based on visuals rather than text.	3	3	3
Symbols, Icons, and Buttons			
10. Universal symbols and icons are used.	3	3	3
11. The functionality of symbols and icons is comprehensible.	3	3	3
12. The design of symbols and icons is simple and understandable.	3	3	3
13. The placement of buttons is consistent and intuitive.	2	2	2
Text and Typography			
14. The typography used is legible.	3	3	3
15. The texts used are short and comprehensible.	3	3	3
Interaction			
16. Interactive elements are highlighted and easy to understand.	2	2	2

17. There are no interactive elements at the bottom edges of the screen that can be accidentally touched.	3	3	3
Error Prevention			
18. Navigation is not complex.	3	2	3
19. Returning to the previous page in case of an incorrect action is easy.	3	2	3
1- Disagree, 2- Partially Agree, 3-Agree			

To measure the reliability of the feedback, Fleiss' kappa coefficient was employed [18].

- *Overall Kappa*: 0.578 (Moderate Agreement).
- *"Agree" Category Kappa*: 0.911 (Almost Perfect Agreement).

Table 2. Findings of expert assessment across 19 articles

Overall Kappa						
	Kappa	Asymptotic Standard Error	Z	P Value	Lower 95% Asymptotic CI Bound	Upper 95% Asymptotic CI Bound
<i>Overall</i>	,578	,132	4,362	,000	,318	,837
Kappas for Individual Categories						
<i>Rating Category</i>	Conditional Probability	Kappa	Asymptotic Standard Error	Z	P Value	Lower 95% Asymptotic CI Bound
2	,667	,578	,132	4,362	,000	,318
3	,911	,578	,132	4,362	,000	,318

According to the guidelines by Landis and Koch (1977), these results demonstrate moderate to almost perfect agreement among raters [19].

5.2 Usability Testing: Measuring Effectiveness and Efficiency

Following identified refinements (improving button intuitiveness and visual size), the prototype was tested with 10 users (Table 3).

Table 3. Demographic information of users who participated in usability testing

DEMOGRAPHIC INFORMATION										
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Gender	Male	Male	Female	Male	Female	Male	Female	Female	Female	Male
Age	25-34	25-34	45-54	18-24	18-24	35-44	45-54	25-34	35-44	25-34
Education	Master Degree	Bachelor Degree	Bachelor Degree	Bachelor Degree	Bachelor Degree	Master Degree	High school Degree	Bachelor Degree	Master Degree	Bachelor Degree

The usability test for the mobile application aimed to measure the levels of *effectiveness* and *efficiency* based on the criteria outlined in ISO 9241-11 (*Ergonomics of human-system interaction - Part 11: Usability: Definitions and concepts*). Effectiveness was evaluated by assessing the user's ability to complete actions fully and accurately, while efficiency was assessed by the ability to complete tasks correctly on the first attempt without assistance.

To ensure transparency and replicability, the usability test evaluated participants against 58 structured tasks divided into four core user-experience categories across two experimental rooms (Space-1 and Space-2). Table 4 details the translated and consolidated task architecture used during the observation sessions.

Table 4. Usability Test Task Architecture (ISO 9241-11 Framework)

UX Evaluation Category	Effectiveness Tasks (Total: 24)	Efficiency Tasks (First-attempt & Autonomy) (Total: 34)
Onboarding & Authentication	• Initiating the application via onboarding button. • Completing account sign-up flow. • Inputting credentials and configuring designer/user portal profiles.	• Autonomous identification of portal entry paths. • Unassisted credential input and navigation execution on the first attempt without system errors.
Architect & Project Discovery	• Selecting the designated interior designer. • Navigating through spatial project info buttons. • Differentiating space categories without external queries.	• Instant recognition of spatial icons as clickable buttons. • Unassisted discovery of UI navigation headers, back buttons, and profile actions.
Spatial Interaction & Toggling (Space-1)	• Interacting with the overview/workspace interface. • Triggering material, lighting, furniture, and opening sub-modules. • Interpreting interface spatial indicators and numbers. • Completing an interactive component toggle swap.	• First-attempt execution of material and fixture swaps. • Correct autonomous parsing of numbered spatial anchors. • Seamless navigation back to the primary project dashboard without researcher assistance.
Spatial Interaction & Toggling (Space-2)	• Replicating comprehensive interactive actions in the second interior layout. • Navigating back to the master project environment via secondary deep links.	• Re-executing autonomous interactive actions in Space-2, verifying learning retention and system ease of use without multi-turn errors.

To this end, an observation checklist was created, consisting of 24 tasks to measure effectiveness and 34 tasks to measure efficiency. When a user completed a task, the researcher marked it as *Yes* on the checklist. If the user failed to complete the task, it was marked as *No*. In cases where the task was completed

after multiple attempts or if partial credit was deemed appropriate due to errors, the checklist was marked as *Partially* (Table 5).

Table 5. ISO 9241-11 Performance Results

EFFECTIVENESS											
Answers	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
<i>Yes</i>	21	23	17	23	22	20	14	23	22	20	205
<i>Partially</i>	3	1	3	1	2	3	6	0	2	2	23
<i>No</i>	-	-	4	-	-	1	4	1	-	2	12
Completed Tasks											240
Score (%)											90.20
EFFICIENCY											
Answers	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
<i>Yes</i>	29	32	22	31	29	28	18	33	31	28	281
<i>No</i>	2	-	3	3	-	-	2	-	-	-	10
<i>Partially</i>	3	2	9	-	5	6	14	1	3	6	49
Completed Tasks											340
Score (%)											89.85

Calculations used success rate formulas [20]. The analysis revealed a strong positive relationship among the variables using Pearson's correlation coefficient (r).

- Effectiveness and Satisfaction: $r = 0.921$ ($p < 0.05$).
- Efficiency and Satisfaction: $r = 0.881$ ($p < 0.05$).

The analysis revealed a correlation value of 0.921 between effectiveness and satisfaction and 0.881 between efficiency and satisfaction. These values indicate a strong and positive relationship among the variables. Additionally, the significance values for both relationships were found to be less than 0.05, confirming that these relationships are statistically significant. In other words, the observed statistics are meaningful and noteworthy.

5.3 Pilot Study Findings: The Qualitative Insight

The pilot study provided deep qualitative insights into the application's impact on spatial comprehension and decision-making.

Spatial Ambiance vs. Detail Retention. The participant noted that while the computer screen (Method A) made visuals appear more "impressive" and enhanced the representation of the space's atmosphere due to its larger size, Method B was superior for detail memorability. The ability to make instant visual changes in the mobile app resulted in the participant remembering more details about materials, fixtures, and lighting.

Decision Reversal: A Sustainability Breakthrough. The most significant finding for sustainable innovation was the "Decision Reversal." The participant reported that a decision she had made while reviewing the project on the computer screen was *changed* after experiencing the mobile application. The rapid transition between material options and the interactive toggling of elements allowed her to identify spatial conflicts and aesthetic clashes that were "hidden" in the static renders. This response suggests that the interactive tool facilitates a more accurate decision-making process, directly preventing the waste of physical resources on undesirable design outcomes.

User Agency and Preference. The participant expressed a sense of control and "ownership" over the design in the mobile application compared to the passive review on the PC. She concluded that she would prefer to use the mobile application for future consultations, citing ease of decision-making as the primary reason.

6 Discussion: Sustainable Transformation through Design Thinking

6.1 Digital Inclusion as Social Sustainability

A critical finding from our usability test was that participants aged 45–54 experienced the greatest difficulty, scoring significantly lower in unassisted efficiency and reporting higher friction during multi-step spatial toggles. This creates a nuanced contradiction with our broader claim of universal and democratic technology design. If creative digital innovations are to act as genuine catalysts for social sustainability, they must actively mitigate digital exclusion rather than assuming baseline technological literacy.

The performance drop in the 45–54 demographic suggests that text-heavy configurations, complex multi-tier menus, and small interactive element boundaries present acute cognitive and visual barriers. To bridge this accessibility gap, we propose specific strategic interface recommendations for older users in design representations:

1. *Contextual Scaling and Dynamic UI*: Implementation of dynamic font sizes and enlarged touch targets (minimum 48x48 dp) tailored to combat age-related visual degradation.
2. *Simplified Interaction Trees*: Reducing multi-step interactive toggles to flat, single-tier menu panels to decrease cognitive loads during rapid spatial alterations.
3. *Persistent Structural Guidance*: Replacing abstract numeric tags with explicit text-based micro-copy or audio-guided interaction loops that support independent social engagement across all demographics.

6.2 Decision Accuracy and the Prevention of Waste

The pilot study yielded a significant qualitative insight: "*Decision Reversal*." The participant reversed a decision she had made on the computer screen after experiencing the mobile application. While the larger computer screen enhanced the representation of the space's atmosphere [21], the immediate adjustment of elements in the app was a significant advantage for detail retention [15]. Interactive tools prevent physical waste by catching design errors in the virtual phase.

6.3 Pedagogical Innovation in Design Education

Design education must shift towards "interaction design for architects," training future leaders to build participatory infrastructures rather than static portfolios [10]. To mainstream sustainability within creative industries, pedagogical frameworks must evolve beyond traditional, resource-heavy methodologies. Integrating digital-first, interactive tools—such as the mobile prototype developed in this study—into design studio curricula can provide students with immediate feedback on the environmental and spatial consequences of their decisions. By shifting the focus from passive presentation to active, democratic co-creation, students learn to treat sustainability not merely as a technical requirement, but as an ongoing social dialogue. While the pedagogical framework proposed in this section remains conceptual and has not yet been empirically tested on a student cohort, it offers a speculative curricular paradigm. Future research will focus on integrating this mobile interface into design studio curricula to systematically measure its direct impact on student learning outcomes and spatial literacy.

6.4 Limitations and Methodological Reflections

While the qualitative findings of this study—most notably the concept of "*Decision Reversal*"—strongly illustrate the potential of interactive tools to prevent resource waste, the comparative pilot study presents certain methodological

limitations. The evaluation of spatial comprehension and decision-making confidence between traditional and interactive methods was conducted with a single representative user. Although this deep-dive qualitative approach provided rich, context-specific insights into the mechanics of user perception and agency, the small sample size inherently limits the broad generalizability of these specific behavioral outcomes. To build upon these initial findings, future research must validate these qualitative insights through large-scale, mixed-methods studies involving diverse demographic groups. Expanding the participant pool will be crucial to understanding how varying levels of digital literacy and cross-cultural backgrounds influence interactive spatial decision-making. Furthermore, it is important to contextualize the interactive limits of the current prototype; it is intentionally structured as a collaborative consultation medium rather than a generative design workspace. While the client interacts with pre-approved material and lighting variations curated by the designer, the co-creative value lies in the discursive feedback loops and mutual spatial alignment it facilitates, rather than direct asset manipulation by the end-user.

7 Conclusion and Future Directions

The interconnection between sustainability and innovation in the creative industries requires a shift toward participatory, digital-first methodologies. This research presents a proof-of-concept exploration suggesting that a user-centered mobile application can enhance spatial comprehension and decision-making accuracy, thereby pointing to new pathways for reducing resource-intensive errors in the built environment.

Future Research should focus on:

1. *AI-Integrated Sustainability Metrics:* Using generative AI to show the "carbon footprint" of different material selections in real-time within the app.
2. *Cross-Cultural Usability:* Expanding the participant pool to explore how diverse cultural contexts influence interactive spatial decision-making.
3. *Mainstreaming HBI:* Developing educational frameworks that position Human-Building Interaction as a fundamental pillar of sustainable design pedagogy.
4. *Integrating Integrated Textual Feedback Loops:* Developing built-in text annotation and micro-commenting features within the mobile interface. This will allow clients to log specific text-based feedback, design suggestions, and qualitative critiques directly pinned to selected material or lighting configurations, further enriching the discursive co-creation process between the designer and the user.

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