The Impact of Smart Systems on Interactive User Experiences in Exhibition Spaces

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Abstract

The integration of smart technologies has transformed exhibition spaces from traditional display environments into interactive and immersive experiences that enhance visitor engagement and participation. Despite the growing adoption of technologies such as Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR), and interactive digital systems, limited research has examined the role of interior design in supporting and maximizing the effectiveness of these technologies within exhibition environments. This study investigates the relationship between spatial design, smart technologies, and user experience in exhibition spaces.

A mixed-methods approach was employed, including a questionnaire survey, a semi-structured interview with a design and technology expert, and an observational study analyzed using the AEIOU framework. Quantitative and qualitative findings were further synthesized through triangulation to identify recurring patterns and generate integrated spatial insights.

The findings reveal that while smart technologies significantly enhance engagement, immersion, and participation, their effectiveness is strongly influenced by spatial organization, circulation clarity, and the integration of technology within the built environment. Open and continuous layouts encourage exploration and interaction; however, inadequate wayfinding and spatial hierarchy may lead to confusion and disorientation. The study concludes that successful exhibition environments require a balanced integration of interior design, user movement, and smart systems to create meaningful, immersive, and user-centered experiences.

Keywords: Keywords: Smart Systems, Exhibition Design, Interactive User Experience, Interior Design, Immersive Environments, Digital Technologies.

Introduction

The rapid advancement of digital technologies has significantly transformed contemporary exhibition environments, shifting them from traditional display settings into interactive and immersive spaces that encourage active visitor engagement. Smart systems, including Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR), data analytics, and interactive digital interfaces,

have become increasingly integrated into exhibition design, enabling exhibitions to respond dynamically to visitor behavior and provide more personalized experiences. As a result, technology is no longer viewed as a supplementary feature but as a fundamental component that shapes how users perceive, navigate, and interact with exhibition spaces.

Previous studies have highlighted the ability of smart technologies to enhance visitor engagement, participation, immersion, and emotional connection with exhibition content. Interactive systems allow visitors to become active participants rather than passive observers, while immersive technologies create multi-sensory experiences that strengthen learning, memory retention, and overall user satisfaction. Furthermore, advancements in behavioral tracking and data analytics have enabled exhibition designers and curators to better understand visitor preferences and optimize exhibition experiences accordingly.

Despite these developments, a significant gap remains in understanding how exhibition spaces themselves can be designed to effectively support and maximize the performance of smart technologies. Existing research primarily focuses on technological capabilities and visitor responses, while comparatively limited attention has been given to the role of interior design in organizing circulation, spatial hierarchy, accessibility, and user movement within technology-integrated environments. Consequently, the relationship between spatial design and technological interaction remains insufficiently explored.

Therefore, this study investigates the impact of smart systems on interactive user experience in exhibition spaces, with particular emphasis on the role of interior design in supporting technological integration. The research aims to unravel how spatial organization, circulation patterns, and environmental design influence user interaction, engagement, and immersion within technology-enhanced exhibition environments. Its objectives are:

1. To identify the ways in which smart systems contribute to interactive user experience in exhibition spaces.
2. To identify the ways in which interior architecture of spaces contributes to interactive user experience in exhibition spaces.
3. To develop a set of principles and practices that can be employed in producing interiors that can integrate technologies effectively to produce exciting exhibition experiences.

Theoretical Background

The rapid advancement of digital technologies has significantly transformed contemporary exhibition environments, shifting them from traditional display settings into dynamic and responsive spaces that actively engage visitors. Within this transformation, smart systems have emerged as a fundamental component of exhibition design, enabling environments to collect, analyze, and respond to user behavior in real time. Technologies such as Artificial Intelligence (AI), data analytics, behavioral tracking systems, and intelligent personalization tools have expanded the ability of exhibition spaces to adapt to individual users, creating experiences that are increasingly responsive, interactive, and user centered.

As technological integration has become more prevalent, the concept of user experience has gained increasing importance within exhibition design. Rather than functioning as passive observers, visitors are now encouraged to participate actively in the exhibition environment through interaction with digital content, responsive installations, and immersive technologies. This shift reflects a broader transition from object-centered exhibitions toward user-centered experiences, where engagement, participation, and usability become critical indicators of success. Consequently, the quality of interaction between visitors, technology, and space plays a significant role in shaping overall exhibition performance.

Alongside the development of interactive technologies, immersion has become a defining characteristic of contemporary exhibition environments. Technologies such as Virtual

Reality (VR), Augmented Reality (AR), projection mapping, and digital storytelling enable visitors to engage with exhibition content through highly immersive experiences that extend beyond conventional methods of display and communication. These technologies allow users to explore digital environments, interact with reconstructed narratives, and experience information through multiple sensory channels. The integration of visual, auditory, tactile, and spatial stimuli further strengthens immersion by creating environments that encourage exploration, curiosity, and prolonged engagement.

Beyond their influence on interaction and immersion, smart technologies also contribute to the emotional and cognitive dimensions of visitor experience. Through emotional computing, behavioral analysis, and adaptive digital systems, exhibition environments are increasingly capable of responding to visitor emotions and preferences. Emotional engagement influences how visitors perceive and interpret exhibition content, while cognitive responses affect attention, learning, memory retention, and information recall. As a result, successful exhibition environments depend not only on technological functionality but also on their ability to support meaningful emotional and cognitive experiences. Collectively, these concepts provide the theoretical foundation for understanding the relationship between smart technologies, spatial design, and interactive user experience within contemporary exhibition environments.

Review of Literature

Recent research has begun to look into the exhibition spaces and particularly the role of interior design in producing effective exhibition spaces. Moreover, previous studies have extensively explored the growing role of smart technologies in transforming exhibition environments into interactive and adaptive spaces. Capece et al. (2024) emphasize that technologies such as Artificial Intelligence, behavioral tracking systems, and data analytics contribute significantly to enhancing visitor engagement by enabling exhibition environments to respond dynamically to user behavior. Similarly, Lei (2025) highlights the potential of intelligent systems to analyze movement patterns, optimize visitor flow, and improve overall spatial performance. While both studies recognize the advantages of technological integration, their primary focus remains on the capabilities of technological systems rather than the spatial conditions that support their effectiveness.

The relationship between technology and visitor engagement has also received considerable attention within literature. Research suggests that interactive technologies encourage participation by transforming visitors from passive observers into active contributors to the exhibition experience. Capece et al. (2024) point out that digital interaction enhances engagement and strengthens user involvement, while Han (2024) emphasizes the role of participation in increasing perceived value and visitor satisfaction. These studies collectively indicate that engagement is influenced not only by the presence of technology but also by the quality of interaction it facilitates. However, limited discussions are provided regarding how spatial design can enhance or constrain these interactions.

A growing body of literature further highlights the importance of immersive technologies in shaping contemporary exhibition experiences. According to Lei (2025), technologies such as Virtual Reality and Augmented Reality create environments that encourage exploration and deeper user involvement. Similarly, Capece et al. (2024) emphasize the contribution of multi-sensory integration in enhancing emotional engagement and overall visitor experience. Han (2024) also recognizes the value of immersive environments in creating memorable and meaningful interactions with exhibition content. Despite these findings, much of the existing research focuses on technological features and experiential outcomes, while comparatively less attention is given to the spatial strategies required to support immersive experiences effectively.

The emotional and cognitive impact of interactive exhibition environments has likewise become an important area of investigation. Previous studies indicate that emotionally

engaging experiences strengthen memory retention, improve learning outcomes, and enhance visitor satisfaction. Capece et al. (2024) discuss the role of emotional computing in recognizing and responding to visitor emotions, while Han (2024) highlights the influence of emotional engagement on long-term memory formation. Lei (2025) further suggests that adaptive technologies can support cognitive engagement by responding to visitor interests and behavioral patterns in real time. Together, these studies demonstrate the potential of smart technologies to influence emotional and cognitive experiences; however, the contribution of interior design to these outcomes remains insufficiently explored.

Although previous research has established the benefits of smart technologies in enhancing engagement, immersion, emotional response, and interactive experiences, a significant gap remains regarding the role of exhibition design in supporting these technologies. Existing studies primarily focus on technological capabilities, visitor behavior, and experiential outcomes, while comparatively limited attention has been given to the influence of spatial organization, circulation patterns, accessibility, and environmental design. Consequently, there remains a need to investigate how interior design can facilitate a more effective integration between space, technology, and user interaction. Undeniably, addressing this gap is essential for developing exhibition environments that maximize the potential of smart systems while providing meaningful and user-centered experiences.

Research Methodology

This study investigates the impact of smart systems on interactive user experience in exhibition spaces, with particular emphasis on the role of interior design in supporting technological integration. Its aim is to unravel how characteristics of environmental design influence user interaction, engagement, and immersion within technology-enhanced exhibition environments. Its seeks to identify the ways in which smart systems as well as interior architecture of spaces contribute to interactive user experience in exhibition spaces.

To achieve these objectives, a mixed-methods approach is adopted, incorporating a questionnaire survey, a semi-structured interview, and an observational study. The findings were subsequently synthesized through triangulation to develop integrated insights that contribute to a deeper understanding of the relationship between space, technology, and user experience in contemporary exhibition design. The use of multiple data collection methods enables the research to explore the issue from different perspectives and develop a comprehensive understanding of the factors influencing interaction within technology-integrated exhibition spaces.

The survey provided quantitative data regarding users' preferences, perceptions, and experiences within exhibition environments. The interview analysis offered qualitative insights into the relationship between spatial design and technological interaction from an expert perspective, while the observational study examined actual user behavior and interaction patterns within a real exhibition setting.

The findings obtained from each method were subsequently synthesized through triangulation to generate evidence-based insights regarding the role of interior design in supporting smart technologies and enhancing interactive user experience within exhibition spaces.

The Survey

In order to achieve a confidence level of 95% with an estimated population proportion of 10%, the calculated sample size was 139. Despite that, one hundred and ninety-five people were included in the study, taking into consideration an expected defaulter rate of 20%. A quantitative research method was selected because it allows data to be collected from a large number of participants efficiently and provides measurable insights related to user experiences and perceptions of exhibition spaces. The survey aims to reveal how spatial design supports interactive technologies and influences user experience within exhibition environments.

A special questionnaire was designed in Google Forms as a research data collection tool containing ten questions covering the required variables to achieve the research objectives.

The questionnaire included questions related to user profile, visiting frequency, user preferences, satisfaction with exhibition spaces, spatial behavior, design perception, challenges associated with interactive technologies, and potential design improvements. It was distributed to a convenience sample through WhatsApp, containing a link to the survey together with a brief introduction explaining the purpose and objectives of the study. Participation was voluntary and responses were collected anonymously.

A total of 173 completed responses were received and included in the analysis. The collected data was then analyzed using simple frequency analysis to identify common patterns, user preferences, and spatial issues related to the integration of interactive technologies within exhibition spaces.

Semi-Structured Interview

To complement the survey findings and provide a deeper understanding of the relationship between spatial design and technology integration within exhibition environments, a qualitative interview analysis was conducted. Rather than conducting a primary interview, the study utilizes a publicly available recorded interview featuring Toshiyuki Inoko, founder of team Lab, an internationally recognized organization known for integrating digital technologies with immersive spatial environments.

The interview as a technique is selected because its content closely aligned with the research topic and addressed key themes relevant to the study, including user experience, spatial organization, immersion, movement, interaction, and the relationship between technology and exhibition design. A set of analytical questions was developed based on the research objectives and used to examine the participant's responses within the recorded material.

This method provides expert insights into how technology-integrated exhibition spaces are designed and experienced. While the survey focuses on visitors' perceptions and preferences, the interview analysis provides a professional design perspective regarding the role of spatial organization in supporting technological interaction and user engagement.

The collected responses are subsequently analyzed using the Empathy Map framework to identify what users say, think, feel, and do within exhibition environments. This analytical process facilitates the identification of recurring themes and spatial implications, which are later compared with survey and observation findings through triangulation.

Observation

During the observation phase, the research thoroughly examines the Team Lab Borderless exhibition's spatial context and user interactions. The intention of the observation is to understand how smart systems are incorporated into the exhibition area and how they affect visitor behavior and movement patterns. The first step in the process is examining how visitors moved around the exhibition . we saw that there is a fluid and non-linear circulation system in place, allowing guests to wander about freely without following set paths. Open spatial arrangements and hidden barriers between exhibition areas facilitate this mobility, resulting in a seamless, borderless experience.

The research then looks at the technical systems integrated into the surroundings. It discovers the utilization of advanced motion sensors, IR cameras, and real-time tracking systems that track visitors' positions and movements by observing the interactive responses of the exhibition. These devices seem to be thoughtfully incorporated into walls and ceilings, enabling them to continuously gather user data while remaining undetectable.

The interaction between visitor behavior and the digital material of the show is another aspect of the observation. It documented immediate changes in projections, lighting effects, colors, and animations that resulted from walking, stopping, touching surfaces, and engaging with other guests. This shows how interactive surfaces and pressure-sensitive floors give the system real-time input. Lastly, how the smart systems affect user engagement are analyzed.

Findings and Analysis

This section presents and analyzes the findings obtained from the three research methods employed in this study: the questionnaire survey, interview analysis, and observational study. The collected data are examined to investigate the relationship between smart technologies, interior design, and user experience within interactive exhibition environments. Each research method provides a different perspective on the study topic, enabling a comprehensive understanding of how the users interact with technology-integrated exhibition spaces.

The findings are organized according to the data collection methods used. The survey provides quantitative insights into users' preferences, perceptions, and experiences, while the interview analysis offers qualitative perspectives on the relationship between spatial design and technological interaction. In addition, the observational study examines actual user behavior and engagement within a real exhibition setting.

Beyond presenting the collected data, this section focuses on interpreting and analyzing the findings in relation to the theoretical background and literature reviewed earlier in the study. The analysis aims to identify recurring patterns, behavioral trends, and key factors influencing user experience within technology-enhanced exhibition environments. These findings form the foundation for the subsequent triangulation process, through which integrated design insights are developed to address the research objectives and contribute to a deeper understanding of the role of interior design in supporting smart technologies within exhibition spaces.

In contrast to a technology-driven installation, the findings show that technology was purposefully hidden inside the spatial architecture, allowing visitors to perceive the setting as an interactive and responsive area. Movement consequently evolved as a means of circulation as well as an input that continually shifts the exhibition space, producing a highly flexible and captivating spatial experience.

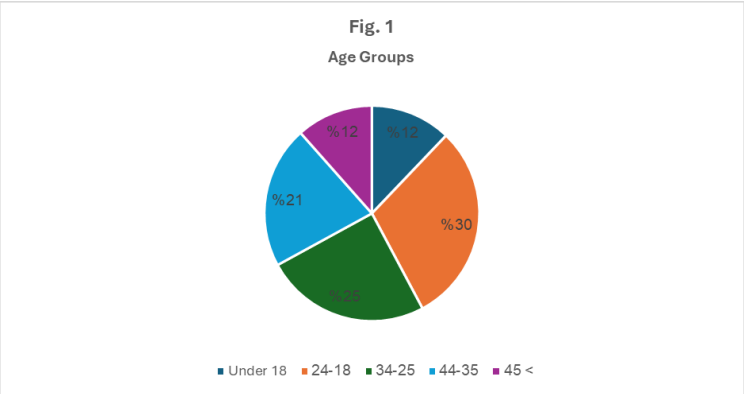
Results of the Questionnaire Survey:

Table 01. Survey Question

Survey Question	Most Selected Answer	Percentage
Age group	18-34	55%
Frequency of Visits	1-2 times per year	64.2%
Preferred exhibition Type	Mixed Experience	60.7%
Impact of Technology	Improve a Little	44%
User Satisfaction	Satisfied	54.3%
Navigation	Sometimes Confusing	67.6%
Movement Behaviour	Explore Freely	53.2%
Design Support for Technology	Moderately Designed	61.3
Main Problem	Crowding	52%
Suggested Improvement	Clear Circulation Paths	28.9%

Prioritization for exhibition spaces

The survey shows that more than half of the participants are young adults aged 18–34 (55%). This young age group domination indicates that the results mainly reflect the preferences of a younger, tech-oriented generation who tends to be more engaged with interactive and immersive environments. This aligns with the findings of the study conducted by Capece et al. (2024). Hence, exhibition spaces should prioritize interactive and digital experiences, while still ensuring inclusivity for different age groups (Fig. 1).



Focus of exhibition design

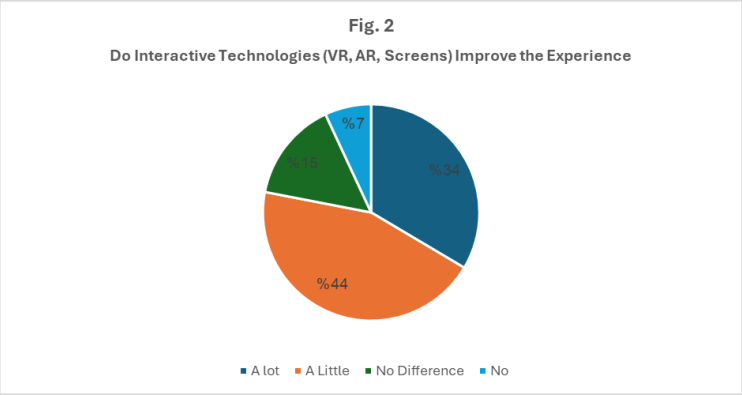
The study also revealed that exhibitions are occasional experiences rather than everyday activities, since most participants (78%) visited exhibitions at least once per year, with the majority attending only 1–2 times. According to Han (2024), engaging and interactive environments are essential to increase visitor interest and encourage repeated visits. Accordingly, exhibition design should focus on creating memorable and impactful experiences.

User Preferences

Most participants (60.7%) also preferred a mixed exhibition experience, which indicates that users seek a balance between traditional and digital elements. This finding is supported by the observation in a study conducted by Lei (2025), who explains that integrating physical space with digital interaction enhances user engagement and participation. As a result, exhibitions spatially should include hybrid zones combining physical and digital experiences.

Impact of Technology on Experience

According to the study, technology has a positive but not fully optimized impact, since most participants reported that technology improves their experience. Meanwhile, according to Capece et al. (2024), interactive technologies increase engagement, but their effectiveness depends on how they are integrated within the space. This ensures the need for better spatial integration of technology (Fig. 2).



Enhancing User Satisfaction

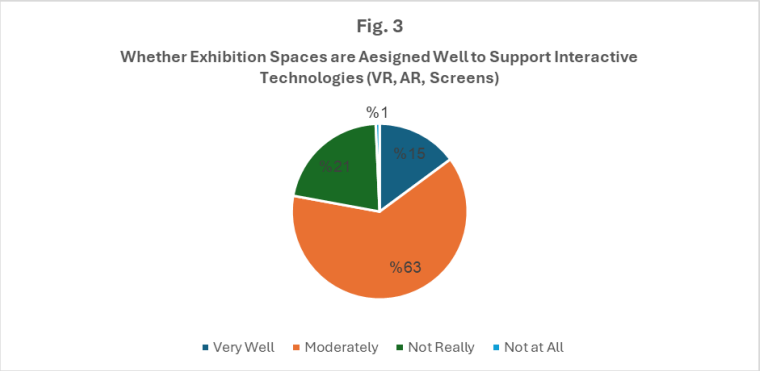
More than half of participants are satisfied, while one-third are neutral. This suggests that the experience is acceptable but not highly engaging. Further, according to Han (2024), higher engagement levels are achieved through interactive and immersive environments that enhance satisfaction levels.

Improving navigation and spatial planning

Lack of clear spatial organization was one of the findings of our study, since a significant percentage of respondents reported that navigation is sometimes confusing. Similar finding was observed by a study conducted by Lei (2025), who emphasizes that spatial layout and circulation significantly affect user engagement and movement within exhibitions. This consistent finding suggests the need for clearer pathways and better spatial planning.

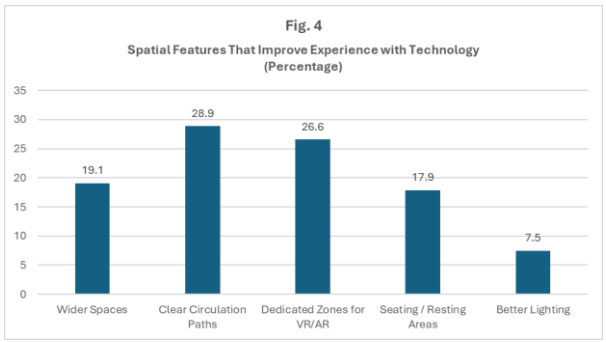
Space-supported smart technologies

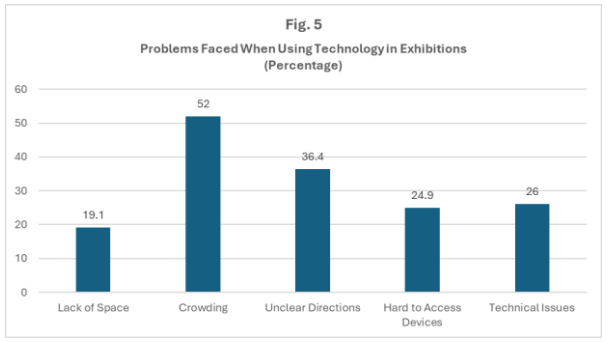
Plenty of studies concluded that exhibition space design should support smart technology. Research conducted by Lei (2025) highlights that there is limited focus on how space supports smart technologies. Most participants in this study believe that exhibition spaces are only moderately designed to support technology. Therefore, better integration between space and technology is required (Fig. 3).



Exhibitions spatial design improvements

More than half of the participants highlighted the need for a clear circulation paths and dedicated VR/AR zones, as shown in (Fig. 4). Furthermore, crowding was identified as the main problem faced (52.0%), as illustrated in (Fig.5). This indicates that users directly relate their experience to spatial design. These findings align with the conclusions in Han study (2024), who emphasizes that spatial design and organization enhance user interaction, improve user experience and reduce crowdedness.





Interview findings and analysis

To gain a deeper understanding of the relationship between spatial design, technology integration, and user experience within exhibition environments, an interview analysis was conducted using a publicly available interview featuring Toshiyuki Inoko, founder of teamLab. The interview was analyzed through the Empathy Map framework to identify recurring perceptions, thoughts, emotions, and behaviors related to technology-enhanced exhibition experiences. This process enabled the extraction of key codes and the identification of broader themes that reflect how visitors interact with both space and technology.

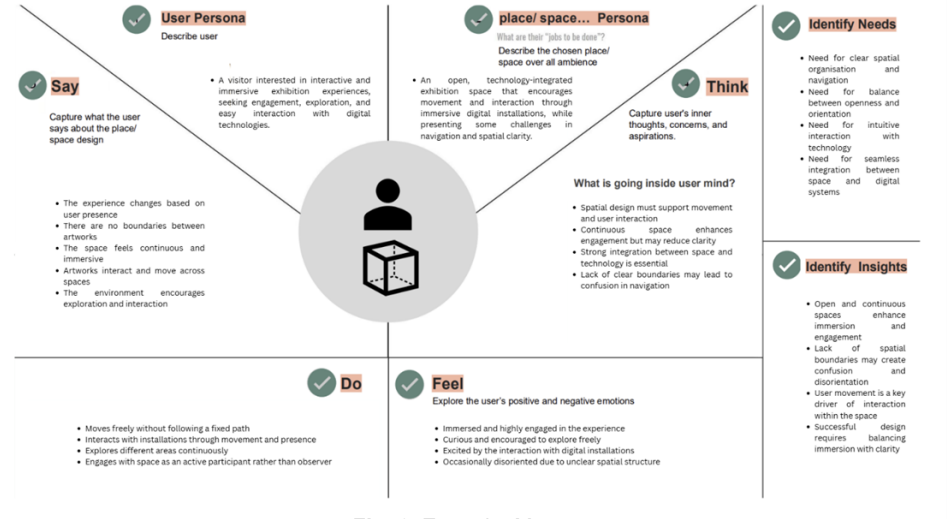


Fig. 6: Empathy Map

The Empathy Map analysis revealed several recurring patterns related to visitor interaction, movement, immersion, and spatial perception. As shown in Table 02, a series of codes were extracted from the four empathy map categories (Says, Thinks, Feels, and Does). These codes represent the key ideas repeatedly emphasized throughout the interview and provide the basis for understanding user experiences within immersive exhibition environments. sit or interaction and engagement.

Table 2: Extracted Codes from the Interview Analysis

Empathy Map Category	Extracted Codes
Says	Interaction, Exploration, Participation, Movement
Thinks	Connectivity, Continuity, Discovery, Curiosity
Feels	Immersion, Engagement, Freedom, Wonder
Does	Navigate, Explore, Interact, Observe

The extracted codes were subsequently grouped into broader analytical themes, as presented in Table 03. These themes provide a structured framework for interpreting the interview findings and understanding the spatial and experiential factors that influence user interaction within technology-integrated exhibition environments.

Table 3: Identified Themes

Theme	Related Codes
Immersive and Interactive Experience	Immersion, Participation, Engagement, Interaction
Spatial Continuity and Openness	Connectivity, Continuity, Freedom, Exploration
User Movement and Engagement	Movement, Discovery, Navigation, Participation
Challenges in Spatial Clarity and Navigation	Orientation, Wayfinding, Spatial Understanding

Immersive and Interactive Experience

The first theme identified through the interview analysis was immersive and interactive experience. As indicated in Table 03, this theme emerged from several recurring codes, including immersion, engagement, participation, and interaction. The interview emphasized that visitors are not passive observers but active participants whose presence directly influences the surrounding environment. This dynamic relationship between users and digital installations contributes to a more engaging and meaningful experience, transforming exhibitions into interactive environments where visitors become part of the experience itself.

This finding supports previous research suggesting that interactive technologies enhance visitor engagement by encouraging participation and creating stronger connections between users and exhibition content. Rather than functioning solely as tools for information delivery, digital technologies act as mediators that facilitate exploration, discovery, and interaction.

Spatial Insight: Exhibition environments should integrate responsive technologies that encourage active participation and create meaningful interactions between visitors and digital content.

5.2.2. Spatial Continuity and Openness

The second theme identified from the interview findings was spatial continuity and openness. As shown in Table 03, this theme was associated with codes such as connectivity, continuity, freedom, and exploration. The interview highlighted the absence of rigid boundaries between exhibition zones, allowing visitors to move seamlessly through space and experience the environment as a continuous journey rather than a sequence of separate rooms.

The findings suggest that spatial openness enhances the sense of exploration and supports more fluid interaction with exhibition content. Visitors are encouraged to discover spaces independently, creating personalized experiences shaped by individual movement patterns and choices. Similar observations have been discussed in previous studies, which emphasize the importance of flexible spatial layouts in promoting engagement and user freedom.

Spatial Insight: Open and interconnected spatial configurations can strengthen user exploration by supporting seamless movement and uninterrupted interaction throughout the exhibition environment.

User Movement and Engagement

Another significant theme identified during the analysis was the relationship between movement and engagement. According to Table 03, this theme emerged from codes including movement, navigation, participation, and discovery. The interview emphasized that movement is not merely a functional activity but an essential component of the overall visitor experience.

As visitors move through the exhibition, they continuously encounter new visual stimuli, interactive installations, and opportunities for exploration. This process transforms circulation into an experiential journey that contributes to engagement and immersion. The findings indicate that allowing visitors to determine their own routes encourages curiosity and supports deeper interaction with exhibition content.

Spatial Insight: Exhibition spaces should provide flexible circulation systems that promote exploration and support diverse user journeys rather than relying exclusively on fixed linear routes.

5.2.4. Challenges in Spatial Clarity and Navigation

Despite the positive outcomes associated with openness and immersive experiences, the interview also highlighted challenges related to spatial clarity and navigation. As presented in Table 03, this theme emerged from codes associated with orientation, wayfinding, and spatial understanding. While open environments encourage exploration, they may also reduce visitors' awareness of spatial boundaries and overall layout organization.

The findings indicate that highly immersive environments can occasionally create moments of confusion or disorientation, particularly when clear navigational cues are absent. Although ambiguity may contribute to discovery and curiosity, excessive spatial complexity can negatively affect comfort and usability. Therefore, achieving a balance between experiential freedom and spatial legibility remains an important design consideration.

Spatial Insight: Effective exhibition environments should balance immersion and openness with clear wayfinding strategies and spatial cues that support orientation without compromising the overall experiential quality of the space.

Observations

In the Team Lab Borderless exhibition, movement patterns are intentionally known as the best and most fluid and non-linear exhibition, but they are strongly guided by a concealed part of fixed smart technologies integrated into the spatial design. Advanced motion sensors, infrared cameras, and real-time tracking systems are strategically distributed across ceilings and hidden within walls to continuously catch and point visitor position and speed as shown in Figure01.

These systems are linked to a centralized computing network that instantaneously modifies the projections around the user via algorithmic programming and real-time rendering. In addition to that, the exhibition is designed as a series of open, darkened environments with seamless or concealed boundaries, allowing projection mapping to fully cover floors, walls, and ceilings without distribution as shown in Fig. 2. In fact, that creates a continuous digital view where content can “flow” from one room to another, which force the concept of borderless space.

Moreover, for the User activities such as walking, pausing, touching, or collaborating in groups directly cause changes in color, light, and animation, as pressure-sensitive floors and interactive surfaces feed data back into the system. The placement of technology is purposefully concealed as shown in Figure03, which makes the experience feel intentionally immersive rather than mechanical; visitors engage with the exhibition environment as alive rather than device driven. As a result, user interaction becomes deeply ingrained, with movement through space serving as both a physical means of circulation and an input mechanism that instantly modifies the exhibition. This implementation of smart system technologies within the exhibition space changes the space into an adaptable place where spatial design and technologies plays and action as a unified system to improve sensory experience and engagement.

Fig. 07:

Fig. 08:

Fig. 09:

Following the observation phase, in order to methodically examine user behavior and spatial characteristics inside the exhibition, the gathered data was arranged using the AEIOU framework. The data was analyzed to find repeated patterns and important conclusions about visitor movement, interaction, engagement, sensory experience, and the use of technology in the area after the observations were organized. These results made it easier to understand how visitors reacted to the interactive devices and exhibition environment.

In order to determine whether the identified findings were consistent with previous research on smart exhibition environments, immersive technology, and user experience, they

were compared with the literature review. This comparison strengthened the research analysis and provided theoretical basis for the observations.

Finally, the relationship between the results and the literature lead to design considerations and spatial insights. Recommendations for circulation, engagement, immersive settings, and technological integration were derived from these observations and subsequently addressed in a series of analytical paragraphs.

Table 4: Findings from the Observations

Category	Observations
Activities - A	Walk freely without following a set route, explore various rooms, stop to look at projections, engage by touching walls or floors, take pictures or films, and congregate in groups to take in interactive works.
Environment - E	confined, dark areas with constant projections on the ceiling, walls, and flooring. open floor plan with unclear room boundaries. Space is mostly characterized by light, music, and computer pictures; there aren't many tangible items.
Interactions - I	Strong participation between users and digital systems artworks respond to movement and touch. Social interaction also occurs as visitors influence each other's experience (crowd presence changes visuals).
Objects - O	cameras, tracking systems, projectors, and hidden sensors. The primary "display elements" are computer projections rather than any obvious traditional exhibition pieces. Visitors often use their smartphones to take pictures.
Users - U	Many groups including individuals, families, and tourists. Users are active participants rather than passive viewers. They frequently spend a lot of time in one exhibition and exhibit interest, excitement, and engagement.

Table 5: Analysis of the Observations

Observation	What It Tells Us (Finding)
Visitors move freely without following a fixed path	Instead of controlled circulation, users seek self-directed experiences and discovery.
People follow light, sound, and moving visuals	When it comes to directing movement, sensory cues work better than signage.
Visitors stop and stay longer in interactive areas	Engagement and stay duration are increased through interaction.
Users touch walls, floors, and digital elements	Immersion and a sense of connection to the environment are improved by physical engagement.
Spaces become more crowded near to interactive installations	Interactive systems attract social gathering and attention.
Visitors take photos and videos frequently	Environments with vibrant visuals promote sharing and unforgettable moments.
Users revisit the same installations multiple times	Content that is dynamic and ever-changing generates replay value.
Minimal visible technology in the space	Invisible systems reduce distraction
Dark environment with full projections on all walls	For engaging digital experiences, controlled lighting is crucial.
Groups influence how individuals move and behave	The user experience is influenced by society as much as the individual.

Table 6: Findings of this Research and Published Findings

Finding	Literature Connection	Spatial Insight
Users prefer free and non-linear movement	Research shows that optimized layouts and flexible circulation improve visitor flow and encourage exploration (Lei, 2025)	Design open-plan layouts with multiple pathways instead of fixed routes
Visitors engage more in interactive installations	Interactive systems increase participation and transform users from passive observers to active participants (Capece et al., 2024; Han, 2024)	Integrate interactive zones where users can physically engage with content
Longer dwell time in immersive areas	Dwell time is an indicator of higher engagement and interest (Lei, 2025)	Design focal immersive spaces that encourage users to stay longer
Users respond to multi-sensory environments (light, sound, visuals)	Multi-sensory integration enhances emotional engagement and user experience (Capece et al., 2024; Lei, 2025)	Combine lighting, sound, and projections to create immersive atmospheres
Visitors interact physically (touch, movement) with the space	Interaction through touchscreens, AR/VR, and gesture systems increases engagement (Capece et al., 2024)	Design responsive surfaces (walls/floors) that react to user input
Group presence affects user behavior	Co-creation and shared interaction enhance experience and engagement (Capece et al., 2024; Han, 2024)	Create spaces that support both individual and collective interaction
Technology is hidden but highly effective	Smart systems (AI, sensors, tracking) operate in the background to create seamless experiences (Capece et al., 2024; Lei, 2025)	Integrate technology invisibly within walls, ceilings, and floors
Visitors revisit installations multiple times	Adaptive and dynamic systems maintain engagement and encourage repeated interactions (Lei, 2025)	Design flexible, changeable environments with dynamic content

Analysis

First, there is a considerable tendency for non-linear and self-directed exploration within exhibition venues, as evidenced by the first observation of people strolling freely without following a set path as shown in activities the Table 4. This tendency implies that when users are given the freedom to explore places according to their curiosity rather than following preset itineraries, they become more engaged. This aligns with Lei (2025), who emphasizes that flexible spatial layouts and optimized circulation enhance visitor flow and encourage exploration as shown in the literature review in the Table 6. Therefore, exhibition design should take into consideration and prioritize open-plan layouts with multiple pathways, allowing visitors to construct their own experience in a more personal and engaging way.

Next, observation tells us the users are more actively involved when they can interact with the environment either physically or digitally as shown in Table05, as seen by the high level of engagement seen in interactive installations. Visitors engage through movement, touch, and response-based technologies instead of only watching. This supports the findings of Capece et al. (2024) and Han (2024), who highlight that interactive technologies transform users into active participants and significantly increase engagement levels. As a spatial implication, exhibition environments should incorporate dedicated interactive zones where users can directly influence and engage with the content.

According to this observation shown in the Table 5, the significance of dwell time as a measure of user engagement is reflected in visitors' propensity to stay longer in immersive environments. Users are more inclined to stay in environments that provide dynamic,

responsive, and visually exciting experiences as referred to in Table04, Users part. Lei (2025) identifies extended dwell time as a key measure of visitor interest and interaction quality. Consequently, designers should create focal immersive areas that encourage users to pause, explore, and remain within space for longer time.

Observational data revealed that User responses to multi-sensory elements such as light, sound, and digital projections highlight the importance of sensory integration in shaping the exhibition experience as shown in the Table 5. When several senses are activated at once, visitors are more emotionally and cognitively engaged. This finding is supported by Capece et al. (2024) and Lei (2025), who emphasize that multi-sensory environments enhance immersion and overall user satisfaction. Therefore, To create completely immersive environments, lighting, acoustics, and visual projections should all be integrated into spatial architecture.

The observation that visitors frequently interact physically with surfaces like touching walls or walking through projections indicates that embodied interaction plays a critical role in user engagement. This behavior demonstrates how crucial movement-based and tactile connection is to improve the experience. According to Capece et al. (2024), interaction through gesture-based systems, touch interfaces, and immersive technologies significantly increases user participation as shown in literature review connection in Table06. As a result, to encourage physical interaction, designers should include interactive features and responsive surfaces in the spatial environment.

In addition, the impact of group presence on user behavior indicates that exhibition experiences are socially and individually created. Around interactive installations, visitors frequently congregate, and their combined presence changes the setting as well as the degree of individual participation as shown in the Table 5. This observation aligns with the concept of co-creation discussed by Capece et al. (2024) and Han (2024), where shared interaction enhances engagement and creates dynamic experiences. In terms of space, this implies the necessity of creating settings that support both individual inquiry and group engagement.

Moreover, the absence of visible technological devices within space, despite the high level of interactivity, indicates that technology is most effective when seamlessly integrated into the environment. When technology functions subtly in the background, visitors are more engaged and the experience feels more immersive and natural. This is supported by Capece et al. (2024) and Lei (2025), who highlight the role of smart systems, sensors, and AI in enabling responsive environments without disrupting user perception (Table 6). As a result, technology needs to be carefully incorporated into architectural features like floors, walls, and ceilings.

Finally, as marked lastly in the Table 2, the observation that visitors revisit installations multiple times suggests that dynamic and adaptive environments sustain user interest and encourage repeated interaction. This behavior suggests that responsiveness and diversity are essential for sustaining engagement. Lei (2025) explains that adaptive systems can modify content in real time based on user behavior, creating continuously evolving experiences shown in Table06. As a spatial strategy, designers should create adaptable spaces where interaction and content may change over time, ensuring that every visit provides a different experience.

Discussion and Triangulation

Following the individual analysis of the survey, interview, and observation findings, a triangulation process was conducted to compare and integrate the results obtained from the three research methods. Triangulation identifies recurring patterns, validate findings across multiple data sources, and develop a comprehensive understanding of the relationship between spatial design, smart technologies, and user experience within exhibition environments.

Although each method approached the research problem from a different perspective, several consistent themes emerged across the findings. The survey revealed users' preferences and perceived challenges, the interview provided expert insights into spatial and technological integration, and the observation documented actual behavioral patterns within a real exhibition setting. The convergence of these findings enabled the development of integrated design insights that address the research objectives and contribute to a deeper understanding of interactive exhibition environments.

Table 7: Triangulation Matrix

Survey Findings	Interview Findings	Observation Findings	Integrated Insight
Users reported navigation difficulties within large exhibition spaces.	Open environments may create challenges in orientation and spatial understanding.	Visitors frequently relied on environmental cues rather than predefined routes.	Clear spatial guidance is essential for maintaining usability within immersive environments.
Participants showed a strong preference for interactive and technology-supported exhibitions.	Interaction was identified as a fundamental component of the visitor experience.	Visitors actively engaged with responsive installations and digital elements.	User participation is a key factor in creating successful exhibition experiences.
Respondents valued freedom of movement and exploration.	Spatial continuity encourages discovery and self-directed navigation.	Visitors commonly followed non-linear movement patterns throughout the exhibition.	Flexible circulation enhances engagement, exploration, and personalized experiences.
Participants identified crowding and movement-related challenges.	Technology should support the experience without overwhelming users.	Spatial conditions directly influenced interaction patterns and visitor behavior.	The effectiveness of smart technologies depends on their integration with spatial design.
Users appreciated immersive environments but reported occasional confusion.	Open and immersive spaces may reduce spatial awareness.	Some visitors experienced moments of disorientation while navigating the exhibition.	Balancing immersion with spatial clarity improves overall user experience.

Integrated Insight 1: User Participation Drives Meaningful Experiences

A consistent finding across all research methods was the importance of active participation in shaping visitor experience. Survey respondents demonstrated a strong preference for interactive exhibition environments, while the interview emphasized that visitors become active contributors rather than passive observers. Similarly, the observation revealed frequent engagement with responsive installations and digital elements. Together, these findings indicate that successful exhibition environments should prioritize participation as a core design principle, enabling users to influence and interact with their surroundings.

Integrated Insight 2: Flexible Circulation Enhances Exploration and Engagement

The findings collectively suggest that visitor movement is closely linked to engagement. Survey responses highlighted the importance of spatial comfort and accessibility, while the interview emphasized exploration and freedom of movement as key characteristics of immersive environments. Observation findings further demonstrated that visitors frequently followed self-directed paths rather than predetermined routes. This suggests that flexible circulation strategies can encourage exploration and support more personalized exhibition experiences.

Integrated Insight 3: Spatial Design Influences the Effectiveness of Smart Technologies

Although smart technologies enhance interaction and immersion, the findings indicate that their success depends significantly on spatial conditions. Survey participants identified challenges related to crowding and navigation, while the interview emphasized the importance of spatial continuity and organization. Observation findings further demonstrated that environmental conditions directly affected how visitors interacted with technological installations. These findings

suggest that technology alone cannot guarantee successful user experience; rather, its effectiveness is strongly influenced by the quality of spatial design.

Integrated Insight 4: Balancing Immersion with Spatial Clarity Improves User Experience

Both the interview and observation findings highlighted the potential for highly immersive environments to create moments of confusion and disorientation. Survey participants similarly identified navigation difficulties as a common challenge. While immersion enhances engagement and exploration, excessive spatial complexity may negatively affect usability. Therefore, successful exhibition environments must balance immersive experiences with clear wayfinding strategies and spatial cues that support orientation and accessibility.

Integrated Insight 5: Technology and Space Should Function as an Integrated System

Across all three methods, a recurring pattern emerged regarding the relationship between technology and spatial design. The findings suggest that technology achieves its greatest impact when it is seamlessly integrated within the physical environment rather than treated as an independent feature. The interaction between users, technology, and space was consistently identified as a critical factor influencing engagement, immersion, and overall experience. Consequently, exhibition design should be approached as an integrated system in which technological and spatial elements work together to support user-centered experiences.

Conclusions

This study investigated the impact of smart technologies on interactive user experience within exhibition environments, with particular emphasis on the role of interior design in supporting technological integration. By employing a mixed-methods approach that combined a questionnaire survey, interview analysis, and observational study, the research examined the relationship between spatial design, user behavior, and technology-enhanced experiences.

The findings revealed that smart technologies significantly contribute to enhancing user engagement, participation, and immersion within exhibition spaces. However, the study also demonstrated that the effectiveness of these technologies is strongly influenced by spatial conditions and design strategies. User participation emerged as a fundamental component of successful exhibition experiences, while flexible circulation and opportunities for exploration were found to encourage deeper engagement and interaction. Furthermore, the findings highlighted the importance of balancing immersive experiences with spatial clarity to ensure both usability and user comfort.

The triangulation of findings further emphasized that technology and space should not be considered as separate components but rather as an integrated system that collectively shapes visitor experience. The study showed that the success of smart technologies depends not only on their technical capabilities but also on how effectively they are incorporated within the spatial environment through circulation design, spatial organization, and user-centered planning.

This research contributes to the understanding of interior design within technology-integrated exhibition environments by highlighting the critical role of spatial design in supporting interaction, immersion, navigation, and user engagement. The findings provide evidence-based insights that can assist designers in creating exhibition spaces that maximize the potential of smart technologies while delivering meaningful and user-centered experiences.

These findings provide practical design guidance for creating future exhibition environments that successfully integrate smart technologies while maintaining user-centered spatial experiences.

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Availability of Data:

This paper presents only some of the data produced through this research. However, most of the data generated through this research is available for scrutiny and can be provided upon request.

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