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Examining Immersive Virtual Reality as a Design Communication Tool for Media Architecture Design Evaluation

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Abstract

Digital information has emerged as an architectural material in media architecture design to enhance the atmosphere, spatial experience, and perception of place meaning, especially in placemaking projects. However, common communication tools, such as 2D visualization, insufficiently represent these intangible aspects in building-scale media architecture projects in the neighborhood context. This study examines immersive virtual reality (IVR) as a design communication tool for evaluating media architecture. Studies on design evaluation addressing the intangible and cognitive aspects of IVR in building-scale media architecture projects are limited. A convergent mixed-methods design was employed to collect quantitative and qualitative data in a within-subject experimental study involving 31 architecture students. It measured the changes in the evaluation ratings of media architecture qualities and technological acceptance between 2D visualization and IVR. Furthermore, it explored the design aspects communicated effectively and the limitations inherent to each tool. Physical and communicative qualities ratings were significantly higher under IVR conditions, dominated by the discussion of spatial-tangible aspects (integration, representation, spatial experience) and spatial-intangible aspects (meaning, clarity, perception). These findings are considered preliminary due to the purposive sampling of architecture students and the small sample size. This study provides insights into the potential of IVR as a design communication tool for media architecture in architectural education and practice, while acknowledging the need for broader validation.

1.0 INTRODUCTION

In this digital era, digital information functions as an architectural material in media architecture, shaping spatial experiences and built forms (Wiethoff & Hussmann, 2017). Media architecture is an architectural design that integrates digital materials with dynamic properties to enhance user interactions (Brynskov et al., 2013). It can support and enrich users' perceptual experience of the designed environment and the meaning of the place through a multisensory experience as a strategy for sustainable placemaking (Lovendianto et al., 2025). Challenges arise in communicating these intangible design features during the evaluation phase with end-users, as common tools such as 2D visualizations and physical models are insufficient to represent multisensory experiences and are not feasible for larger projects. Alternatively, immersive virtual reality (IVR) technologies comprehensively facilitate visual, auditory, and spatial experiences, surpassing the limitations of conventional tools (Kim et al., 2020; Ma et al., 2025).

Existing studies have primarily focused on isolated sensory perceptions in IVR rather than multisensory modalities related to cognitive perception (Du et al., 2026; Kerruish, 2019; Linares-Vargas & Cieza-Mostacero, 2025; Marzouk et al., 2022). This gap is critical in media architecture design that deploys sound, light, and spatial experiences simultaneously to construct atmosphere and place meaning. There is a notable absence of studies that directly use media architecture as an object in IVR evaluation. Existing studies explore IVR in media architecture as virtual reality, virtual tours, or real-scale installations in design implementation, as in the Lost Palace, 360 Riot Walk, and HKMALA, rather than as a design communication tool during the design evaluation process (Kenderdine et al., 2021; Leung, 2023; Morrison et al., 2017).

This study investigates the use of IVR as a design communication tool in media architecture design. Studies on design evaluation using IVR for building-scale media architecture in neighbourhood contexts across various settings are limited. The media architecture design process typically uses physical prototypes and mockups in the final stage (Dalsgaard & Halskov, 2017; Halskov, 2021). The architecture field commonly employs IVR to simulate the tangible aspects of a design as a digital prototype of a physical architecture proposal (Strand, 2020). Cognitive measures linking sensory perception and architectural design, such as how design shapes users' emotions and introduces place meaning, remain insufficiently addressed (Du et al., 2026; Linares-Vargas & Cieza-Mostacero, 2025).

In this study, the term "design communication tool" refers to the medium employed to communicate a media architecture design during the design evaluation stage. Specifically, the two tools investigated were 2D visualization and IVR. This study employed convergent mixed methods to collect quantitative and qualitative data to provide a comprehensive perspective on the problem (Creswell & Creswell, 2023). This study addressed the intangible and cognitive aspects that were effectively communicated by each tool, as well as the limitations inherent to each. A virtual model represented a building-scale media architecture design in a neighborhood context across day-night and indoor-outdoor settings. In a within-subject experimental study involving 31 architecture students, Likert-scale data were employed to assess the impact of IVR on their evaluation ratings of media architecture designs and their acceptance of technological tools in communicating the design compared to a common 2D visualization. Open-ended questions explored design aspects, effective communication of design, and limitations inherent to each tool, leading to a comprehensive understanding of this issue.

The research questions of this study are as follows.

i. How do evaluation ratings of media architecture qualities differ between IVR and 2D visualization, and which design aspects (formal, spatial, tangible, intangible) are effectively communicated by each tool?

ii. How do technological acceptance ratings compare between IVR and 2D visualization, and what are the perceived limitations inherent to each tool in media architecture design evaluation?

iii. What is the relationship between technological acceptance and media architecture quality ratings, and what theoretical and practical insights does this study contribute to the understanding of IVR as a design communication tool in media architecture evaluation?

To situate these questions within existing knowledge, the following section reviews the emergence of IVR technology use in architecture, IVR roles in design evaluation, IVR as a design communication tool, and the current state of IVR studies in this context. This review derives the study methodology and provides a basis for discussing the findings.

2.0 LITERATURE REVIEW

IVR technologies are emerging tools in architecture, especially in the design process, documentation, and presentations (Korkut & Surer, 2023; Strand, 2020). Recent studies have shown that these technologies encourage creativity in the design process (Chang et al., 2023; Obeid & Demirkan, 2020). It has been explored as a design tool for architecture and design education (Globa et al., 2023; Salman et al., 2025). IVR simulation enhances efficiency in the design process, especially at the evaluation stage, across various project scales, from interior design to building and urban design practices (Ali et al., 2025; Ma et al., 2025; Malek & Samadi, 2025). IVR enhances visual communication between designers and stakeholders to optimize design proposals before the implementation phase (Bagader & Abuznada, 2021). In cultural heritage places, IVR provides an effective visualization strategy for assessing usability and the user experience (Chong et al., 2022).

In design evaluation, IVR was more effective when combined with other conventional media for users with little exposure to design, covering spatial and intangible aspects of projects with complex features (Liu et al., 2020). IVR can represent the multisensory aspects of the design, site, and place for both designers and users (Globa et al., 2022; Yildirim et al., 2024, 2025). Well-designed virtual environments with suitable thematic narratives engage users' senses and improve their understanding of the environments (Linares-Vargas & Cieza-Mostacero, 2025). Most studies addressed visual sensory, followed by visual+auditory and thermal+visual. Studies on cognitive measures linking sensory perception and architectural design are scarce. Furthermore, the impact of modifications to pre-occupancy design configurations on users' cognitive performance is underexplored (Du et al., 2026).

Design communication tools play a crucial role in the evaluation of design. Spatial perception among architecture students improved significantly with IVR compared to 2D sketches (Gómez-Tone et al., 2021). A comparative study on the effectiveness of IVR, physical space, and 2D visualization in design evaluation examined the affective appraisal and preferences of the tools, while being limited to the interior room scale (Ma et al., 2025). An existing study highlighted the advantages of IVR headsets over non-immersive displays for engaging in participatory urban design evaluations. However, it was limited to the public park case, despite its suggested transferability to public installations, including media architecture (Van Leeuwen et al., 2018). A systematic literature review of immersive digital placemaking identified community engagement in spatial co-production, in which IVR and related immersive tools consistently supported place meaning (Lo et al., 2025).

In practice, users prefer IVR over 2D visualization (Fiorentino et al., 2020). IVR with a head-mounted display (HMD) improved end-users' affective evaluations, especially for spatial dimensions and preferences for certain design elements (Ma et al., 2025). The software preferred for developing IVR environments was Unity, followed by Unreal Engine and Twinmotion. In most cases, they were displayed on the HTC Vive, Oculus Rift, and Oculus Quest (now the Meta Quest). The indicators of software efficiency depend on the research objectives and target experiences (Linares-Vargas & Cieza-Mostacero, 2025).

The gaps identified in this review are limited empirical evidence on IVR as a design communication tool for media architecture evaluation and the absence of studies examining the relationship between the technological acceptance of the tool and perception of architectural qualities. These gaps motivated the development of the methodology in this study, including the sampling, virtual model type and scale, aspects of the simulated environment, and tool settings. The following section describes a convergent mixed-methods design to address these gaps through a within-subject experimental comparison of 2D visualization and IVR.

3.0 METHODOLOGY

3.1 Data Collection

3.1.1 Participants

Participants were recruited from a pool of architecture students. Purposive sampling was conducted in the design education and practice context because they were the primary users of design communication tools in practice. Nevertheless, their background knowledge of spatial and design representation may correspond with their perceptions and acceptance ratings of the tools. Thirty-one participants (mean age = 23 ± 2.37) were recruited through broadcasted online invitations, including a survey for a 2D visualization session and offers for a further IVR session (Table 1). Previous studies have conducted within-subject comparative analyses of IVR technology acceptance with similar sample sizes (Ma et al., 2025; Yildirim et al., 2025).

Table 1. Descriptive statistics of the participants' demographics (*N* = 31).

Variable		Type	*n*	%
Gender		Male	9	29.03
		Female	22	70.97
Education level		Undergraduate	16	51.61
		Graduate	15	48.39
Previous immersive virtual reality (IVR) experience	Cave automatic virtual environment (CAVE)	Never	24	80.00
		1-3 times	6	20.00
		4-6 times	0	0.00
	Head-mounted display (HMD)	Never	17	54.84
		1-3 times	13	43.33
		4-6 times	1	3.33

3.1.2 Variables

A within-subject experimental design was employed to examine the effects of design communication tools on the user evaluation of media architecture design. The independent variable was the type of design communication tool employed (2D visualization and IVR condition). The dependent variables were participants' subjective ratings, using a Likert scale and open-ended questions, of media architecture qualities and user's technological acceptance. As control variables, the contents presented in both tools were the same scenes (point of view, texture, lighting) with the same explanatory scripts (written and verbal). The confounding factors included device limitations (smartphone/laptop screen and IVR headset) and differences in the instruction modalities (written and verbal) between the two sessions.

3.1.3 Procedures

The experimental design involved participants experiencing both conditions (see Figure 1) (Creswell & Creswell, 2023). Informed consent was obtained from all participants involved in the study. First, the participants completed online pre-questionnaires to evaluate the 2D design using written instructions. This may be constrained by device limitations (screen size) as a potential confounding factor. Nevertheless, viewing 2D visualizations on a smartphone or laptop is a realistic condition. Later, the participants were scheduled to experience the IVR simulation with a verbal explanation and complete the post-questionnaires. The difference in instruction modality was a limitation of this study. The nature of IVR renders written instructions impractical for users. Differences in the cognitive mechanisms for processing auditory and textual information are a confounding factor. Both sessions were spaced on different days to mitigate carryover, memory, and fatigue effects. Participants completed each questionnaire based on their experience in each session rather than comparing the two sessions.

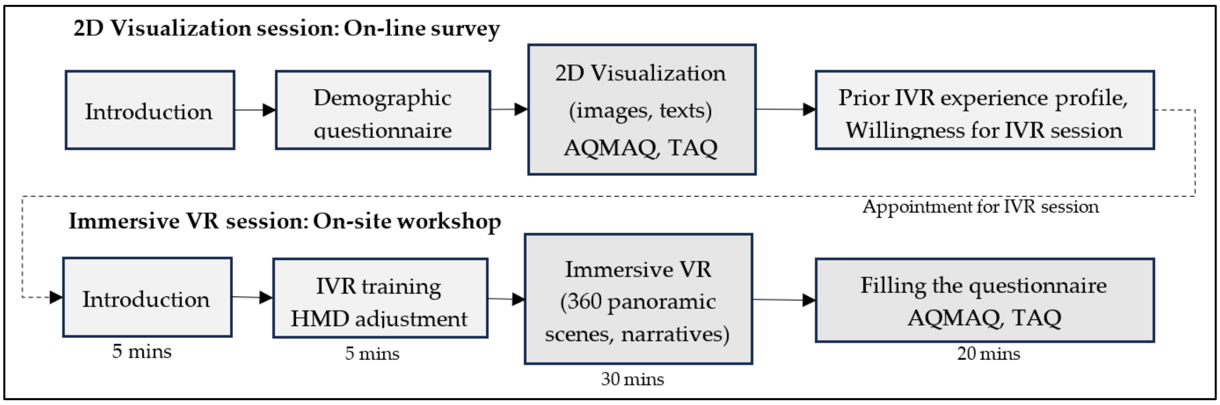
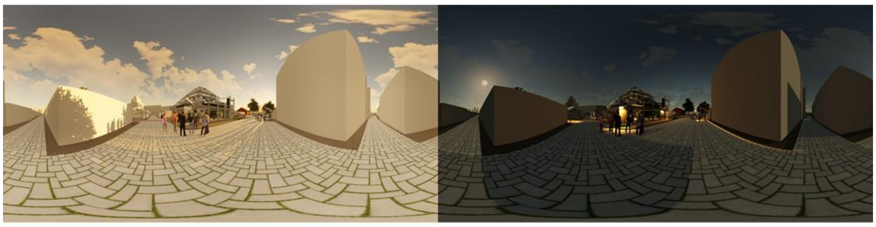


Figure 1. Procedural diagram of the within-subject experimental design, illustrating the administration of two design communication tool conditions, 2D visualization and immersive virtual reality (IVR) condition, with one evaluation session conducted for each condition ($N = 31$).

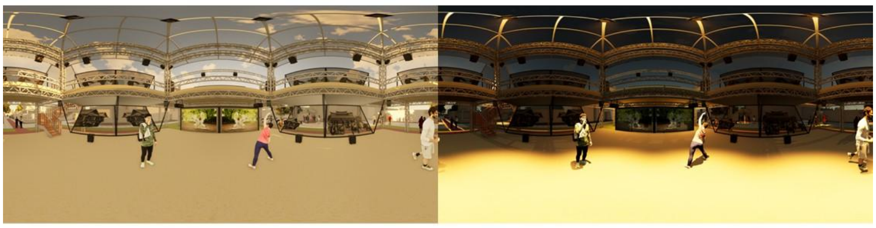
3.1.4 Virtual Model

The virtual model depicted a media architecture design within the historical urban village context of three neighboring plots in Kampung Kungfu Kapasan, Surabaya. This Chinese-Indonesian settlement from the Dutch colonial era holds historical significance for the independence war and cultural significance for the acculturation of Chinese and Javanese. The designed object was a hub for historical tourism, consisting of a Kungfu studio (a, b, c), a digital underground bunker (d), a plaza (e), and a digital park (f) (Figure 2). It portrays media architecture installations of virtual layers (b, c, f) and projection mapping (d). The digital aspects are visually (lighting, photographs, projection, illusion) and audibly (soundscape) dominant (Lovendianto et al., 2026). The combination of both sensory cues improved the user's perception (Latini et al., 2024).

Several indoor, semi-outdoor, and outdoor environments were displayed in both day and night settings. Previous IVR studies have primarily focused on indoor environments in single-time settings (Latini et al., 2024; Ma et al., 2025). It was modeled at the building scale and situated in a neighborhood context, rather than only at the installation-to-interior scale, as in existing media architecture studies. It was designed to shape the meaning of the place. This design intention extended users' virtual experience in evaluating design from tangible to intangible aspects and from sensational-perceptual to cognitive aspects. This study addressed the gaps in existing studies (Du et al., 2026; Kerruish, 2019; Linares-Vargas & Cieza-Mostacero, 2025; Marzouk et al., 2022).



(a)



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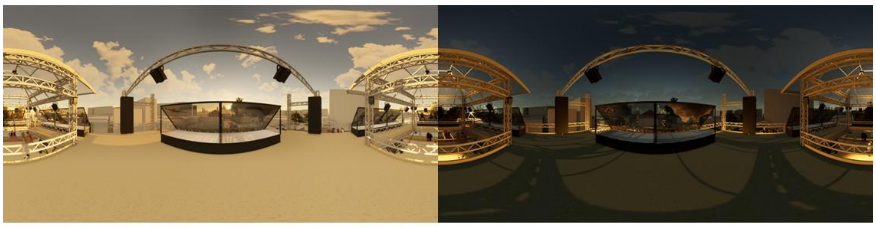

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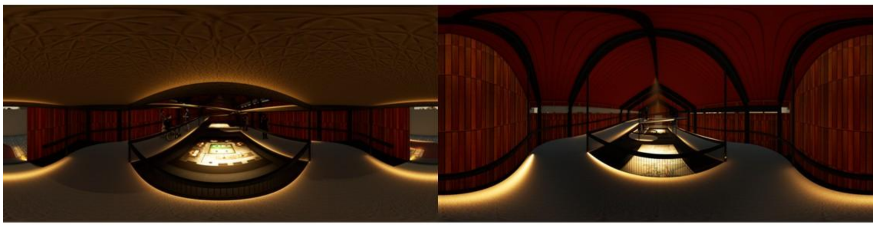

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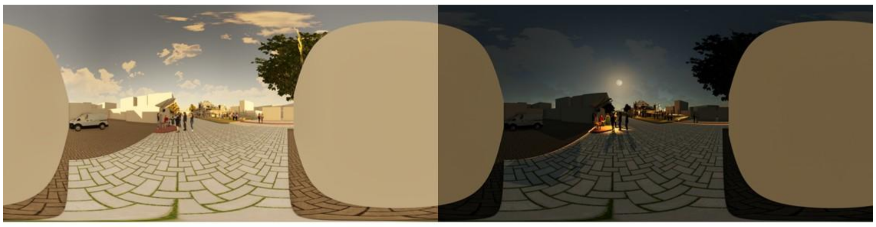

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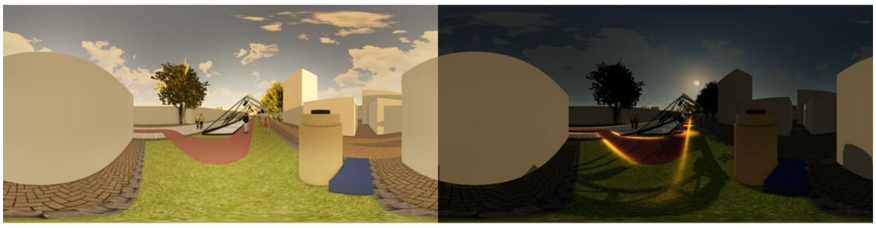


(f)

Figure 2. The equivalent scenes from the media architecture design model as presented through each of the two design communication tools, 2D visualization and immersive virtual reality (IVR) condition. The six scenes depict: (a) the outdoor environment at the site entrance; (b) the semi-outdoor environment of the Kungfu studio; (c) the outdoor environment at the rooftop of the Kungfu studio; (d) the indoor environment of the digital bunker; (e) the outdoor environment of the communal plaza; and (f) the outdoor environment of the digital park.

3.1.5 Instruments

The evaluation employed questionnaires to collect quantitative data via a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) and qualitative insights from open-ended questions (Liu et al., 2024). These measures assessed the user experience in a design environment, capturing both subjective assessments and participants' concerns. (Bagader & Abuznada, 2021; Kim et al., 2020). It addressed architectural quality and technological acceptance using questions adapted from relevant studies to align with the objectives of this study.

The Architectural Quality of Media Architecture Questionnaire (AQMAQ) was developed to evaluate the design (Table 2) and assess four qualities:

- ***physical quality (PQ) on how it could coexist architecturally,***
- ***experiential quality of atmosphere (EA) on how it could augment spaces,***
- ***experiential quality of responsiveness (ER) on how it could respond to contextual changes,***
- ***communicative quality (CQ) on how it could deliver relevant content (Wouters et al., 2016).***

Table 2. Architectural Quality of Media Architecture Questionnaire (AQMAQ) items applied in this study.

Number	Questions
	Likert's scale questions
PQ1	The digital media volumetrically and proportionally aligns with the architecture that supports it
PQ2	Its modularity extends architectural rhythm and repetitiveness
PQ3	Media architecture as a new materiality blends in with the architectural expression
EA1	The visual elements of the design support place meaning
EA2	The atmosphere shapes mood for delivering narratives related to place meaning
EA3	The overall design supports and promotes placemaking
ER1	The digital media within the design dynamically align with changing activities
ER2	Digital media and their constituent digital information (light, color, projection, illusion, etc.) shape each scene
ER3	The atmosphere changes along with the scene movement
CQ1	The design concept is shown clearly
CQ2	Digital media and their constituent digital materials (light, color, projection, illusion, etc.) shape perception of place meaning
CQ3	The place meaning is contextualized properly in the architecture
	Open-ended questions
	What do you think about each quality [Physical/Atmosphere/Responsiveness/Communicative] of this media architecture design?

Note. PQ = physical quality; EA = experiential quality of atmosphere; ER = experiential quality of responsiveness; CQ = communicative quality.

The Technological Acceptance Questionnaire (TAQ) assessed the participants' adoption of IVR during the design evaluation. It was developed based on the technological acceptance model, including perceived ease of use (PE), perceived usefulness (PU), perceived immersion (PI), output quality (OQ), system characteristic (SC), perceived discomfort (PD), and intention to use (IU) (Table 3) (Liu et al., 2024; Ma et al., 2025). In the absence of an equivalent questionnaire for 2D evaluation, a concise questionnaire was developed (Table 4). A single global item represented each dimension to capture the corresponding IVR construct in a 2D context.

Table 3. Technological Acceptance Questionnaire (TAQ) items for the immersive virtual reality (IVR) session.

Number	Questions
	Likert's scale questions
PE1	I can easily learn to use this IVR system
PE2	I have clear and understandable interaction with this IVR system
PE3	I can easily adapt to use this IVR system for design evaluation
PU	*By using this IVR system for design evaluation:*
PU1	I can increase my understanding of space design
PU2	I can learn more about certain elements of the design
PU3	I can easily review the proposed design
PI	*When I use this IVR system:*
PI1	I feel completely immersed in the IVR environment.
PI2	I feel immersed in the design evaluation process.
PI3	I find the building evaluation process more interesting.
OQ1	I think the quality of the graphics on this IVR system is excellent.
OQ2	I think the quality of the audio on this IVR system is great.
OQ3	I believe that each stage of this IVR system contributes to the evaluation
SC	*When using the IVR system:*
SC1	It feels like the objects on the screen are same as in real world
SC2	I can see the building in 360°
SC3	I can hear the soundscape around the design
SC4	I was pleased with the ability to move freely around the scene.

Number	Questions
PD1	Using this IVR system makes me feel dizzy
PD2	Using this IVR system causes me to experience eye strain
PD3	The discomfort of using this IVR system interrupted me when I am reviewing the design
IU1	I would like to use IVR equipment for architectural evaluations in the future.
IU2	I would recommend the IVR service to others.
IU3	I believe that this IVR system has the potential to be sustained.
	Open-ended questions
	What disadvantages or shortcomings do you see in this IVR system for the design evaluation stage?

Note. PE = perceived ease of use; PU = perceived usefulness; PI = perceived immersion; OQ = output quality; SC = system characteristic; PD = perceived discomfort; IU = intention to use.

Table 4. Technological Acceptance Questionnaire (TAQ) items for the 2D visualization session.

Number	Questions
	Likert's scale questions
PE	Images and narratives are easy to use for design evaluation.
PU	The images and narratives make the design easy to comprehend.
OQ	The graphic quality of the images is good for evaluating the design.
SC	The information presented is adequate for evaluating the design.
PD	I feel comfortable evaluating the design using images and narratives provided.
	Open-ended questions
	What disadvantages do you see in them as design communication tools for the design evaluation process?

Note. PE = perceived ease of use, PU = perceived usefulness; OQ = output quality; SC = system characteristics; PD = perceived discomfort.

3.1.6 Tools

The evaluation object was 3D-modeled in SketchUp 2023, with the surrounding site imported from the CADmapper website and rendered in Twinmotion 2020. Several scenes were exported as images for 2D visualization and panoramas for the IVR conditions.

The IVR device utilized was a Meta Quest 3S HMD with a Snapdragon XR2 Gen-2 chipset (8 GB RAM), HD resolution (1832 x 1920 pixels per eye), a Fresnel lens with a 3-position interaxial adjustment distance, and 96° horizontal and 90° vertical field of view. HMD was preferred over smartphones and desktops in terms of engagement and presence (Globa et al., 2023). It isolated users from the real world while creating a fully immersive experience, allowing them to interact freely with the environment (Chen et al., 2021). It raised students' interest, improved concept learning, and enhanced a sense of presence (Huang & Roscoe, 2021).

The IVR UX framework classifies participants, devices, user activities, and applications (Kim et al., 2020). It features a head-tracking system and handheld controller in a non-see-through mode for immersion. It provides multisensory outputs, including visual, auditory, and motion cues. Each participant explored the virtual design site in 360° panoramic views for 30 min, either sitting or standing on a non-movable platform. They were introduced to the design brief and IVR navigation system. The device was cast into the Meta Horizon platform, allowing the experimenter to observe the participant's view and provide guidance.

3.1.7 Data Analysis Techniques

Quantitative data were analysed using the Wilcoxon signed-rank test for statistical significance ($p < 0.05$) and effect size, followed by Spearman's correlation due to ordinal data and non-normally distributed differences. The Likert ratings between the 2D and IVR sessions for both AQMAQ and TAQ were compared using Google Spreadsheets and SPSS 27. Although the sample size was modest for validating the technological acceptance model, this exploratory study qualitatively strengthened the analysis. Qualitative data were analysed using the descriptive method (Creswell & Creswell, 2023). Emerging keywords related to design aspects were manually coded from open-ended responses in the AQMAQ. This analysis identified and mapped the design aspects communicated effectively to the participants in terms of architectural quality and design communication tools. The same analysis of TAQ open-ended answers identified the limitations inherent to each tool. Integrative data analysis compared the data side-by-side, transformed qualitative codes into quantitative data, and merged the data in a joint display to draw meta-inferences.

4.0 RESULTS

Based on the experimental design and analytical procedure, the following sections present the quantitative and qualitative findings according to the three research questions: AQMAQ ratings and communication of design aspects, TAQ ratings and limitations inherent to each tool, and the relationship between IVR acceptance and ratings of architectural qualities. Some limitations are addressed as a caution for subsequent analyses.

4.1 Evaluation of Architectural Qualities of Media Architecture Design

Reliability analysis using Cronbach's alpha (α) indicated that it was acceptable for a small number of items (three), and all item-total correlations exceeded 0.3. Quantitative data indicated significantly higher ratings of overall (ALL) media architecture design in the IVR condition ($M_{\text{IVR}} = 6.08$) than in 2D visualization ($M_{2\text{D}} = 5.89$), especially in terms of physical quality (PQ) ($M_{\text{IVR}} = 5.95$, $M_{2\text{D}} = 5.51$) and communicative quality (CQ) ($M_{\text{IVR}} = 6.27$, $M_{2\text{D}} = 5.86$) (Table 5 and Figure 3). The Wilcoxon signed-rank test indicated a statistically significant difference and a large effect in the overall AQMAQ ratings ($W = 125.5$, $p < 0.05$, $r = 0.37$), as well as in the physical quality ($W = 38$, $p < 0.01$, $r = 0.63$), and communicative quality ratings ($W = 46$, $p < 0.05$, $r = 0.53$). No statistically significant differences were observed in the experiential qualities of atmosphere and responsiveness.

Moderate internal consistency was found for physical quality (PQ) ($\alpha_{2\text{D}} = 0.551$, $\alpha_{\text{IVR}} = 0.577$). The PQ construct comprised three indicator items adapted from the architectural quality of the media architecture framework (Wouters et al., 2016). It represents distinct theoretical dimensions of physical quality regarding proportional, rhythmic, and material integration. Item-total statistics indicated that no single item consistently weakened the scale across conditions, as the weakest item differed between the 2D and IVR conditions. Moderate reliability reflects the multidimensionality of the construct. Hence, the original items were retained to preserve the construct's conceptual integrity and content validity. Therefore, subsequent analyses should be interpreted with caution.

Table 5. Descriptive statistics, internal consistency reliability, and Wilcoxon signed-rank test results comparing Architectural Quality of Media Architecture Questionnaire (AQMAQ) ratings between the 2D visualization and immersive virtual reality (IVR) conditions (*N* = 31).

Dimension	2D				IVR				Wilcoxon Signed-rank Test		
	M	*SD*	*Mdn*	α	*M*	*SD*	*Mdn*	α	*W*	*p*	*r*
PQ	5.51	0.89	5.50	0.551	5.95	0.69	6.00	0.577	38.0	0.002**	0.63
EA	6.03	0.90	6.33	0.793	6.19	0.50	6.17	0.663	145.5	0.296	0.20
ER	6.17	0.58	6.33	0.667	5.65	1.25	6.00	0.722	114.0	0.192	0.26
CQ	5.86	0.92	6.00	0.836	6.27	0.63	6.33	0.712	46.0	0.016*	0.53
All AQMAQ	5.89	0.70	6.04	0.892	6.08	0.55	6.04	0.857	125.5	0.047*	0.37

Note. 2D = two-dimensional visualization; IVR = immersive virtual reality; PQ = physical quality; EA = experiential quality of atmosphere; ER = experiential quality of responsiveness; CQ = communicative quality; AQMAQ = Architectural Quality of Media Architecture Questionnaire; *M* = mean; *SD* = standard deviation; *Mdn* = median; α = Cronbach's alpha coefficient; *w* = Wilcoxon signed-rank statistic; *p* = exact probability value (two-tailed); *r* = rank-biserial correlation coefficient (effect size). Effect size (*r*) is interpreted as small ($0.10 \leq r < 0.30$), medium ($0.30 \leq r < 0.50$), and large ($r \geq 0.50$). Statistically significant at *: $p < 0.050$; **: $p < 0.010$; ***: $p < 0.001$.

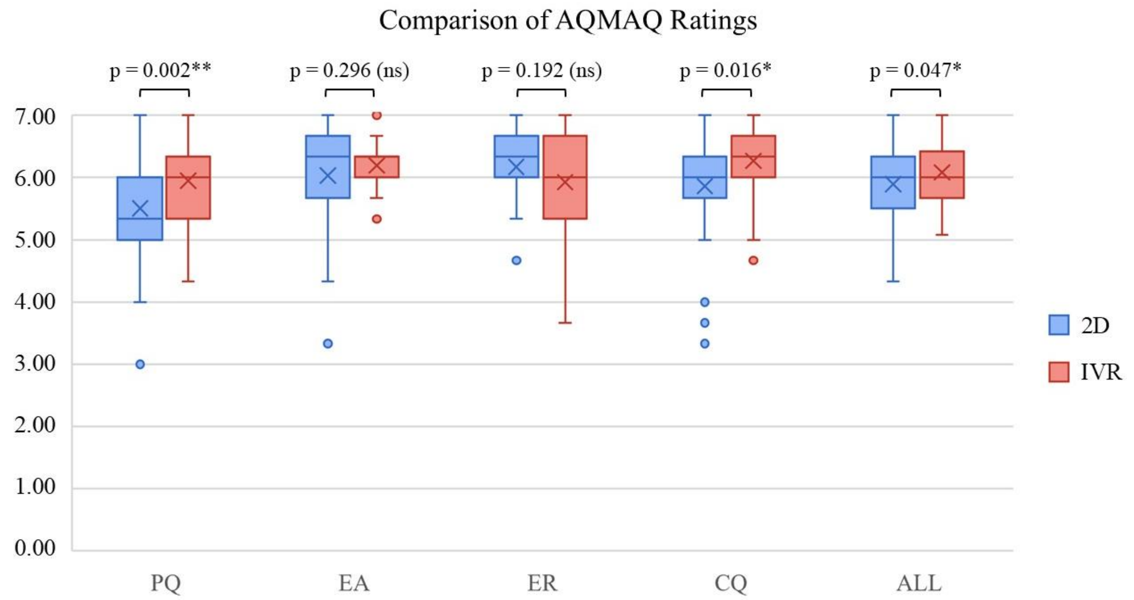
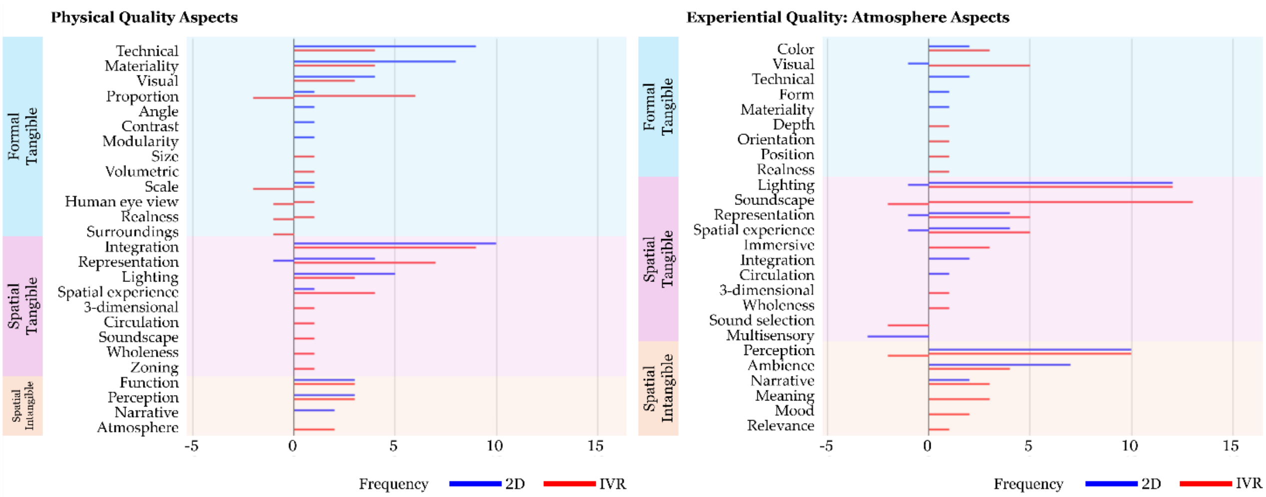


Figure 3. Boxplots comparing Architectural Quality of Media Architecture Questionnaire (AQMAQ) ratings across architectural-quality dimensions between 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

Qualitative data revealed the formal, spatial, tangible, and intangible aspects of each architectural quality, which were effectively communicated through 2D visualization and the IVR condition. The diagrams mapped each keyword to each aspect and counted its frequency (Figure 4). The evaluation of physical quality was dominated by formal-tangible (technical, materiality, visuals in 2D visualization) and spatial-tangible aspects (integration, lighting in 2D visualization; representation in IVR condition); atmospheric quality by spatial-tangible (lighting; soundscape in IVR condition) and spatial-intangible aspects (perception, ambience in 2D visualization); responsiveness quality by formal-tangible (flexibility in 2D visualization), spatial-tangible (activity in 2D visualization), and spatial-intangible aspects (adaptability in 2D visualization; atmosphere in IVR condition); and communication quality by spatial-intangible aspects (clarity, meaning in IVR condition; narrative in 2D visualization).



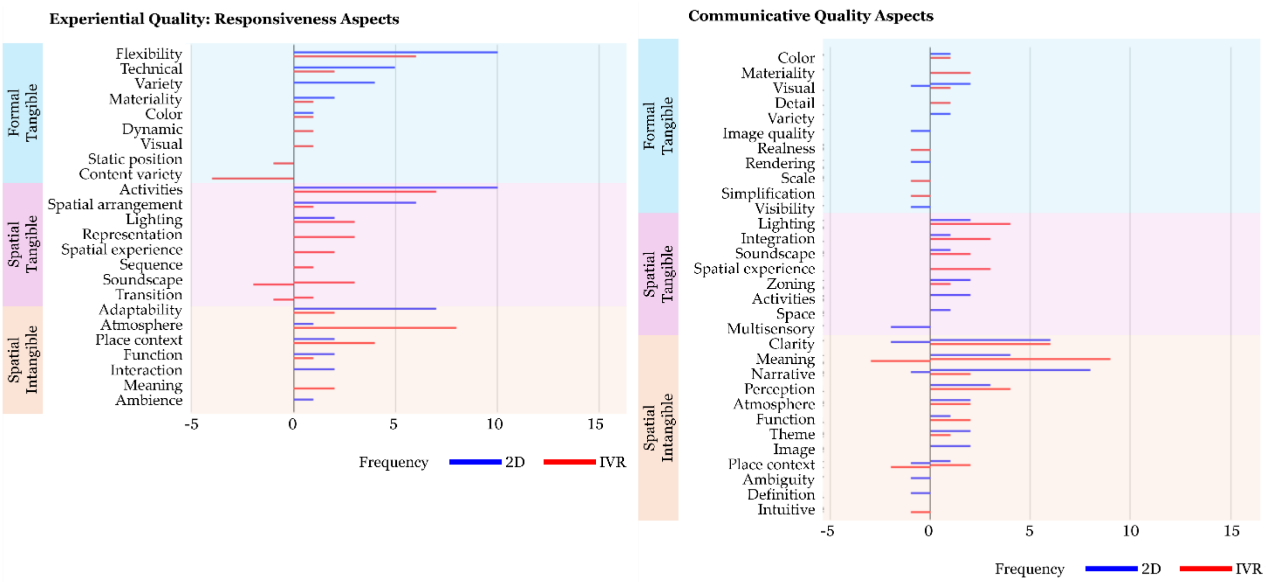


Figure 4. Thematic mapping of coded design aspect keywords derived from participants' open-ended responses, organized by Architectural Quality of Media Architecture Questionnaire (AQMAQ) dimensions, across 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

The frequency and number of keywords evaluated by the participants were classified and counted for each aspect (Table 6). The participants primarily evaluated spatial aspects (36.51%), followed by tangible (33.16%), intangible (16.84%), and formal (13.49%) aspects, in proportions similar to those in the two sessions. Simultaneously, when comparing the IVR condition to the 2D visualization, spatial and tangible aspects were discussed more than the formal and intangible aspects. In addition to frequency, the number of keywords was dominated by tangible aspects (45), followed by spatial (34), formal (28), and intangible (17) aspects, with similar proportions in both sessions. The number of keywords indicated how broad and varied the participants' evaluations of an aspect were. When comparing the IVR condition to the 2D visualization, the discussion of tangible and formal aspects became more varied, whereas that of intangible aspects became less varied. In both sessions, spatial aspects were the most frequently discussed topics. The tangible aspects were discussed most variably by the participants.

Table 6. Frequency and number of coded design aspect keywords derived from participants' open-ended responses across 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

Aspect	Frequency of Keywords						Number of Keywords					
	2D *n*	**IVR *n***	**Total *n***	**2D %**	**IVR %**	**Total %**	**2D *n***	**IVR *n***	**Total *n***	**2D %**	**IVR %**	**Total %**
Formal (F)	63	66	129	14.38	12.74	13.49	15	20	28	18.75	20.83	22.58
Spatial (S)	156	193	349	35.62	37.26	36.51	25	28	34	31.25	29.17	27.42
Tangible (T)	142	175	317	32.42	33.78	33.16	26	35	45	32.50	36.46	36.29
Intangible (I)	77	84	161	17.58	16.22	16.84	14	13	17	17.50	13.54	13.71
Total	438	518	956	100.00	100.00	100.00	80	96	124	100.00	100.00	100.00

Note. 2D = two-dimensional visualization; IVR = immersive virtual reality.

Figure 5 shows the formal, spatial, tangible, and intangible aspects of all architectural qualities of media architecture design, which were evaluated well in 2D visualization and IVR conditions. The formal-tangible aspects primarily evaluated by participants in 2D visualization were technicality, materiality, and flexibility, whereas in the IVR condition, they were visual, materiality, and proportion. The spatial-tangible aspects primarily evaluated by participants in 2D visualization were lighting, integration, and activities, while in the

IVR condition, they were lighting, representation, and soundscape. Spatial-intangible aspects were primarily evaluated by participants in 2D visualization: perception, narratives, and ambiance; whereas in the IVR condition, perceptions, place meaning, and atmosphere were evaluated.

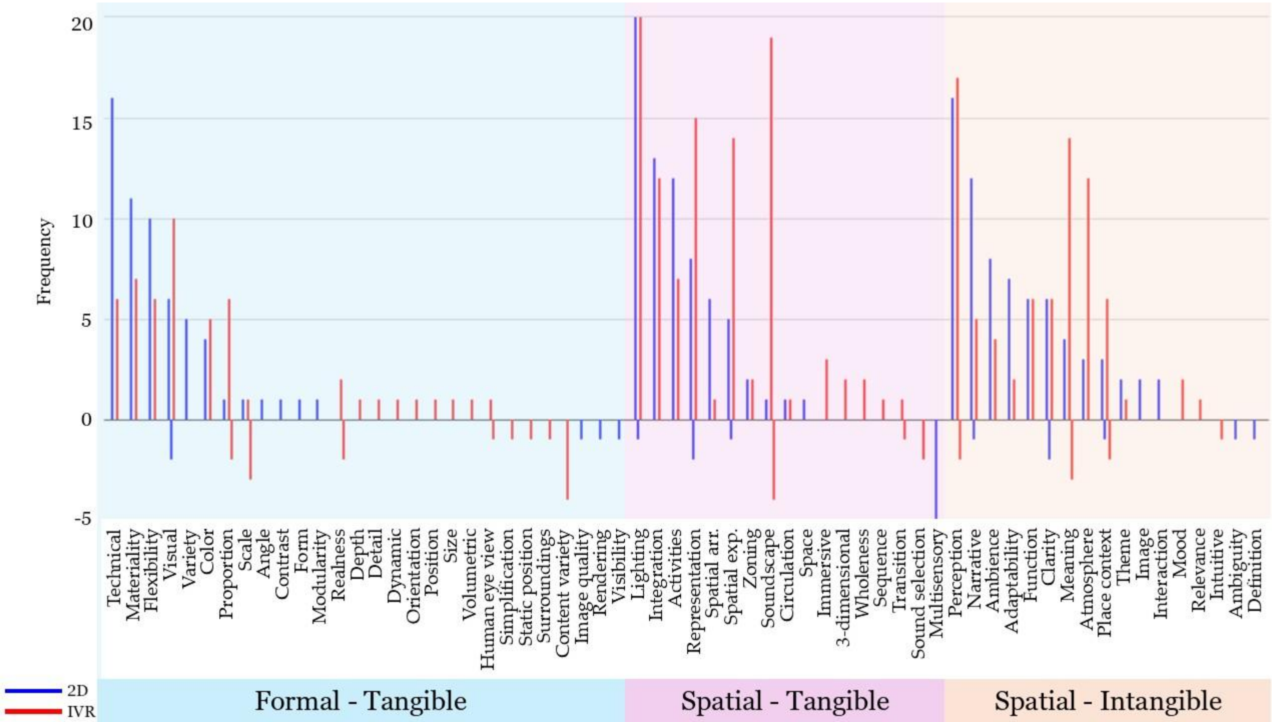


Figure 5. Thematic mapping of coded design aspect keywords derived from participants' open-ended responses for all media architecture qualities across 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

The participants' evaluation ratings of the media architecture qualities and how each design aspect was communicated varied significantly according to the design communication tool conditions. The following section analyzes how the participants accepted each tool and the constraints identified in using each during the design evaluation process.

4.2 Technological Acceptance of 2D Visualization and IVR as a Design Communication Tool

The modest sample size of this exploratory study limits its statistical robustness. Reliability analysis of the IVR measures using Cronbach's α indicated acceptable results. The evaluation of the IVR condition employed multi-item scales adapted from the available TAQ framework, while the evaluation of 2D visualization employed a single global item developed to capture equivalent perceptions for each dimension in the 2D context. Therefore, the internal consistency reliability could not be assessed for these 2D measurements. The different structures limited the comparison to analogous perceptual dimensions.

Quantitative data showed significantly higher overall TAQ ratings in the IVR condition than in the 2D visualization, especially for perceived ease of use and perceived usefulness (Table 7 and Figure 6). The Wilcoxon signed-rank test indicated a statistically significant difference and a large effect on overall ratings ($W = 57.5$, $p < 0.001$, $r = 0.66$), as well as on perceived ease of use ($W = 26$, $p < 0.001$, $r = 0.75$) and perceived usefulness ($W = 46$, $p < 0.001$, $r = 0.66$). No statistically significant differences were observed in the output quality, system characteristics, or perceived discomfort.

Table 7. Descriptive statistics, internal consistency reliability, and Wilcoxon signed-rank test results comparing Technological Acceptance Questionnaire (TAQ) ratings between the 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

Dimension	2D				IVR				Wilcoxon Signed-rank Test		
	M	*SD*	*Mdn*	α	*M*	*SD*	*Mdn*	α	*W*	*p*	*r*
PE	5.16	1.29	6.00	N/A	6.46	0.61	6.67	0.669	26.0	<0.001***	0.75
PU	5.19	1.54	6.00	N/A	6.41	0.65	6.50	0.875	46.0	<0.001***	0.66
PI	-	-	-		6.59	0.55	7.00	0.831	-	-	-
OQ	5.77	1.41	6.00	N/A	5.59	0.84	5.67	0.683	150.5	0.355	0.18
SC	5.52	1.29	6.00	N/A	5.55	0.92	5.50	0.701	226.5	0.902	0.02
PD[a]	2.94	1.55	2.50	N/A	3.70	1.80	3.33	0.867	170.0	0.126	0.27
All TAQ	4.92	0.73	5.20	0.920	5.54	0.56	5.46	0.870	57.5	<0.001***	0.66

Note. 2D = two-dimensional visualization; IVR = immersive virtual reality; PE = perceived ease of use; PU = perceived usefulness; PI = perceived immersion; OQ = output quality; SC = system characteristic; PD = perceived discomfort; TAQ = Technological Acceptance Questionnaire; *M* = mean; *SD* = standard deviation; *Mdn* = median; α = Cronbach's alpha coefficient; *w* = Wilcoxon signed-rank statistic; *p* = exact probability value (two-tailed); *r* = rank-biserial correlation coefficient (effect size). Single-item measures do not produce Cronbach's α coefficients and are therefore reported as N/A (not applicable). [a]PD ratings were inverted prior to analysis, such that higher values indicate greater comfort. Effect size (r) is interpreted as small ($0.10 \leq r < 0.30$), medium ($0.30 \leq r < 0.50$), and large ($r \geq 0.50$). Statistically significant at *: $p < 0.050$; **: $p < 0.010$; ***: $p < 0.001$.

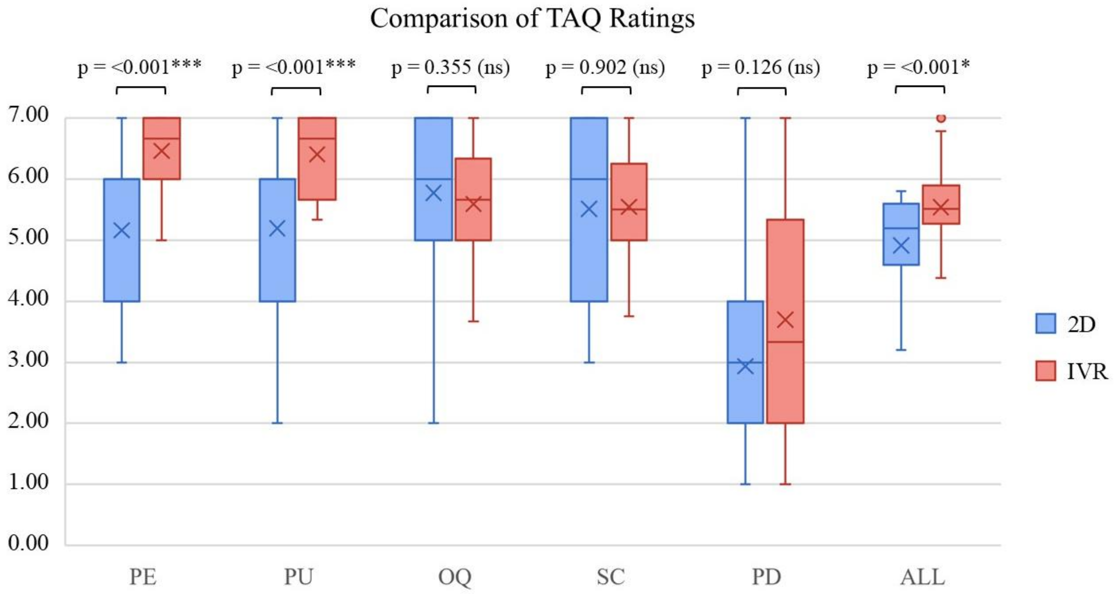


Figure 6. Boxplots comparing Technological Acceptance Questionnaire (TAQ) ratings across technological-acceptance dimensions between 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

Qualitative data identified the shortcomings of each design communication tool (Figure 7). Weaknesses in the IVR condition output quality were primarily compromised by blurry vision and viewpoint distortion, whereas in 2D visualization, the principal concern was insufficient content visibility attributable to screen size and display limitations. Perceived discomfort in IVR was associated with dizziness and eye fatigue. The perceived ease of use of IVR was constrained by battery capacity, which limited the duration and continuity of the evaluation sessions. The shortcomings in usefulness were attributed to the participants' unfamiliarity with IVR as a design communication tool and media architecture as a design concept, as well as difficulty envisioning dynamic design qualities during the 2D evaluation. The constraints in the system characteristics were associated with the fixed viewpoint imposed by the 360° VR panorama format, the perceived lack of realism of the virtual design model, and partial image framing in the 2D visualization.

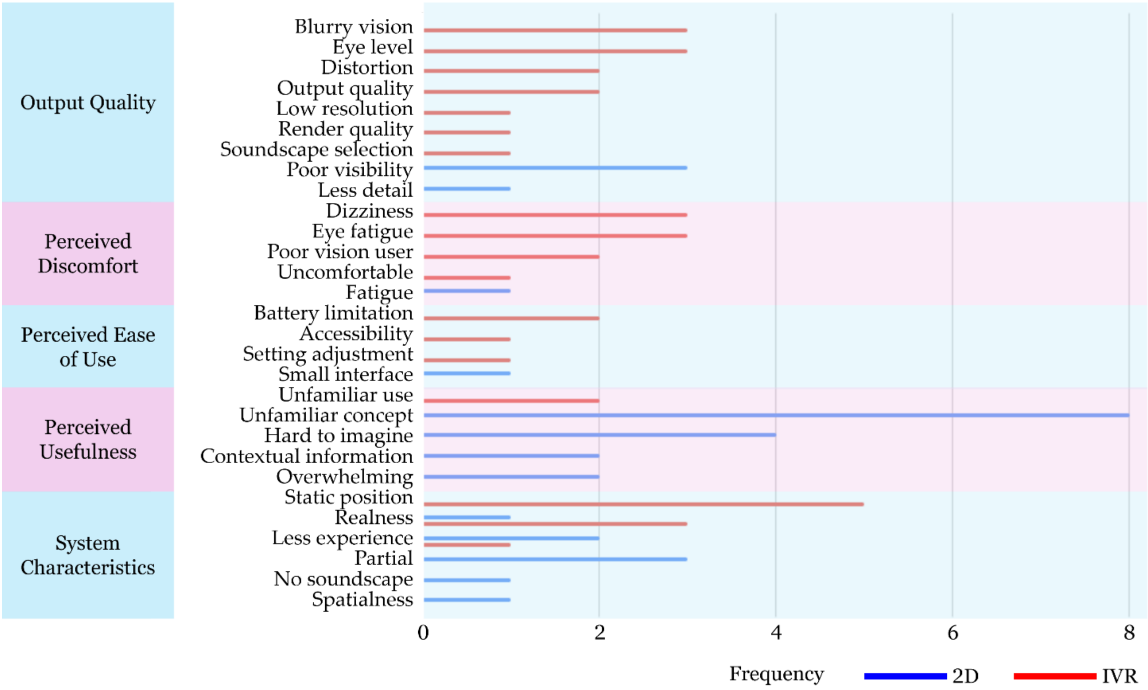


Figure 7. Thematic mapping of coded limitation keywords derived from participants' open-ended responses, organized by technological-acceptance dimension, across 2D visualization and immersive virtual reality (IVR) conditions ($N = 31$).

4.3 IVR as a Design Communication Tool for Design Evaluation

The preceding sections established that the IVR condition had significantly higher ratings of perceived architectural qualities and technological acceptance than 2D visualization. This section explores the correlational relationship between these two sets of ratings and their implications for the role of IVR as a design communication tool in the design evaluation.

Spearman's correlation analysis revealed a strong positive relationship between perceived usefulness (PU) and experiential quality of responsiveness (ER) ($\rho = 0.67$, $p < 0.001$), and overall AQMAQ ratings ($\rho = 0.67$, $p < 0.001$). A strong positive relationship was also observed between output quality (OQ) and f physical quality (PQ) ($\rho = 0.64$, $p < 0.001$), experiential quality of responsiveness (ER) ($\rho = 0.70$, $p < 0.001$), and overall AQMAQ ratings ($\rho = 0.65$, $p < 0.001$) (Table 8).

A moderate positive relationship was found between overall TAQ ratings and the ratings of physical quality (PQ) ($\rho = 0.51$, $p = 0.003$), experiential quality of responsiveness (ER) ($\rho = 0.47$, $p = 0.008$), and overall AQMAQ ratings ($\rho = 0.51$, $p = 0.003$). System characteristics (SC) were also related to the ratings of the physical quality (PQ) ($\rho = 0.46$, $p = 0.010$), experiential quality of responsiveness (ER) ($\rho = 0.55$, $p = 0.001$), and overall AQMAQ ratings ($\rho = 0.51$, $p = 0.003$). A similar relationship was found between perceived ease of use (PE) and experiential quality of responsiveness (ER) ratings ($\rho = 0.41$, $p = 0.021$), as well as between perceived usefulness (PU) and physical quality (PQ) ($\rho = 0.48$, $p = 0.007$) and communicative quality (CQ) ratings ($\rho = 0.55$, $p = 0.001$).

Table 8. Spearman's rank correlation coefficient (ρ) between the Architectural Quality of Media Architecture Questionnaire (AQMAQ) and Technological Acceptance Questionnaire (TAQ) dimension ratings in the immersive virtual reality (IVR) conditions (*N* = 31).

		PQ	EA	ER	CQ	All AQMAQ
PE	Correl. coef. (ρ)	0.30	0.14	0.41*	0.32	0.38*
	Sig. (2-tailed) (*p*)	0.099	0.450	0.021	0.078	0.037
PU	Correl. coef. (ρ)	0.48**	0.31	0.67***	0.55**	0.67***
	Sig. (2-tailed) (*p*)	0.007	0.092	<0.001	0.001	<0.001
OQ	Correl. coef. (ρ)	0.64***	0.27	0.70***	0.34	0.65***
	Sig. (2-tailed) (*p*)	<0.001	0.148	<0.001	0.064	<0.001
SC	Correl. coef. (ρ)	0.46*	0.16	0.55**	0.29	0.51**
	Sig. (2-tailed) (*p*)	0.010	0.392	0.001	0.113	0.003
PD	Correl. coef. (ρ)	-0.10	0.10	-0.36*	-0.27	-0.23
	Sig. (2-tailed) (*p*)	0.600	0.602	0.047	0.147	0.207
All TAQ	Correl. coef. (ρ)	0.51**	0.28	0.47*	0.28	0.51**
	Sig. (2-tailed) (*p*)	0.003	0.123	0.008	0.133	0.003

Note. 2D = two-dimensional visualization; IVR = immersive virtual reality; PQ = physical quality; EA = experiential quality of atmosphere; ER = experiential quality of responsiveness; CQ = communicative quality; AQMAQ = Architectural Quality of Media Architecture Questionnaire; PE = perceived ease of use; PU = perceived usefulness; PI = perceived immersion; OQ = output quality; SC = system characteristic; PD = perceived discomfort; TAQ = Technological Acceptance Questionnaire; ρ = Spearman's rank correlation coefficient; *p* = exact probability value (two-tailed). Correlation strength (ρ) is interpreted as very weak ($\rho < 0.20$), weak ($0.20 \leq \rho < 0.40$), moderate ($0.40 \leq \rho < 0.60$), strong ($0.60 \leq \rho < 0.80$), and very strong ($\rho \geq 0.80$). Statistically significant at *: $p < 0.050$; **: $p < 0.010$; ***: $p < 0.001$.

Higher TAQ ratings and lower perceived discomfort (PD) ratings were associated with higher architectural quality ratings. Participants who rated the architectural qualities higher tended to rate the technological acceptance higher. However, a perceptual relationship between architectural quality and technology acceptance needs to be established through further studies, with the direction or causality yet to be determined.

5.0 DISCUSSIONS

The findings presented in the preceding section are interpreted here in relation to the three research questions and discussed in light of existing studies. First, a detailed analysis of the AQMAQ ratings and design aspects communicated effectively by each tool is elaborated for each architectural quality. Second, the technological acceptance ratings and limitations inherent to each tool were interpreted for each TAQ item. Third, the correlation between both findings in the IVR condition was examined to understand how tool acceptance in IVR shapes perceived architectural qualities. Some findings should be interpreted cautiously because of the study's limitations.

5.1 Evaluation of Architectural Qualities of Media Architecture by IVR

Based on these results, some insights into the evaluation of each quality can be inferred.

5.1.1 Physical Quality

Significantly higher ratings with a large effect size ($W = 38$, $p = 0.002$, $r = 0.63$) were found in physical quality ratings in the IVR condition compared to the 2D visualization; however, the low alpha value (α =

0.551) raised caution regarding this interpretation. The increasing rating suggests that the IVR condition may have facilitated the participants' ability to perceive the volumetric and proportional relationship between digital media and architecture. As expected, IVR's immersive depth and the real-scale simulation in IVR condition allowed participants to experience spatial context in 3D, addressing the limitations of 2D visualization. This resulted in a stronger perception of physical integration.

The evaluation shifted from the formal to the spatial aspects of the design. In both sessions, the participants primarily discussed the integration of design elements between the site context, digital materials, and architectural expression, particularly the spatial and tangible aspects. In the 2D visualization, the participants focused on the formal and tangible aspects of technical and materiality, as the rendered images were framed around specific elements or features. Meanwhile, in the IVR condition, participants predominantly addressed the representation of the design concept in architectural expression (spatial-tangible aspects) and the proportions between design elements. The immersion provided by IVR enabled participants to experience the entire scene and provide comprehensive evaluations.

In 2D visualization, participants primarily noticed the display and its representation, particularly its visibility. In the IVR conditions, participants could delve deeper into integration, spatial experience, and the three-dimensional wholeness of the design. This allowed the participants to sense the proportions and volumetrics of the design. Systemic and comprehensive information, such as circulation and zoning, was better delivered to the participants.

5.1.2 Experiential Quality: Atmosphere

The difference in design communication tools for the experiential quality of atmosphere indicated a non-significant small effect. It implies that atmospheric qualities can be effectively communicated using both tools in this study. The visual renderings and narratives in 2D visualization may have conveyed the intended ambiance if the mood, lighting, and color of the media content were well-represented. These aspects do not necessarily require immersive depth for perception.

Discussions on lighting and perception dominated both sessions. In the 2D visualization, participants primarily noticed the lighting environment, which shaped the overall atmosphere. They predominantly discussed the visual ambiance displayed in the images. Despite the insignificant quantitative results, the participants in the IVR condition predominantly discussed the soundscape, providing a richer experience of the atmosphere. The visual element of the lighting, supported by either ambiance or soundscape, facilitated participants' spatial experience and shaped their perception of place meaning.

5.1.3 Experiential Quality: Responsiveness

A non-significant small effect was shown by the variation in design communication tools for the experiential quality of responsiveness in this study. This may indicate that participants primarily evaluated the concept of responsiveness rather than directly experiencing responsive behavior. The compact, higher ratings of 2D visualization (M_{2D} = 6.17, M_{IVR} = 5.65) may reflect that participants could more easily imagine the responsivity when reading written and graphic representations. In contrast, the IVR's fixed, pre-rendered environment may have felt more rigid and less suggestive of dynamic potential.

Discussions on flexibility and activity aspects dominated both sessions. In the 2D visualization, participants predominantly discussed the design's adaptability, as shown in some images and written explanations. Participants in the IVR condition primarily discussed the atmosphere, as they were fully immersed in the design space and were exposed to the lighting and soundscape.

In the 2D visualization, the participants understood the concepts of adaptability and flexibility through various images and written narrative explanations. In the IVR condition, implementing these concepts requires more effort from designers to provide a wider range of content for the changing atmosphere between scenes. If they displayed only minor changes, the participants hardly noticed them.

5.1.4 Communicative Quality

With a large effect size, the communicative quality ratings were significantly higher in the IVR condition than in the 2D visualization condition. It suggests that IVR conditions are associated with a more consistent understanding of information communicated by media architecture. Experiencing spatial context through immersive environments may support participants' perception of content clarity and the meaning of a concept.

In both sessions, the evaluation was dominated by spatial-intangible aspects, especially the clarity of the design concepts and how they represented the meaning of the place itself. In the 2D visualization, participants discussed the design narratives, particularly the historical value of the place. In the IVR condition, the discussion shifted to tangible aspects, primarily lighting and its integration, and how they shaped the spatial experience of the place.

The 2D visualization was more for communication than the IVR condition. The 2D visualization can focus on a single part or angle framed in the image. In the questionnaire format, communication did not rely solely on images but was also supported by written explanations regarding the visibility of the images and written text. Meanwhile, the IVR conditions provided a more informative and richer spatial experience, delivering a better context of the place. The 2D visualization provided straightforward, partial, and framed communication intent. However, IVR condition is characterized by immersion; therefore, designers must build the entire design and its surroundings more realistically. If not, any unrealistic details, simplification of surroundings, or minor mistakes would be easily noticed by the participants and may disturb them. In 2D visualization, this inconvenience became less noticeable and remained unaddressed.

5.1.5 Overall Qualities Ratings

Overall quality ratings were significantly higher with a medium effect size in the IVR condition than in the 2D visualization condition ($M_{IVR} = 6.08$, $M_{2D} = 5.89$, $W = 125.5$, $p = 0.047$, $r = 0.37$). Significantly large effects were observed for physical and communicative qualities. In both sessions, participants primarily discussed lighting and how it shaped their perceptions of the place's meaning. When comparing the IVR condition to 2D visualization, the discussion of spatial and tangible aspects increased more than that of formal and tangible aspects. Overall evaluations in the IVR condition were dominated by spatial-tangible aspects (lighting, soundscape, representation, spatial experience), followed by spatial-intangible aspects (perception, meaning, atmosphere). Lighting aspects dominated the images and scenes in both 2D visualization and IVR conditions. In the 2D visualization, the participants discussed the formal-tangible aspects of the technical elements more. Owing to the system's characteristics, the spatial-tangible aspects of the soundscape were discussed more in the IVR condition.

These findings extend previous studies on the use of IVR for design evaluation in media architecture design. A previous study noted that IVR can provide comprehensive details of a design space in a single view (Liu et al., 2020). Additionally, this characteristic makes participants less overwhelmed than in 2D visualization, where participants must check several images and text explanations. A previous study focused on formal-tangible aspects (size, scale, volume, and depth of space), enabling participants to understand the physical spatial settings of the design more accurately (Ali et al., 2025; Liu et al., 2020; Strand, 2020). Conversely, some participants in this study reported distortions in height and scale, likely due to differences between the default rendering settings and the actual height.

Furthermore, the IVR condition exerted a stronger influence on participants' affective responses, including emotional engagement and sense of presence, than on their cognitive appraisal of the design qualities. This study extends to spatial, tangible, and intangible aspects, in which the digital setting of lighting and soundscapes shapes the spatial experience in media architecture design. These aspects play a key role in shaping the experiential quality of the atmosphere in media architecture design (Wouters et al., 2016). Participants significantly noticed and discussed these aspects, which are associated with the intangible aspects of emotion, perception, and meaning of place.

Multisensory feedback (audio-visual) enhances immersion in IVR systems (Globa et al., 2022; Kim et al., 2020). Combined with the lighting environment, the soundscape in the IVR condition supported the atmosphere and the user's perception of the place's meaning compared to 2D visualization alone. Participants primarily gave higher ratings ($M_{\text{IVR}} = 6.19$, $M_{\text{2D}} = 6.03$); however, the difference was not significant ($W = 145.5$, $p = 0.296$, $r = 0.20$). Some participants suggested adding background sounds of natural surroundings and human activities rather than playing the designed soundscape. Future research should include movement and haptic feedback.

Previous studies have reported that the virtual model in the IVR condition contains comprehensive and detailed geometric information, thereby making it easier for participants to understand and more effective in review time than partial 2D visualizations (Liu et al., 2020; Ma et al., 2025). It was effective in delivering spatial experience and place context. However, this study found that it is not necessarily effective in communicating design intent. 2D visualization provides more effective communication because it can focus on a single part or angle, which is then framed as an image supported by a written explanation. The straightforwardness and partiality of 2D visualization allow designers to focus on specific design elements.

IVR is characterized by immersion. However, depending on the rendering quality, the simulated surroundings may lack realism (Strand, 2020). During this study, participants were annoyed by some unrealistic details in the IVR experience; meanwhile, those same details went unnoticed and remained neglected in the 2D visualization session. Consequently, designers must construct the entire design and its surroundings in a more realistic manner, which is more time- and resource-consuming.

5.2 Technological Acceptance of IVR for Media Architecture Design Evaluation

Based on these results, the following insights into each technological acceptance item can be inferred.

5.2.1 Perceived Ease of Use

Significantly higher ratings with a large effect ($W = 26$, $p < 0.001$, $r = 0.75$) in terms of perceived ease of use were observed in the IVR condition compared to the 2D visualization. This likely reflects how effortlessly participants could perceive and evaluate design qualities through the tool, as spatial information could be explored directly in the IVR. However, it requires an initial technical setup. Participants in the 2D visualization session struggled with the small interface (smartphone or laptop screen), which was related to the visibility of the content throughout the evaluation process. Meanwhile, the IVR condition introduces technical difficulties, such as initial setting adjustments and battery limitations (2 hours of continuous use). Initially, the participants needed to adjust the headset band comfortably for a clear vision. Once it was set well, the design could be easily evaluated. It was usable while charging, but the cable was annoying and limited the participant's movement.

5.2.2 Perceived Usefulness

Perceived usefulness ratings were significantly higher in the IVR condition than in the 2D visualization condition, with a large effect ($W = 46$, $p < 0.001$, $r = 0.66$). The 2D visualization session faced challenges related to design concepts and the presentation of information. Participants found the concept unfamiliar and had difficulty imagining it using only 2D representations. The image displayed also focuses on design rather than on contextual information. A large number of images, written explanations, and questions made them feel overwhelmed by the material.

Meanwhile, in the IVR condition, they noted the unfamiliar use of IVR headsets. After familiarization, they were immersed in the design evaluation process and provided feedback. Despite the unfamiliar concept, they could easily imagine it using IVR, contextual information, and verbal explanations. Receiving information through both sight and hearing was less overwhelming than receiving it through vision alone.

5.2.3 Output Quality

There was a non-significant difference with a small effect size between the 2D visualization and IVR conditions in terms of output quality rating ($M_{\text{IVR}} = 5.77$, $M_{\text{2D}} = 5.59$, $W = 150.5$, $p = 0.355$, $r = 0.18$). The similar ratings across tools indicated that the 2D visualization already provided adequate graphical information, and the immersivity of IVR did not elevate the output quality ratings. However, in the 2D visualization session, the participants experienced poor visibility and detail owing to the small display interface. Meanwhile, IVR issues included blurry vision, eye-level distortion, low resolution, and render quality, which were particularly noticeable early in the headset's setup. Some participants felt that their point of view was distorted and elevated, likely because of differences in the default rendering settings and actual user height. Although both the 2D images and IVR scenes were created using the same software, the resolution and rendering quality were only apparent on the larger IVR display.

5.2.4 System Characteristics

Regarding system characteristics, the difference in design communication tools (2D visualization and IVR condition) indicated a small and insignificant effect. The 2D visualization may have already conveyed sufficient information, thereby reducing the perceived advantage of the IVR condition. These findings imply that system capability alone is insufficient to differentiate tools, but experiential and spatial dimensions are more crucial. In the 2D visualization session, participants criticized the design's partiality and lack of spatiality because it was shown only in selected images and angles without a soundscape. In the IVR condition, the use of 360° panoramas restricted movement at the design site. The distortion in the eye-level angles made the view less realistic and immersive.

5.2.5 Perceived Discomfort

The difference between 2D visualization and IVR as design communication tools showed a non-significant medium effect in terms of perceived discomfort. The 2D's wide variance and lower mean likely reflected hardware limitations. The discomfort associated with the IVR condition was more moderate and consistent. In the 2D visualization session, participants reported only some fatigue owing to the small interface and overwhelming amount of information. During the IVR condition, participants reported mild dizziness, eye fatigue, and discomfort owing to the weight of the tool.

In summary, this study confirmed that, among a purposive sample of architecture students, IVR had higher technological acceptance ratings than 2D visualization ($M_{\text{IVR}} = 5.54$, $M_{\text{2D}} = 4.92$, $W = 57.5$, $p < 0.001$, $r = 0.66$). Previous studies have reported users' preference for the IVR condition over 2D visualization (Fiorentino et al., 2020; Globa et al., 2023). Although 54% had never had an IVR experience, the participants demonstrated prior familiarity with digital interfaces and virtual environments, consistent with the technological fluency characteristic of Gen-Z users. They were able to navigate the IVR system after receiving brief guidance. Further studies should include more varied user demographics. Users from various backgrounds and levels of digital literacy may have different levels of acceptance of IVR because of the digital divide (Dijk, 2020; Hartanti & Prabowo, 2024).

Consistent with previous studies, users reported a low level of perceived discomfort, such as mild dizziness, eye fatigue, heavy HMD use, and glasses adjustment (Chen et al., 2021; Liu et al., 2024; Ma et al., 2025; Strand, 2020; Yildirim et al., 2025). This was mitigated by regularly checking their conditions and providing break time. Nevertheless, it has a weak negative relationship ($\rho = -0.24$) with the AQMAQ ratings.

The quality of the output plays a significant role in increasing user attention to the system (Liu et al., 2024). It has a strong positive relationship with users' ratings of physical quality ($\rho = 0.64$, $p < 0.001$), experiential quality of responsiveness ($\rho = 0.70$, $p < 0.001$), and overall quality ($\rho = 0.67$, $p < 0.001$). IVR enhances the accuracy of affective evaluations related to spatial dimensions (Ma et al., 2025). Furthermore, the IVR experience affected users' emotions, thereby shaping their perception of the meaning of the place.

5.3 IVR as a Design Communication Tool for Media Architecture Design Evaluation Process

IVR is better supported by other design communication tools (Liu et al., 2020). In addition, the IVR efficiently communicates formal, spatial, and tangible aspects. Other media, such as narratives, convey design briefs, intents, and goals more effectively. Their combination shapes intangible aspects, such as perception and meaning.

In evaluating the architectural qualities of media architecture design, IVR is more effective and accurate in terms of physical (formal-tangible and spatial-tangible) and communicative (spatial-intangible) qualities than 2D visualization. The immersivity and multisensory characteristics of IVR enrich the user experience in evaluating atmospheric quality, particularly in terms of lighting and soundscapes. Further studies may include more sensor feedback, such as movement, haptic, olfactory, and thermal feedback. Regarding responsiveness quality, more varied scenes are required to represent the flexibility of users' activities and the adaptability of the media architecture installation.

The perceived usefulness and output quality of the IVR system were associated with architectural qualities of media architecture design ratings, especially for physical and experiential qualities. It was observed only in a group of architecture students; further studies should include a more varied set of user demographics. As IVR is effective for immersive and comprehensive communication, other tools may be needed to complement detailed, focused, and framed design communication. Designers should consider the audience, time, and resources when choosing effective and efficient communication tools.

6.0 CONCLUSIONS

This study extends previous studies on IVR in architectural design, focusing on its role as a design communication tool for evaluating building-scale media architecture in the neighbourhood context. The virtual model employed was limited to a media architecture design for a digital placemaking project, in which digital materials and intangible aspects play a significant role in shaping users' perceptions of a place's meaning. Previous studies have primarily discussed the role of IVR in site visits, heritage documentation, design exploration, reviews, and education, in which the virtual model focused primarily on physical and tangible objects.

Participants' evaluation ratings of media architecture design and technological acceptance ratings were significantly higher in the IVR condition than in the 2D visualization condition. As a design communication tool, IVR effectively portrays both spatial-tangible and spatial-intangible aspects, especially the physical (with cautious interpretation regarding moderate internal consistency) and communicative qualities of the media architecture design. During the IVR condition, discussion frequency of spatial and tangible aspects increased, while discussion frequency of formal and intangible aspects was more varied than in the 2D visualization condition. The perceived usefulness and output quality of the IVR system were associated with the design evaluation ratings. The low level of perceived discomfort did not significantly differ from the design evaluation ratings. IVR comprehensively represents the design's wholeness, although it may be better supported by other tools to detail specific design elements. Target audience, time, and resources are considerations for designers when choosing effective communication tools for the target audience.

These findings focused on building-scale media architecture in a neighbourhood context, while also applying to various scales of architectural projects. The study was limited to an audio-visual IVR experience among a group of architecture student participants in a single institution. Their tool perception and acceptance ratings may be associated with their spatial literacy. Therefore, the findings are limited to the context of design education and its practice. Further studies should include diverse participants, including professionals and non-expert end-users from various backgrounds and ages. Other sensory feedback, such as movement and haptics, can be incorporated to optimize multisensory immersion. The combination of other tools and media should be evaluated for more effective communication. Future studies should replicate this study with larger sample sizes for more robust statistical analyses.

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