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Design Project Booklet

Emotive Storyliving

Constructing a Virtual Reality Experience of Khaju Bridge to Enhance Emotional Connections to Cultural Heritage

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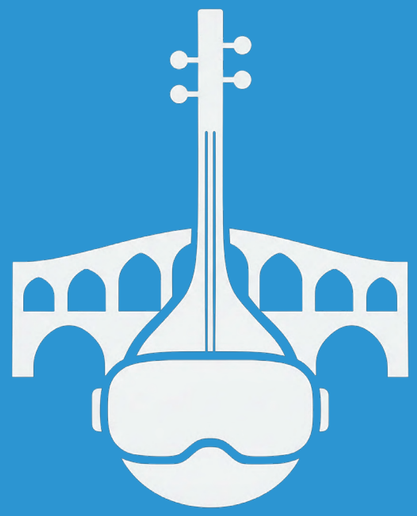

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Title:
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01 CHAPTER ONE

INTRODUCTION

01.1 Research Background

In the previous ten years, Virtual Reality (VR) has transitioned from mainly an entertainment-based technology to an accepted and considerable candidate in education, preservation, and affective storytelling. In the past 10 years, researchers have begun to study VR's ability to generate emotions, depth, and presence that traditional media do not have [1], [3], [12], [20], 23]. Cultural heritage has embraced VR technology to reconstruct sites, promote empathy, and engage the viewer personally with history [6], [7], [31], [32], [33].

In this context, emotion is not considered a passive reaction, but rather as a cognitive–affective process that shapes attention, memory, and engagement with heritage environments [1], [5], [10], [16]. Research in affective VR has indicated that emotional engagement leads to not just user enjoyment but understanding and retention of cultural information [7], [10], [29]. For example, studies of "storyliving" in virtual heritage spaces have shown that the use of interactive narratives leads to greater sympathy for cultural narratives and artifacts [6], [11], [31].

The emotional aspect of the challenge is particularly important in developing connections to cultivate engagement across the psychological divide between the modern audience and historical environments. Often, young visitors distance themselves from traditional cultural values and view heritage sites as static and faraway [24], [26], [27]). To facilitate emotional meaning to the experience, designers can use immersive VR technologies with vision immersion, spatial sound, and participatory narratives to facilitate feelings of authenticity and belonging [4], [6], [25], [32].

Improvement in affective computing and psychophysiological monitoring (i.e., heart rate, EEG, GSR) now allows more objective measurements of emotional state influenced by VR [8], [9], [19], [30]. Though many of these methods are more experimental, they establish emotion as a design variable to be measured rather than a casual response or impression.

A significant part of the larger research agenda has not included works of cultural heritage in Iran, specifically in poetry, architecture, and music, which use immersive practices. The Khaju Bridge in Isfahan, a 17th-century Safavid-period structure, demonstrates a valuable case study of employing emotional engagement in VR to rediscover a historical identity and renew citizens' connections to heritage.

lectus. Ut ullamcorper ligula mauris, sed sollicitudin nulla sollicitudin eget. Mauris eget mattis leo, a commodo dui. In eleifend erat atmauris, sed sollicitudin nulla sollicitudin eget.

01.2 Motivation and Context

This discussion of the purposes is motivated by the increasing disconnect experienced by the younger generations from heritage sites. Although Iran has a substantial collection of cultural assets, public interaction and involvement with the places and physical monuments are diminished due to urbanization, other digital forms of entertainment, and insufficient heritage education [24], [26], [27]. The Khaju Bridge, once a site of convening for music lovers, community, and poetry, is suffering from both literal decay and symbolic estrangement.

While most would agree that the objective is not just to preserve these sites as visual markers of heritage (authentic), or to run an exhibition where the heritage is passed on as curated visual assets. The challenge is to revive emotional engagement with heritage, a vital ingredient in the sustainable care of heritage which encourages empathy, identity, and personal sense of belonging [6], [7], [31], [32]. Digital storytelling and [3], [4], [11], [29], [33] virtual reality-based museum experiences offer opportunities to curate and recreate affective atmospheres for the public, for curiosity and reflection to occur.

From a design perspective for this project, it places the user in the role of active participant, rather than passive observer, as someone walking the bridge, playing musical instruments (such as the Setar), listening to poetry from the Safavid period, and experiencing the cultural rhythm of life. This is in the spirit of storyliving, living the story rather than observing the story [6], [32].

These cultural and emotional motivations are the foundation of the research and are therefore twofold:

1. To provide an emotional connection to Iran's heritage by using immersive technology as a means of bridging the past with the present.
2. To explore the relationship between emotional engagement, presence, and usability, and how these might inform users' perception of cultural authenticity.

2. Khaju Bridge images in Isfahan

Recent studies, like the EMOTIVE project at the Hunterian Museum [31], illustrated the capacity of digital storytelling to prepare and open a person to emotion and reflection. Yet, the simultaneous immersion of narrative form, music, and architecture with multisensory VR environments has not been researched to better facilitate a shared emotional experience, for example, for a cultural heritage site like the Khaju Bridge.

01.3 Research Aims

The proposed research project will consider the benefits of the medium of Virtual Reality (VR) for emotionally engaging with cultural heritage, specifically the Khaju Bridge. The framework for the research will engage and draw on studies around emotional design, meanings of heritage, and immersive technology.

The introduced objectives are:

1. To produce an immersive virtual reality experience of the Khaju Bridge that includes visual, auditory, and interaction elements (i.e., Setar interaction, Safavid poetry, all sound effects),
2. To evaluate the emotional and perceptual effects this experience has on users, particularly younger users, by measuring emotional engagement, presence, cultural understanding, and usability.
3. To develop design principles that promote emotional authenticity and cultural empathy in VR heritage environments, and;
4. To investigate emotional engagement as a mediator between presence, usability, and perceived authenticity of cultural heritage.

These objectives reflect techniques employed in previous projects in this stream [4], [6], [7], [31], [32], [33], while further expanding the methodologies through Iran's specific cultural context.

01.4 Research Aims

Following the goals identified above and the gaps identified in the literature, the research questions guiding the study are as follows:

1. What possible benefits does VR provide related to emotionally connecting with cultural heritage sites such as the Khaju Bridge?
2. What single or composite design elements (visual, auditory, and/or interactive) are most effective in creating presence and affective emotional responses in VR experiences based on heritage?
3. What are the relationships among emotional engagement, presence, and usability for users' cultural understanding and perceived authentic experience?
4. What are the possible measurable indicators (quantitative and qualitative) of researching emotional impact and user experience, in immersive heritage-based experiences?

The previous questions derive from the above studies that conversely pointed to: emotional focus as an essential emotional motivator without constraint [1], [6], [31], immersion and presence as elements of the framework that impact the creation of affective experiences [3], [8], [13], [20], and use of multisensory/embodied design elements as means to reinforce user's connection with cultural material [5], [9], [21], [25].

Integrating these questions informs a design-research question that links emotional design theory [17], [24], [35] with heritage interpretation [7], [31], [32] through an empirical prototype in an immersive virtual reality setting.

01.5 Research Method Overview

This research adopts a mixed-methods approach, combining qualitative and quantitative evaluation methods, assessed in a controlled, virtual reality technology space, to evaluate emotional and experiential outcomes.

01.5.1 Design Dimension

Stage one clarified the historical and cultural performance of the Khaju Bridge in the Safavid period based on historic documents, photographs, and fieldwork. Visual artifacts and soundscapes were created to emulate the ambiance of social events, music performances, and reflection on the water below the bridge.

The interaction design merged a playable Setar instrument, Zayandeh Rud, as a spatial sound, and animated characters that described local life.

This s tage was situated within "storyliving" examples of VR cultural heritage [6], [32], integrating narratives and interactivity to allow emotional participation rather than simple observation.

01.5.2 Evaluation Stage

The second phase of data collection involved user testing as well as emotional response measuring.

Twenty participants aged between 18 and 30 years engaged with the VR experience using a Meta Quest 3 VR headset. Upon the end of the experience, all participants completed a semi-structured questionnaire, done in isolation, which included four validated scales:

- Geneva Emotion Wheel (GEW) [1], [16], [26]: measuring emotional response and affective valence.
- Presence Questionnaire (PQ) [3], [8], [13]: evaluates a feeling of presence or "being there" in the environment.
- User Experience Questionnaire (UEQ) [12], [17], [19]: evaluates usability, clarity, and aesthetics.
- Cultural Understanding Scale (adapted from [7], [31], and [32]): perceived authenticity, empathy, and engagement with heritage content, because the measure focused on the heritage content.

01.5.3 Data Analysis

Descriptive statistics (mean, standard deviation) were used to analyze the quantitative data and identify dominant patterns across the four themes:

1. Emotional Engagement
2. Presence and Immersion
3. Cultural Understanding and Authenticity
4. Usability and Aesthetic Appeal

The findings indicated a high mean rating for normative consensus leisure for participants by the four themes (M = 4.25-4.43) and a lower to moderate standard deviation (SD = 0.63-0.68), which is indicative of a positive experience relative to all participants in the four categories.

For the qualitative data, a thematic analysis framework [41] was used, and there were some cross-project themes such as authentically sounding monuments, nostalgia, cultural pride, and wondering about more historic context. Emotional responses, as described by participants, aligned with quantitative data, while noting upgrades in the best practice 'learn-and-share' design considerations for future (e.g., [1], [6], [31], [33]).

This methodological choice illustrates good practice in immersive heritage research as it links subjective reflections on emotional experiences with formal empirical data [4], [7], [13], [19], [25].

01.6 Thesis Structure

The thesis consists of six chapters, in line with the typical structure of design-based research in immersive cultural heritage:

Chapter 1. Introduction:

The historical and cultural relevance of the Khaju Bridge is described, and conceptual and aesthetic considerations that influenced the VR experience are addressed, including design intentions, visual references, a story arc, and interactive elements.

Chapter 2. Theoretical Foundation:

Presents an extensive review of prior work regarding the experience of emotion in virtual reality (VR), presence and immersion, cultural storytelling, and the emotional design framework, including a comparison of the 33 papers that were analyzed and their methodological approaches.

Chapter 3. Design Process:

Describes the historical and cultural importance of the Khaju Bridge, and then addresses conceptual and aesthetic considerations that guided the VR experience, including design intentions, visual references, a story arc, and interactive features.

Chapter 4. Implementation:

Talks about the overall technical development of the VR prototype in Unreal Engine (UE 5.4) including modeling, animation, lighting and sound design. It also considers usability by applying their usability within an immersive VR context.

Chapter 5. Findings and Discussion:

Outlines both quantitative and qualitative outcomes from user testing. User questionnaire results are subjected to statistical analysis, and the open-ended responses are thematically interpreted to assess emotional engagement and cultural knowledge. Moreover, the future works will be discussed.

01.7 Chapter Summary

The thesis acknowledges its limitations and future directions for research, attempts to combine the heritage fieldwork, VR design, and mixed-method evaluation in an experimental interdisciplinary project that investigates how immersive design VR with rich narrative could revive emotional connections to a place of cultural heritage: Khaju Bridge. The project has some grounding in the literature about emotive storytelling and storyliving, including some more simultaneous academic work, while also using primary field data collected in Isfahan about Khaju Bridge.

In sum, the project intends to create not only an empirically evaluated prototype but also some realistic guidance for practitioners in the heritage industry who wish to think about using VR as a methodological approach for emotional and educational engagement. Chapter Two will discuss some of the literature and review how the project is situated within questions about presence, authenticity, and story in cultural heritage interpretation.

3. Khaju Bridge, Isfahan

02 CHAPTER TWO

THEORETICAL FOUNDATION

This chapter provides a consideration of the theoretical and conceptual foundations for this research. It offers a review of literature related to the use of Virtual Reality (VR) in cultural heritage, the foundations of experience design and immersion, and the psychological constructs of presence, empathy, and engagement. It further reviews interaction design approaches within the VR environment and includes related case studies that inform the present research project.

02.1 Cultural Heritage and Virtual Reality

The use of Virtual Reality (VR) has been seen as an innovative medium for engaging, preserving, interpreting, and conveying our cultural heritage. Researchers often differentiate VR from basic visualization, arguing for the importance of the embodied and experiential narrative that captures emotional and sensory experience as an integral part of our interpretation of the past [31], [6], [7].

In one example of this function, Economou et al. (2021) provides an example, from the EMOTIVE project on the Antonine Wall, of how visitor engagement with digital storytelling techniques using immersive technology elicited emotional responses between visitors/participants and ancient heritage objects, engaging participants in empathetic and personal processes of identification with the past [31]. Choi et al. (2022) offered a similar view by describing VR as a "storyliving" medium that creates active audiences who participate in a co-construction of meaning through embodied action and interaction [6].

VR heritage experiences have typically been regarded in either of two paradigms. The first of these is reconstruction-based VR, concerning the accurate re-creation of historical sites (e.g., [3], [4]), while the second paradigm is experience-based VR, which focuses more on creating emotional and interpretive feelings instead of photorealistic visual detail (e.g., [5], [7]).

Recent reviews [16], [19], [24] have stated that immersive technologies, especially if reinforced by sound, narrative, and interactivity, create better emotional connection, curiosity, and value for heritage values. In the wider field, people have moved away from just thinking about accuracy and started to consider designing for affective authenticity, or a traveler's “feeling” for/thinking about history as opposed to just “seeing” history.

Additionally, research by Le et al. (2023) illustrates that VR heritage contexts increase visitor intent for continuation or further inquiry, supporting the notion that emotional engagement produces lasting cultural education [4]. Thus, the link between technology and affect becomes most important: immersive heritage experiences need to comprise a refining aspect between competing on aesthetic fidelity and interpretations of emotional influence.

Shuang et al. (2022) remind us that good cultural VR practices include effective narrative cohesion, sensory immersion, and possible interactive aspects, which can encourage curiosity and empathy, elements that guide design decisions for the Khaju Bridge VR project [5].

02.2 Experience Design and Immersion

Experience design in the VR heritage context borrows principles from Human-Computer Interaction (HCI), user experience (UX), and emotional design theory [35]. Norman's emotional design framework helps us understand how users can have attachments to digital artifacts through the use of affective feedback loops, pleasure, surprise, empathy, or awe, all of which affect learning and memory retention [7], [17], [25]. In VR heritage, these effects operate under a condition of higher magnitude due to immersion, which is simply defined as the perceptual illusion of being inside the environment [36]. Immersion is a technical condition, but it creates the psychological sense of presence that allows users to experience cultural narratives as lived experiences [8], [13]. Huang et al. (2022) identified “story-driven immersion” as a critical contributing factor in their case study, Re-Live History, in which users participated in prehistoric rituals, and emotional learning outcomes were greater when the environment encouraged embodied engagement rather than passive watching [7].

Exploration of VR museums and educational contexts [19], [10], [25] supports multisensory design, employing sound, light, and spatial dynamics that amplify the sense of "being there". For instance, user emotionality is affected by the presence of sound, especially music and gentle water sounds in Affective Landscapes (2024) and The Role of Sensory Experiences in Evoking Emotional Responses in VR (2025).

4

5

6

4. The Antonine Wall: Rome's Final Frontier(Economou et al. (2021)) [31]
5. VR experience in the American Museum of Natural History
6. Seoul City Wall (Hanyangdoseong) in South Korea (Choi et al. (2022)) [6]

As we have noted above, the implications demonstrate that immersive experience design is not about a dichotomous reality; rather, it is about affective coherence, the connection between sensory, narrative, and spatial elements that leads to an emotional arc. For cultural heritage design, the goal is transformed away from representation towards resonance, enabling the user to emotionally occupy historical space.

As we noted earlier, an increasing number of scholars are discussing aesthetic distance in relation to affect. While "too much realism can cause cognitive overload" [P1], having too little realism can lead to disengagement entirely. This implies a heritage VR experience will try to find equilibrium, striking a middle ground between realism and the symbolic, using surgical and selective detail to stimulate emotional memory, thereby not taking away decision-making and interpretive agency from the user.

In the Khaju Bridge VR, this translates to elevated atmosphere (light, sound, music) and the rituals of interactive experiences (i.e., playing the Setar, the closeness of the local crowd, walking with local people). The aim will not solely be high emotional involvement through learning, but rather have an affective quality to the experience with opportunities for empathy and aesthetic pleasure.

02.3 Presence, Empathy, and Engagement

The principles of presence, empathy, and engagement provide the psychological foundation for VR experiences that provoke emotional involvement in the context of cultural heritage.

Presence, the sensation of "being there", is as emotional as it is perceptual; it is mediated via immersion, interaction, and attention [36]. Economou et al. (2021) and Chang et al. (2023) extend presence in cultural virtual reality to not merely support realism but to develop empathy and allow users to emotionally cross the temporal and cultural gap between the past and present [31], [4].

As Huang et al. (2022) and Choi et al. (2022) note, empathy transports users from external spectators to participants in a shared exposition. Users cannot help but internalize historical emotion when they engage with heritage by also actively participating, by walking the bridge, hearing the music of the area, and engaging with direct artifacts of history [6], [7].

This, sometimes referred to as "affective presence", adds to the notion of storyliving over storytelling; the user does not view history, they live it.

In the case of "Seoul City Wall" studied by Choi et al. (2022), there was higher empathy from research participants based on the opportunity to perform local rituals and interact with some of their Safavid-era equivalents [6]. This demonstrates the depth of connection between agency and empathy. More agency and interactivity resulted in a more emotive connection to cultural meaning.

User engagement is the behavioral "marker" of presence and empathy. Shuang et al. (2022) describe user engagement as a multidimensional construct that consists of cognitive engagement, emotional engagement, and motivational engagement [5]. Their results aimed to show a peak of engagement when users reported perception of narrative continuity and sensory harmony. In VR heritage contexts, the balance of exploration and guided exploration is key; users need to be free to explore while being slightly guided to cues of emotional significance (e.g., through sound, light, or gestures of characters).

Recent psychophysiological research [13], [15], [16] has shown an association between heart rate variability (HRV) and skin conductance index with emotional arousal and presence, indicating that immersive environments create genuine affective responses. It should also be noted that many cultural heritage applications continue to utilize self-report approaches (e.g., Likert scales and open-ended reflection) based on ethical, reasonable, and practical implications of assessing psychophysiology.

For the purposes of this thesis, emotional engagement describes how the participants in VR experience characteristics of empathy, connection, and presence while experiencing the Khaju Bridge environment.

This definition aligns with Economou et al. (2021) perspective (emotional storytelling) [31], Choi et al. (2022) (storyliving and empathy) [6], and Huang et al. (2022) (emotional learning through embodied experience) [7].

02.4 Interaction/ Interactivity Design within VR Environments

Interaction, or interactivity as it is often referred to when discussing VR, is an important mediating aspect of how users experience presence and emotion within an experience. In a VR context, interaction is not just about input mechanics, but rather a form of dialogue between user and environment.

Academic research, such as that conducted by Norman (2004) and Sherman & Craig (2019), has stated that interaction in VR must encompass emotional affordances, meaning that gestures, gaze, and tactile feedback should indicate emotional significance beyond normative functional usages [34], [35].

Cultural heritage VR projects often rely on symbolic actions; interactions that engender an emotional connection between user and heritage practice. For example, Huang et al. (2022) engaged participants in simple gestures to simulate pre-historical rituals in Re-Live History [7], while Economou et al. (2021) in the EMOTIVE project allowed participants to work through choices that situated them within a personally constructed version of an ancient story [31]. Despite their minimal actions, the emotional charge of these interactions implied a connection between physical action and heritable cultural significance.

Design research [5],[7], [9] has shown that interactivity increases emotional engagement when three principles are met:

1. Transparency: controls and feedback should feel natural and responsive.
2. Symbolism: there should be cultural or narrative significance to every action.
3. Reflection: the outcome of actions should lead to emotional or cognitive reflection.

In addition, Škola et al. (2023) and Chang et al. (2023) found that multimodal feedback, visual, auditory, and haptic, enhanced memory encoding [3], [4]. For example, touching an object or experiencing authentic soundscapes would elicit autobiographical memories and empathy [1], [21].

In the VR rendition of the Khaju Bridge, these understandings are showcased in a design that emphasizes ritualized micro-interactions. The micro-interactions include:

- Strumming the Setar to trigger historical poetry (symbolic action);
- Walking under arches and allowing the spatial acoustics to alter in situ (immersive feedback);
- Coming into contact with local animated figures, who register your presence by being close to each one (social cueing).

These design decisions shift the experience from being a more passive observer to being engaged as an embodied participant in the experience of storyliving and experiential empathy.

02.5 Background Research and Case Studies

The domain of virtual reality (VR) for cultural heritage has established itself with a variety of experimental case studies that illustrate both technical advancements and their affective possibilities.

Some of the most prominent are:

1. EMOTIVE Project: The Antonine Wall (Economou et al., 2021) [31]
    - **Focus:** Emotional engagement through narrative and storytelling contexts within a museum environment,
    - **Key Finding:** Affective storytelling is significantly more effective for making meaning and building empathy than static displays.
    - **Relevance:** This case study uses the narrative voice and emotional tone to directly inform the case study crafted for this thesis.

2. Re-Live History: Immersive Learning of Intangible Heritage (Huang et al., 2022) [7]
    - **Focus:** Emotional learning and cultural understanding through VR - interactive rituals.
    - **Key Finding:** Embodied interaction (gesture and music) sparked higher levels of emotional retention.
    - **Relevance:** This case study influenced this thesis's use of musical and/or performance-based rituals (Setar interaction) in the Khaju Bridge VR.

3. Storyliving the Seoul City Wall (Choi et al., 2022) [6]
    - **Focus:** The combination of spatial storytelling and user agency to promote historical empathy.
    - **Key Insight:** Emotions are aroused; however, if you allow users to direct their own narrative.
    - **Relevance:** Provides the semi-guided exploratory framework for the Khaju Bridge.

4. Affective Landscapes (2024) [1], and The Role of Sensory Experience in Evoking Emotional Response in VR (2025) [25]
    - **Focus:** Stimulating the senses (sound, touch, light) and emotional engagement.
    - **Key Insight:** Sensory integration is positively correlated to the generation of affect, but one should keep cognitive load to a minimum.
    - **Relevance:** Provides a rationale for the use of layered sound design in (water, music, voices).

5. The influence of digital storytelling in virtual reality museum exhibitions exploring cultural sites (Chang et al., 2023) [4].
    - **Focus:** Presence, enjoyability, and continued intention.
    - **Key Insight:** An emotional connection with the experience predicts continued engagement in the future.
    - **Relevance:** Lends both metrics and methods for evaluating the experience in a follow-up study.

6. VR in Museums: Visitor Enjoyment and Learning [25]
    - **Focus:** To compare learning with VR vs. traditional learning with an exhibit.
    - **Key Insight:** Engagement emotions support both learning and continued satisfaction
    - **Relevance:** Reaffirms that an emotional connection is an acceptable academic outcome.

02.6 Synthesis and Relevance to This Thesis

The literature review stressed emotional engagement as a mediating variable of immersion and cultural understanding. These conclusions were gathered from a review of the literature surrounding 33 studies, with three key takeaways:

1. Sensorial moderators (music, sound, or light) increase presence and empathy.
2. Interactivity and narrative coherence enhance connection and meaning.
3. Emotional authenticity and not realistic-looking footage create experiential value in cultural VR.

In order to consolidate the literature discussed in this chapter, I created a comparative summary table that shows how recent studies in Virtual Reality and Cultural Heritage have approached emotional engagement, stories, and audience interaction to understand the differences and similarities. I summarized seven papers, which are conceptually or methodologically linked to the thesis. In this summary, I describe how emotion is defined, what methods and actions were used, and how emotional engagement was measured. These papers provide the theoretical basis and methodological inspiration for designing and evaluating the Khaju Bridge VR experience.

Across these seven studies, findings collectively establish that emotional engagement occurs in cultural heritage VR experiences when storytelling, sound and interaction are closely aligned. Their approaches, especially those incorporating storyliving, multisensory feedback, and mixed narrative structures shaped the development of the Kha ju Bridge VR prototype in theory as well as design practice.

Table 1. The most related papers summary

No	Paper Title	Year	Authors	How Emotion is Defined	Method Used	Actions Used	Emotion Factors Measured	How Measured
1	Evaluating Emotional Engagement in Digital Stories for Interpreting the Past. The Case of the Hunterian Museum's Antonine Wall EMOTIVE Experiences [31]	2018	Economou et al.	Emotional engagement via affective storytelling	Observation and self-report survey	Interaction with digital VR storytelling	Emotional engagement	Questionnaire (Likert scale)
2	Centennial Drama Reimagined: An Immersive Experience of Intangible Cultural Heritage through Contextual Storytelling in Virtual Reality [32]	2025	Yu et al.	Embodied emotion via cultural performance	Motion capture, rigging, user testing	Martial arts gestures, character-driven VR	Anger, rhythm, immersion	Observation, animation quality review
3	Virtual Reality with 360-Video Storytelling in Cultural Heritage: Study of Presence, Engagement, and Immersion [3]	2020	Škola et al.	Presence, engagement, immersion	360° storytelling VR and post-survey	Guided exploration	Presence, engagement, enjoyment	Presence/immersion scale
4	The Impact of Digital Storytelling on Presence, Immersion, Enjoyment, and Continued Usage Intention in VR-Based Museum Exhibitions [4]	2025	Chang et al.	Enjoyment, immersion, presence	Pre/post survey and comparative modeling	Digital storytelling in exhibition	Enjoyment, presence, continued intention	Questionnaire and statistical model
5	Increasing User Engagement in Virtual Reality:The Role of Interactive Digital Narratives to Trigger Emotional Responses [33]	2020	Irshad et al.	Triggered emotional response via narrative	Interactive VR app and user study	User choices in narrative	Emotional response, engagement	Self-report and engagement scoring
6	An Interactive Virtual Reality Approach to Understanding Cultural Heritage Through Storyliving: A Case Study of Seoul City Wall (Hanyangdoseong) in South Korea [6]	2024	Choi et al.	Emotional engagement through storyliving	Interactive VR tour and observation	Interactive exploration, narrative triggers	Emotional engagement	Post-experience survey & interviews
7	Re-Live History: An Immersive Virtual Reality Learning Experience of Prehistoric Intangible Cultural Heritage [7]	2022	Barbara et al.	Emotional learning experience via VR	Story-driven learning in VR and post-survey	Cultural tasks	Immersion, emotional response	Questionnaire and learning impact score

02.7
Chapter Summary

Consequently, this dissertation situates the Khaju Bridge VR experience within the affective turn within heritage interpretation. The affective turn has been described as the trend to emphasize emotional affinity and participatory narration as the mechanism to attract new generations of individuals to experience historical heritage sites.

This framework draws on emotional psychology, immersive media design, and heritage interpretation, with the aim of establishing that virtual reconstruction can, therefore, be regarded as an act of emotional reconstruction, whereby people are not just connected to the architectural structure of the bridge, but the living spirit and cultural memory that come with it.

7

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7. Khaju Bridge with water
8. Khaju Bridge without water
9. Khaju Bridge implementation in Unreal Engine 5

03 CHAPTER THREE

DESIGN PROCESS

This chapter presents the complete design process implemented to formulate and create the VR experience of Khaju Bridge, aiming to evoke a living resonance with the insights from the field research through an emotionally engaging, interactive, and technically functional immersive experience. The design process mentioned above followed a Research-through-Design (RtD) model, which involved empirical fieldwork studies, scenario-based design, conceptual design, and iterative prototype making.

03.1 Research-through-Design Approach

Research-through-Design (RtD) was established as the overall method. In RtD, design artifacts are viewed not only as the tidy outcome, but as instruments of inquiry too. A buildup developed iteratively into the VR prototype from early sketches, to low-fidelity builds, to final, fully functional builds in Unreal Engine was as much a process of inquiry as was the research to anticipate, iterate, and build.

This approach treats the act of designing not only as a way to make artifacts but also as a way of producing knowledge. The notion originates with Frayling's (1993) influential typology of design research that distinguishes between research into design, research for design, and research through design [37]. Within this understanding, through design refers to a process where making artifacts becomes a reflective and epistemic act, generating knowledge that cannot be accessed through solely theoretical analysis or empirical observation.

In Human–Computer Interaction (HCI) and Interaction Design, RtD has become an established research strategy for investigating rich and complex questions around experience that involve things such as human perception, emotion, and interaction [38], [40]. It enables designers to move iteratively between making and reflecting, treating the design artifacts they are producing as probes that represent hypotheses and make abstract ideas concrete. In this way, knowledge produced through RtD is situated, experiential, and generative in its nearness to engagement with materials, tools, and users, rather than from analyzing the knowledge from afar.

This study frames RtD as enabling the Khaju Bridge VR experience to act both as an artifact and an instrument for research. The design process, which encompasses field data collection, scenario creation, prototyping, and user testing, acts as an experimental context and as a type of reflection-in-action [39]. Each iteration in the design (e.g., adjustments in sound spatialization, NPC behavior, haptic feedback through the physical Setar instrument, etc.) can be considered a micro-experiment that investigates how engagement can be enhanced through sensory and narrative design. The study produces both practical knowledge for design and theoretical knowledge about affective interaction in cultural heritage VR through cycles of enactment, observation, and redesign.

The rationale for the selection of RtD relates to the ultimate research question: How can a VR reconstruction of Khaju Bridge catalyze emotional engagement in young visitors? The RtD design-based and adaptable process allowed for systematic experimentation through design iteration by adapting and evaluating different variables, such as sound, lighting, NPC behaviour, and interactivity, against their emotional effect.

The fieldwork completed in Isfahan developed the empirical basis for this process. Each empirical design iteration was sustained by the onsite data of over 200 photographs, 21 videos, 21 voice memos, and a series of short and long interviews that explored different elements of the sensory and social characteristics of the Khaju Bridge environment, especially the combination of music, water, and proximity to an assemblage of people, which informed experiential design.

In the end, the RtD framework legitimizes design as a rigorous type of inquiry: the learning, prototypes, reflections, and evaluation data from this project are not simply creative outputs, but knowledge artifacts that reflect empirical learning about how immersive media can re-engage contemporary audiences with intangible cultural heritage.

	Photos	Videos	Sounds
Number	206	21	21

Table 2. Total number of environmental features recorded

The process consisted of five systematic steps:

1. Discovery and Data Collection: Using observation, photography, and audio recording to identify sensory triggers and observable behavior patterns that took place in and around the bridge. We extracted emotional and environmental triggers (representations), including trending results of flowing water, traditional music, and singing in a group of individuals, as contexts of affect.

2. Synthesis: Interview and field not e insights were organized with affinity diagrams and persona creation.

Two primary personas were developed: Sara, a young tourist who is looking for cultural connectedness and experiences to share, and Hossein, a local who is looking for nostalgia and community memory.

3. Concept Development: Various design directions were evaluated, including guided tours, traditional museum-style presentations, and participatory ritual scenarios. The "storyliving" model [6] was selected as the design framework, focusing on engaging emotionally and actively rather than observing passively.

4. Prototype Development: The design progressed through low-, medium-, and high-fidelity stages, starting as varying prototypes in block-level form with Unreal Engine and progressing through to a textured modeled environment with animated exploration and something that keeps sound in consideration through spatial audio, and interaction blueprints.

5. Evaluation and Iteration: Internal and external pilot user tests were performed to identify and improve interaction, comfort, and emotional pacing. Observations and post-questionnaire reflections informed the iterative revisions of the prototype, as it recognized sound levels, NPC diversity, and responses, especially the ones that were unprompted.

The RtD approach facilitated continual consideration of theoretical and practical experiences. Each round of design resulted in both an enhanced artifact and evidence of theoretical understanding of emotional engagement within heritage VR.

03.2 User Analysis

User analysis was based on the personas generated from field interviews and affinity clustering.

Primary Users Groups:

1. Travelers (Sara Persona): Younger people visiting and looking for cultural experiences, taking pictures, and having stories to share on social media. Their emotional engagement is through visual beauty, narrative cues, and feeling "part of the story."

2. Locals (Hossein Persona): Residents who hold the Khaju Bridge as a representation of shared memory, music, and identity. They desire authentic experiences and adherence to fidelity of sensory experiences, especially sound and social presence.

Design Requirements: descriptions of functional and non-functional design requirements to develop specifications.

Category	Description
Functional	Time-layer switching (current time ↔ Safavid era); interactive ritual object (Setar); dynamic NPC behavior.
Non-functional	Historically authentic, low motion sickness, optimal Quest 3 performance, physically prototyped, and safety.

Table 3. Functional and Non-Functional Descriptions for Design Requirements.

7 July 2025 – 17:00
The weather was warm but pleasant, and the bridge was full of both tourists and local families. Children were running across the arches while older men sat quietly, watching the riverbed. The lack of water created a strange feeling of emptiness, yet people filled the silence with music and conversations. The evening light highlighted the tiles and made them glow softly. I felt a mix of nostalgia and curiosity, imagining how the bridge must have looked centuries ago.

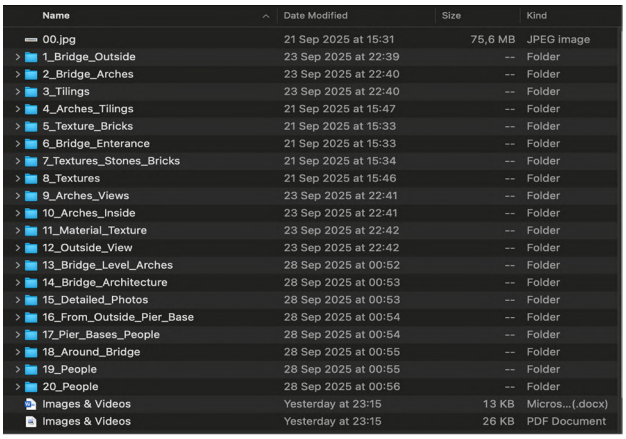
8 July 2025 – 11:30
The midday sun was strong, and the bridge felt less crowded. A few tourists were taking pictures, while a group of students sketched the arches. The heat created shimmering reflections on the stone. I noticed how quiet it was compared to the evening, and the bridge seemed more like a monument than a gathering place. My feeling was one of stillness, though a little discomfort due to the heat.

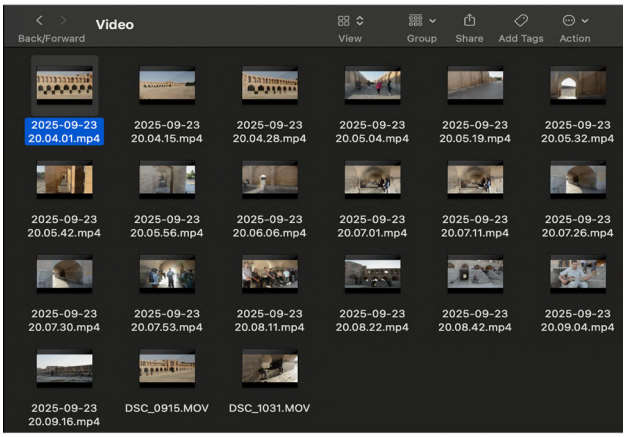
9 July 2025 – 18:15
The bridge came alive in the evening. Musicians had gathered under one of the arches, playing tar and singing, while people clapped along. Families sat in groups, some drinking tea, some chatting. The atmosphere felt communal and vibrant. I was struck by how the music seemed to echo with the natural acoustics of the arches. It made me imagine how similar gatherings might have taken place in the Safavid era.

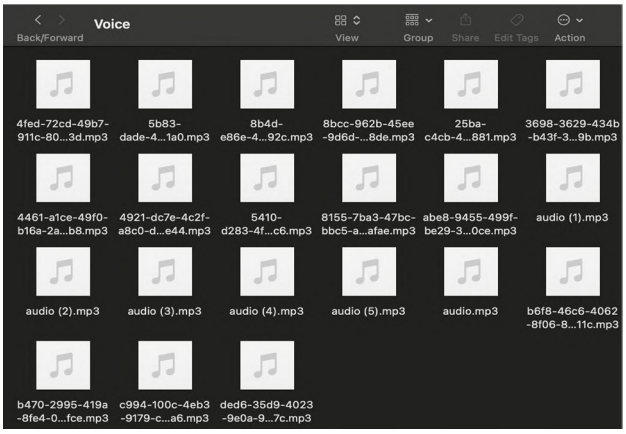
10. Fieldwork Collage: Photos, Audio Capture, and Observation Notes

I. July 27, 2025

Date/Time	Location on Bridge	Observed Activity	No. of People	Notes / Context
2025-07-27 – 17:00	Middle span (upper level)	Tourists taking photos & selfies	8	Two children running while parents posed for photos
2025-07-27 – 17:15	Under arch (lower level)	Live music performance (setar & santur)	3	Small crowd gathered to listen
2025-07-27 – 17:30	Side walkway	Local families sitting & chatting	12	Tea and snacks being shared
2025-07-27 – 17:45	By water edge	Teenagers making TikTok videos	5	Playful, noisy atmosphere
2025-07-27 – 18:00	Central viewpoint	Elderly man telling stories	1 + 6 audience	Audience mostly locals listening quietly
2025-07-27 – 18:10	Lower arches	Couples enjoying the acoustics	4	Whispering, clapping echoes
2025-07-27 – 18:20	Entrance area	Tourist group with guide	15	Guide explaining history in English
2025-07-27 – 18:30	On bridge deck	Street vendor selling tea/snacks	2 sellers + ~10 customers	Strong social interaction
2025-07-27 – 18:45	Near tilework section	Tourists photographing tiles	6	Focus on colors and symmetry
2025-07-27 – 19:00	Lower steps by river	Children playing & running	7	Parents watching from distance
2025-07-27 – 19:15	Under arch (east side)	Small singing group	5	Traditional song, some clapping
2025-07-27 – 19:30	Bridge midpoint	Mixed crowd, relaxing	20+	Blend of locals and tourists enjoying sunset







11. Affinity Diagrams

Sara

"I want to feel the history come alive, not just see an old stone bridge."

ABOUT

Sara is an Iranian living in Tehran who visits Isfahan for the first time. She loves photography and Instagram stories, and cultural trips are her favorite kind of travel. She feels both like a visitor and like someone returning to her roots. She is especially fascinated by how history, music, and emotions blend at Khaju Bridge. She hopes to capture moments that connect past and present, and she is curious about how VR could help her relive the bridge's stories in a more immersive way.

AGE	24
JOB TITLE	Graphic Designer
STATUS	Single
LOCATION	Tehran, Iran

Curious and open-minded | Enjoys cultural exploration | Nostalgic about Persian heritage | share experiences online

PERSONALITY

Tech-savvy	Tech-illiterate
Curious about culture	Culturally indifferent
Social sharing oriented	Private/Reserved
Prefers guided/structured info	Self-directed/Exploratory
Sensitive to emotions & aesthetics	Pragmatic/Utilitarian

GOALS

- Learn the historical context and legends of the bridge
- Capture memorable, photogenic experiences
- Experience "time travel" into the Safavid era with VR
- Connect emotionally with Iranian heritage

NEEDS

- A VR tool that complements her visit (not replaces it)
- Comfortable and lightweight VR equipment
- Have easy access to stories, music, and history
- Clear signage in multiple languages

PAIN POINTS

- Heavy or dizzying VR headsets reduce enjoyment
- Overcrowding makes it hard to immerse herself
- Lack of water in the river creates sadness
- Not enough official information on site

Gains

- An engaging VR experience that enhances memories
- Shareable cultural content (photos, stories)
- Emotional connection to heritage
- A mix of relaxation and learning

Hossein

"This bridge is our stage, our soul. If it loses its music, it loses its life."

ABOUT

Hossein has been coming to Khaju Bridge for decades. Sometimes he sells tea and snacks, sometimes he joins other locals to play traditional music. For him, the bridge is a living part of his identity and his community. He has seen tourists come and go, but for him the bridge is about continuity, memory, and music. He feels a responsibility to pass on the stories and traditions of the place to younger generations. The bridge is not only a monument to admire but also a gathering spot where he feels truly at home.

AGE	29
JOB TITLE	Musician
STATUS	Married
LOCATION	Isfahan, Iran

Deeply rooted in tradition | Enjoys cultural exploration | Balances work and art | Friendly and welcoming

PERSONALITY

Tech-savvy	Tech-illiterate
Curious about culture	Culturally indifferent
Social sharing oriented	Private/Reserved
Prefers guided/structured info	Self-directed/Exploratory
Sensitive to emotions & aesthetics	Pragmatic/Utilitarian

GOALS

- Maintain the cultural role of the bridge as a gathering place
- Gain recognition and appreciation for local musicians
- Share music and stories with younger generations
- Keep the atmosphere of Khaju Bridge authentic

NEEDS

- Simple, non-intrusive technology he can use without training
- VR experiences that respect and showcase local stories
- Mixed experience: physical presence and digital add-ons
- Preservation of silence, acoustics, and tilework

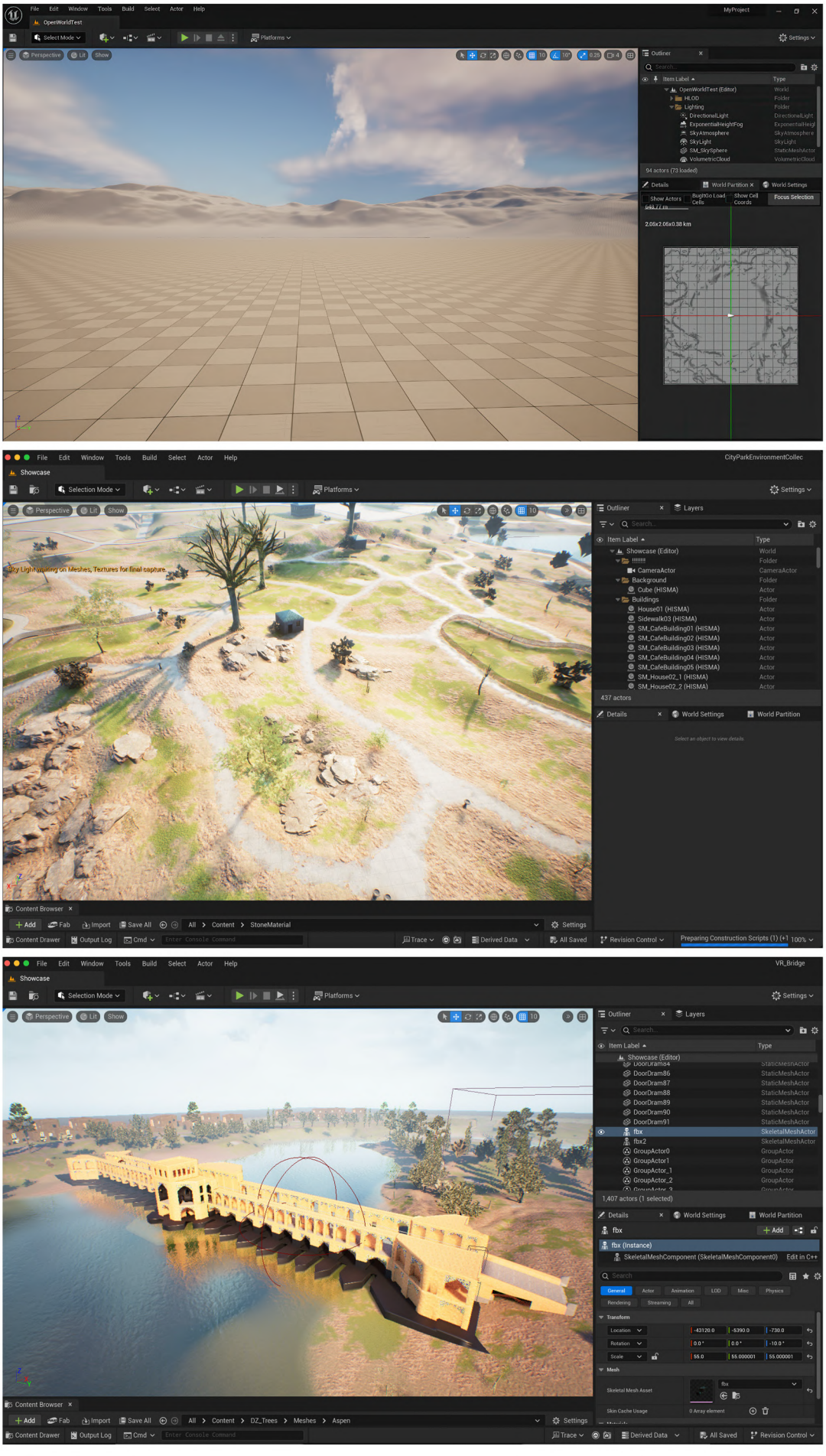
PAIN POINTS

- Generational gap: younger people embrace VR, elders hesitate
- Fear that VR might replace rather than support real gatherings
- Risk of commercialization and fake experiences
- Loss of water makes the bridge feel empty

Gains

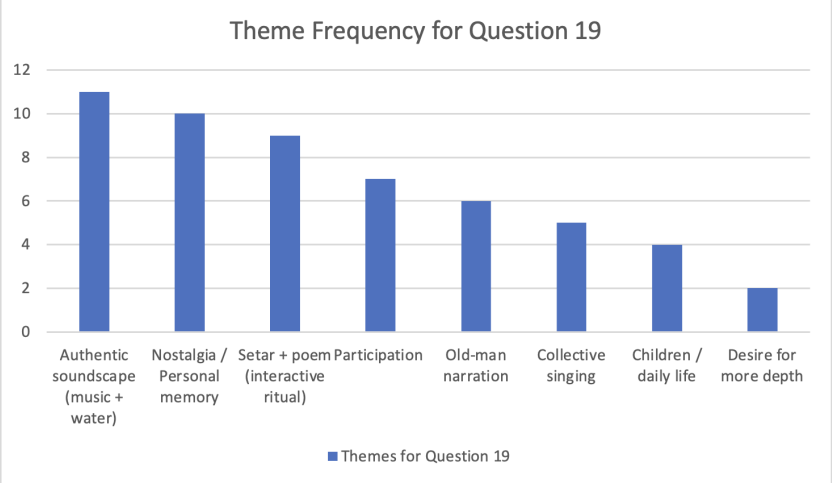
- Emotional continuity: bridge as a "silent witness" for future generations
- Opportunities to teach stories through VR to younger audiences
- Reaching tourists beyond physical presence
- Pride in sharing cultural heritage globally

12. Two Personas: Sara (Visitor), and Hossein (Local)



13. Prototype Evolution: From Low-Fidelity Blocks to Final Environment

The interviews indicated that music and water involvement were the most emotionally impactful components, which informed the decision below and prioritization of spatial audio, water animation, and synchronizing rhythm with the user.



Design Priority Graph: Emotional Triggers Ranked by Interview Responses

03.3 Scenario-Based Design

Scenario-Based Design (SBD) was used to represent user-centric principles as an experience-based narrative. Three scenarios were designed, mappin g to the respective persona and research objective.

Scenario 1 - Sara (Tourist): "Time- Travel Photography & Story":

Sara is in the VR experience on the upper deck of the bridge during the Safavid period. Sara has the opportunity to walk around, take photographs, and find a playable, interactive setar instrument. Strumming the strings starts a poem recitation, which eventually illuminates non-player characters (NPCs) who all start singing a choral song.

Scenario 2 - Hossein (Local): “Memory and Community”:

Hossein’s experience starts under the arches, where the sound of water and music are amplified through listening acoustics. An elder NPC recites the Saeb Tabrizi poem, and as proximity-based triggers engage, the user is invited to join the community in song. The experience wraps up with a symbolic gathering that evokes both nostalgia and identity.

Using these storyboards, user journeys were constructed to depict how each persona would navigate emotionally and interactively through the VR experience.

A semi-guided mode allows the users to experience the hydraulic structure of the bridge. Interactive overlay visuals demonstrate sluice gates, as well as cross-sections, which altogether illustrate a combination of technical knowledge with immersive visuals.

A major innovation was the hybrid interaction with a Setar, which connected a physical object to the VR system via Arduino.

03.4 Concept Development

The final concept, Khaju Bridge, Storyliving: A Time-layered Ritual Experience, integrated historical reconstruction with emotionally-driven storytelling.

Core Concept Pillars:

1. Layered Time: Users would feel the Safavid era as temporal layers were smoothly blended.
2. Ritual as Interaction: The Setar functioned as a ritual interface that enabled participants to unlock layers of poetic, narrative, and musical responses.
3. Sound as Driver: The emotional heart of the experience was composed of spatialized music, ambient sounds of the river, and human voices.
4. Accessibility and Performance: The experience was designed for encrypted, Quest 3 standalone deployment, but also operated on a PC.

(1) Sara opens her eyes and suddenly stands on Khaju Bridge in the Safavid era.

(2) She walks slowly, amazed by the arches and glowing tiles.

(3) Families, children, and merchants surround her, bringing the past to life.

(4) She hears traditional music echoing and finds musicians under an arch.

(5) Sara feels nostalgia, imagining her ancestors crossing this bridge.

(6) She takes one last look as the sun sets and the VR fades away.

(1) Hossein finds himself young again, sitting on the bridge in Safavid times.

(2) He serves tea and snacks to locals gathering in the lively atmosphere.

(3) Hossein joins a group of men, singing and playing daf with pride.

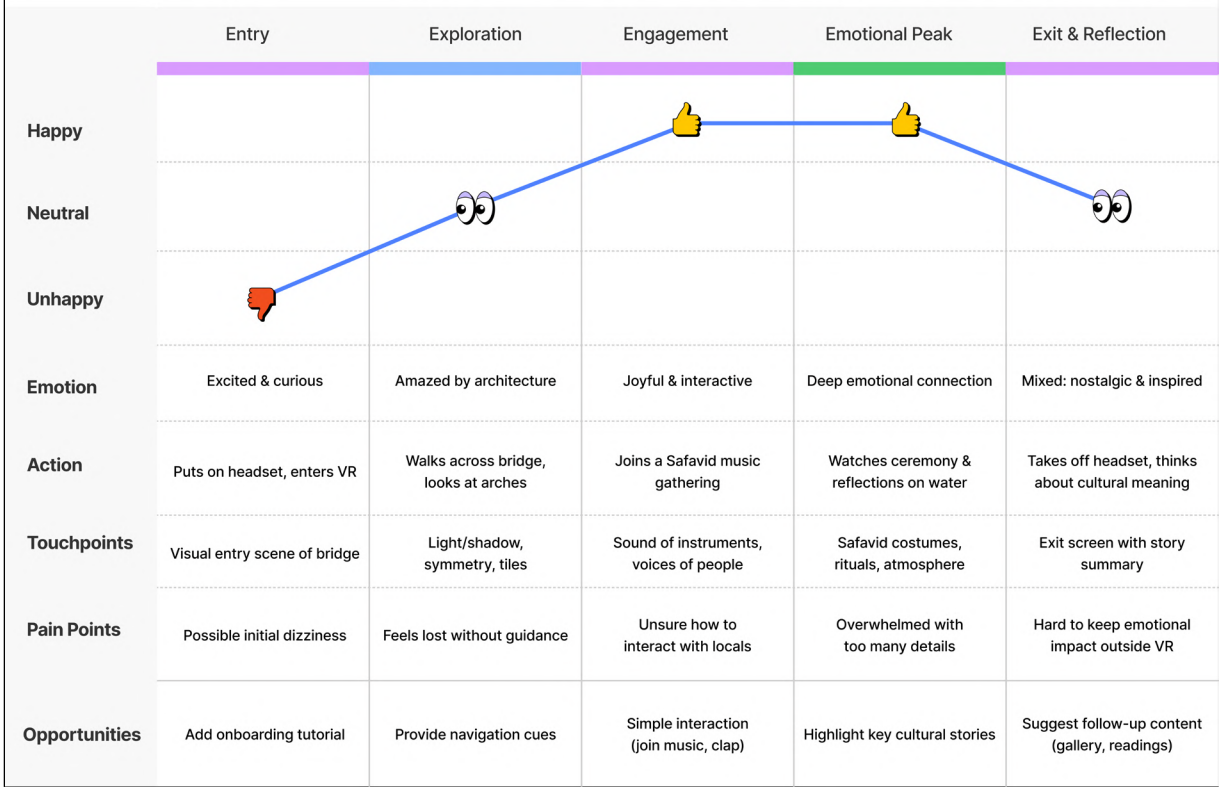
(4) He notices travelers with camels crossing the bridge full of life.

(5) He looks at Khaju Bridge, feeling it as part of his own soul and history.

(6) The vision fades, and he returns to the present, proud of his heritage.

14. Storyboard Frames for Sara (Visitor) Persona
15. Storyboard Frames for Hossein (Local) Persona

User's Journey Map 1



	Entry	Exploration	Engagement	Emotional Peak	Exit & Reflection
Emotion	Excited & curious	Amazed by architecture	Joyful & interactive	Deep emotional connection	Mixed: nostalgic & inspired
Action	Puts on headset, enters VR	Walks across bridge, looks at arches	Joins a Safavid music gathering	Watches ceremony & reflections on water	Takes off headset, thinks about cultural meaning
Touchpoints	Visual entry scene of bridge	Light/shadow, symmetry, tiles	Sound of instruments, voices of people	Safavid costumes, rituals, atmosphere	Exit screen with story summary
Pain Points	Possible initial dizziness	Feels lost without guidance	Unsure how to interact with locals	Overwhelmed with too many details	Hard to keep emotional impact outside VR
Opportunities	Add onboarding tutorial	Provide navigation cues	Simple interaction (join music, clap)	Highlight key cultural stories	Suggest follow-up content (gallery, readings)

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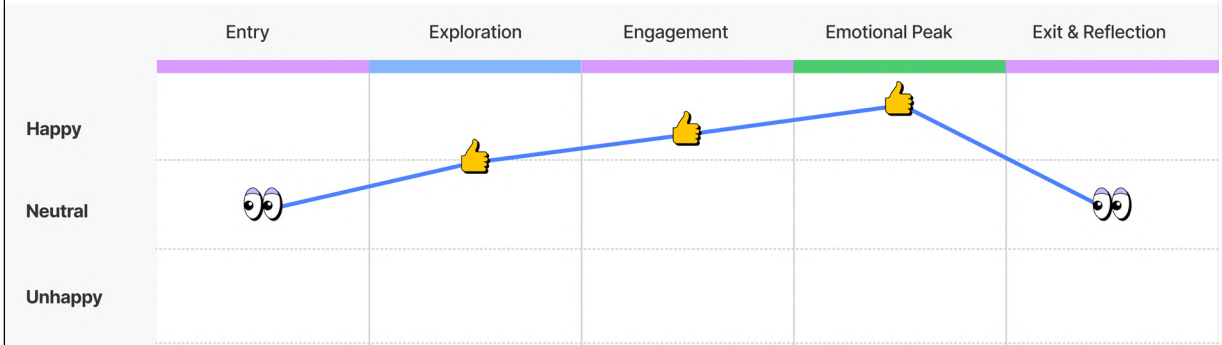
User's Journey Map 2



	Entry	Exploration	Engagement	Emotional Peak	Exit & Reflection
Emotion	Curious but cautious	Recognizes familiar details	Proud & engaged	Nostalgic, deeply touched	Calm, reflective
Action	Puts on headset skeptically	Walks and checks historical accuracy	Listens to Safavid-era storytelling	Plays virtual instrument, joins locals	Removes headset, compares with real bridge
Touchpoints	Initial VR onboarding	Bridge details, lower arches	Ambient sound, local dialogues	Traditional music, water flow restored	Ending summary of heritage importance
Pain Points	Suspicious of VR usefulness	May critique accuracy of tiles/arches	Feels artificial if voices aren't authentic	VR headset weight, realism limits	Worries young people forget real bridge
Opportunities	Add cultural context at start	Ensure high fidelity visuals	Use authentic local voices	Enable tactile feedback (instrument vibration)	Link VR to heritage preservation messages

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16. User Journey Map for Sara (Visitor Persona)
17. User Journey Map for Hossein (Local Persona)

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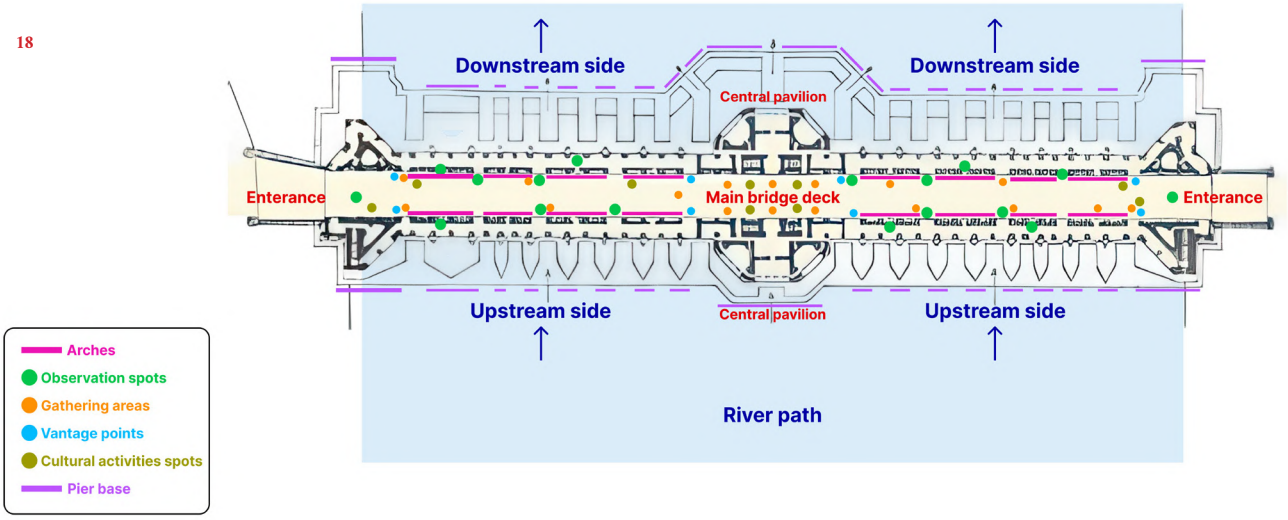

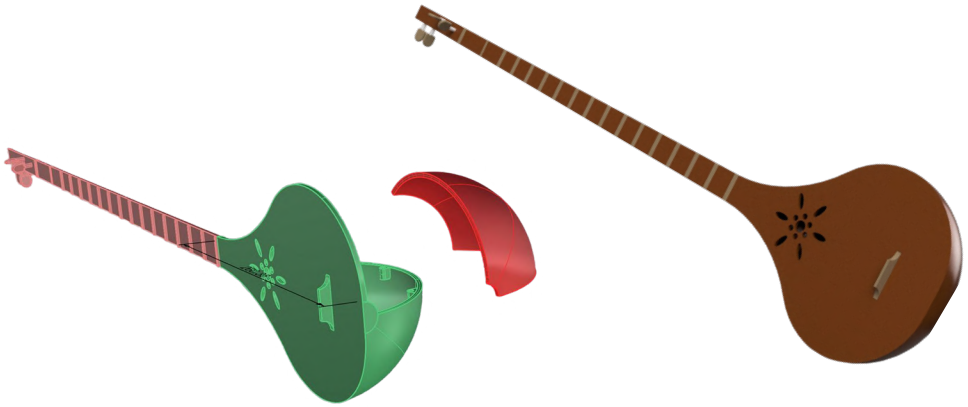

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18. Interactive Overlay: Sluice System Visualization
19. Rhino Model of Physical Setar
20. Unreal Level Screenshot: Upper Deck and Reflected Water Layer

Environment Design:

The 3D model of the bridge was created using photographs of the structure and field measurements. Textures in pictures of the real tile and bricks were taken and processed, to add a sense of realism to the model. The Unreal level consisted of both upper and vertical scenes, with dynamic planar reflections on the water.

NPC Design:

A number of groups of NPCs were created and animated through the use of Meshly and custom rigs. Their behaviors helped to simulate social interactions, with groups of musicians, families, and storytellers actively 'communicating'.

Interactive Setar Design:

The Setar was modeled in Rhino and physically built using a vibration sensor (piezo), a MOSFET transistor, a solenoid motor, and an Arduino Uno R4. The piezo (or vibration sensor) would detect when the Setar was plucked, activating a mechanical vibration, and recording data on the Setar controller for the VR to pull from.

Narrative Content:

The narrative was arranged with three ritual modes:

1. Poetic Mode: the activation of Saeb Tabrizi's verses.
2. Elder Mode: the storytelling of the bridge's history.
3. Communal Mode: the collective singing of "Be Souye To" (traditional song).

Each ritual mode activated a unique sound world, animation, and light sequence.

03.5 Narrative Content in details

The content of the three implemented narrative and interactive sections is as follows:

03.5.1 Poetic Mode

According to research, a well-known poet from the Safavid period was Saeb Tabrizi, who had lived in Isfahan, and some lyrics are selected featuring the second bridge of the Zayandeh Rad (Khaju Bridge), as follows:

شد دو بالا زین پل نوآب وتاب زنده رود
طاق ابرویی چنین می خواست آب زنده رود

تا به آیین تمام این پل نقاب از رخ گشود
چشم حیران گشت سر تا سر حباب زنده رود

دوربادا چشم بد زین پل که هر طاقی ازو
شد مه عید دگر از بهر آب زنده رود

نیست ممکن از تماشایش نظربرداشتن
صد پری در شیشه دارد هر حباب زنده رود

گر ز آب زندگی سرسبز گردد جسم ها
زنده جاوید گردد دل ز آب زنده رود

از دل زهاد می شوید غبار زهد خشک
جلوه مستانه دریا رکاب زنده رود

همچو داغ تازه در زیر سیاهی شد نهان
چشمه جان بخش حیوان از حجاب زنده رود

از گوارایی دو بالا می شود کیفیتش
باده را ممزوج اگر سازی به آب زنده رود

English translation of the poem:

The newly constructed Khaju Bridge extended above the marvelous Zayandeh-Rood waters, the waters that seemed alive with the glow and twist of the shimmering lights. It seemed at last the river had grown tired of its own beauty and exquisite arch to frame its flowing spirit. This bridge, once unveiled, astonishingly carried every shimmer and ripple of apparent youthful love of the immortal water. Long may the bridge remain untouched; every arch twinkling as though a new moon hangs above the river, its singular intention, the art of the bridged river's spirit.

It is nearly impossible to look away as a hundred spirits are seemingly dancing in every sparkling bubble of the river. The waters that would make bodies green and alive also awaken the soul, for the Zayandeh-Rood is not just a river but a stream of eternal life. The stream washes away the dust of dead, lifeless piety; it reflects the ecstatic light of the ocean beneath a tranquil exterior. It is like the flame that hides beneath shadows, carrying with it the secret source of vitality, pure and bright; the taste is so divine that even if mixed with wine, it would only render the wine more divine.

03.5.2 Elder Mode

The second tale recounts the life and history of the bridge, and the elder said to the VR visitors:

"Oh, young man, you are standing on a magnificent piece of art, the foundation of which was built over three hundred and fifty years ago, during the time of Shah Abbas II, around (approximately) 1040 AH. It was built to provide a mechanism to accommodate the wayfaring caravans carrying goods to Isfahan and enjoying happiness, congregating, and solitary moments alongside the Zayandeh-Rood River." This bridge was never just a means to cross the river, but it is a celebration in itself. The large arches and the large pavilions of the bridge were constructed in such beauty that as you walked, you felt as if you were walking in a royal palace. Here big poetry gatherings of dueling musicians and poets occurred as the sound of tar and setar reverberated through the arches and pavilions, and children played at the edge of the pavilions. It has been said of the architecture that it was designed so that the water beneath it could reflect the arches back as if it were a mirror.

Because of this, it is sometimes referred to as "the most beautiful bridge of the Zayandeh-Rood." I remember evenings when the light came through the arches and people would gather to sing.

Great poets like Saeb Tabrizi recited poems and verses here.

This bridge has experienced countless incidences of joy, sorrow, love, and memory collectively across generations.

And still today, if you listen closely,

You could still hear the echoes of those voices."

03.5.3 Communal Mode

As part of the additional story and history aspect of this experience, a few people on the bridge sing the old and familiar Persian song To You (Be Suye To), which more or less says:

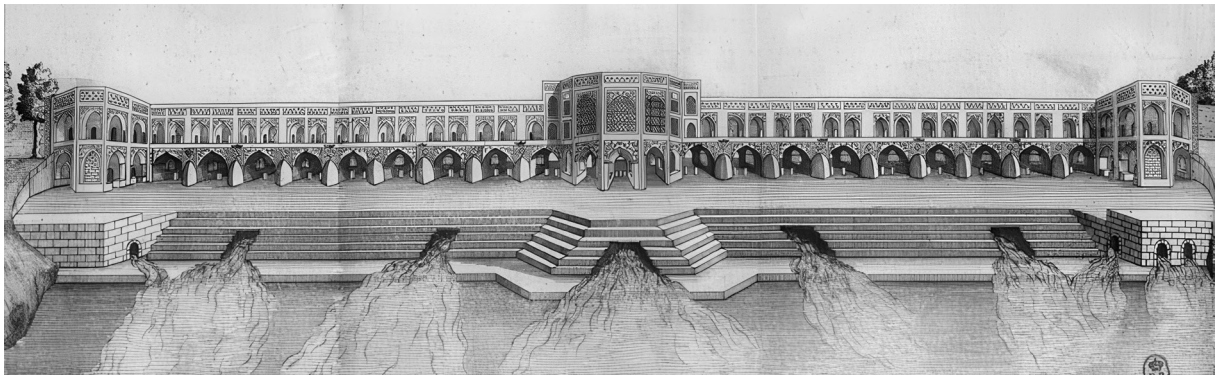
It describes a deep yearning for a loved one, who is both close and far away. It speaks to the heart of a wanderer, the restlessness of earth and sky, guided only by love or memory. The singer reaches out to his beloved who is absent, offering if for no other reason than his weary heart and asking for what more there is to desire. Each verse treats timeless themes of ishq (divine love), separation, and devotion that elide spiritual yearning and human desire. Within the Iranian context, the songs represent the grieving heartbeat of lovers to the feelings of love and longing with the poetic and musical heritage that has shaped the country's emotional currents.

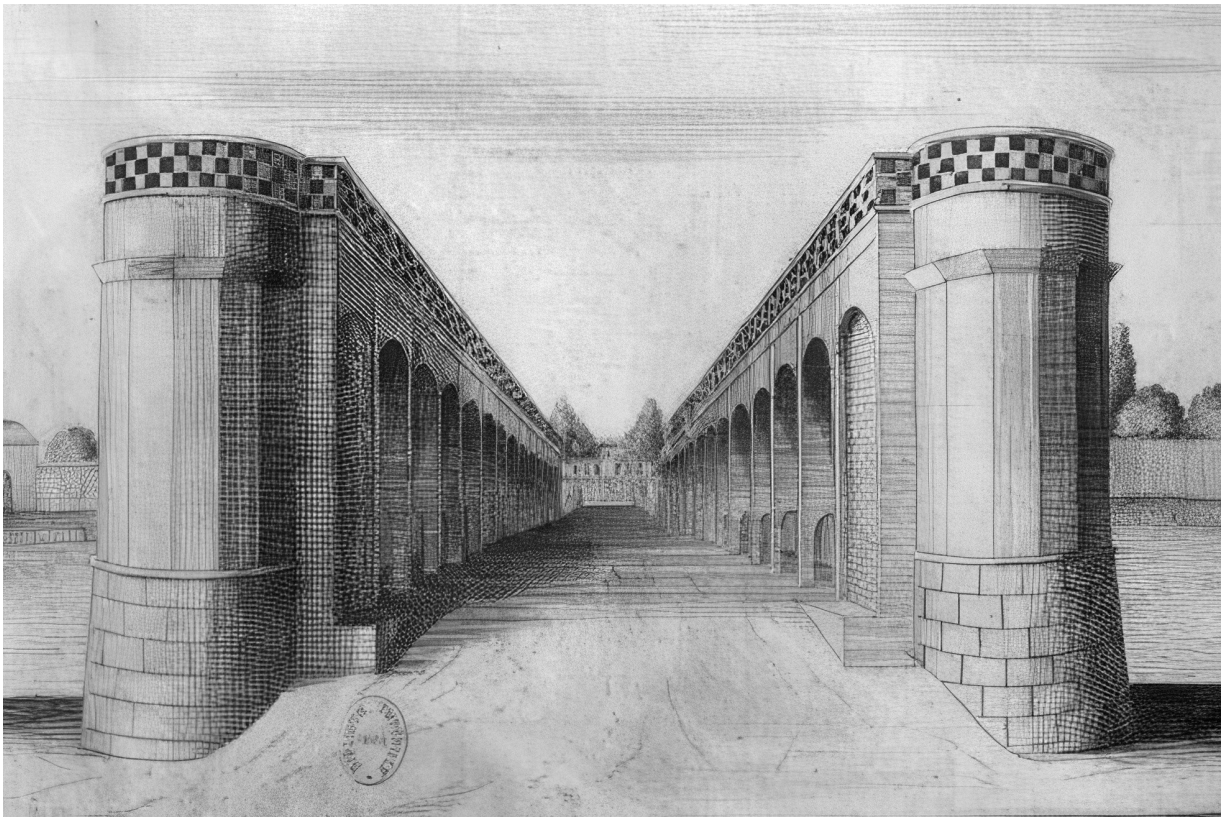
21. NPC Characters made for Unreal Engine experience

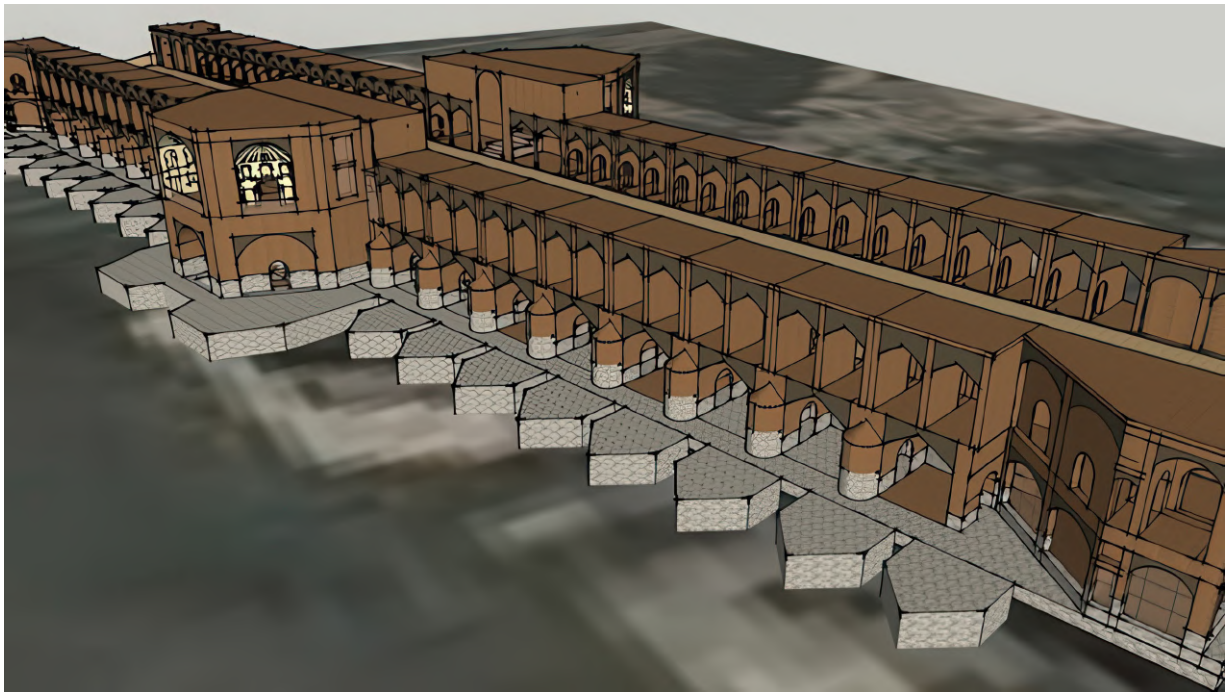
03.6
Summary of Design Insights

The design process illuminated the ways in which emotional engagement in heritage VR is made possible through the action of aligning three primary levers of embodied engagement: music, water, and ritual interaction. The combined effect of sensory immersion and symbolic participation led to greater empathy and retention of memory. The hybrid integration of a physical Setar bridged the gap between tangible culture and digital reconstruction, grounding the virtual experience in embodied practice.

The final prototype thus serves as both a technological artifact and cultural narrative, an emotionally charged re-imagining of Khaju Bridge as a living, participatory heritage site.







22. Khaju Bridge Sketches and its 3D Model design

04 CHAPTER FOUR

IMPLEMENTATION

The implementation of the Khaju Bridge Virtual Reality Experience represented the technical and creative culmination of the research-through-design process established in the previous chapter. Chapter 3 concerned the conceptual and narrative foundation of manifesting these ideas into a functional and immersive system affecting users with historical context, cultural meaning, and emotional attachment. The making process included real-time rendering, 3D modeling, interactive scripting, sound design, and hardware integration; all elements working together as one system. All components are created in the Unreal Engine 5.4, optimized for publishing on the Meta Quest 3. The production workflow utilized a MacBook Pro (M3, 2023) as the main developing machine.

The main goal of the implementation phase wa s to take effective design concepts and create a technically stable experience. This required an infrastructure capable of maintaining the synchronization between the digital environment and a perceivable physical interface, the augmented Setar instrument, which served a dual purpose as both a controller and a ritual object, allowing for the bridging of human gesture with narrative activation. Therefore, development became a point of dialogue between hardware and software, as material vibration became digital storytelling, and vice versa.

04.1 Technical Setup and Development Environment

The hardware and software setup were foundational to this integration. All work was conducted on the MacBook Pro (M3, 2023), which was selected for its high-efficiency GPU and its ability to support the Unreal Engine's Apple Silicon optimization. The Meta Quest 3 headset was selected as the target device for deployment and review. The pairing of the MacBook and Quest occurred through a USB-C connection with the use of the Oculus Developer Hub for initial testing and later installation of the Android (ARM64) version through SideQuest for sideloading. In total, testing occurred in a 2 x 2-meter physical area, supporting standing experiences.

04.2 Physical Setup: The Augmented Setar Interface

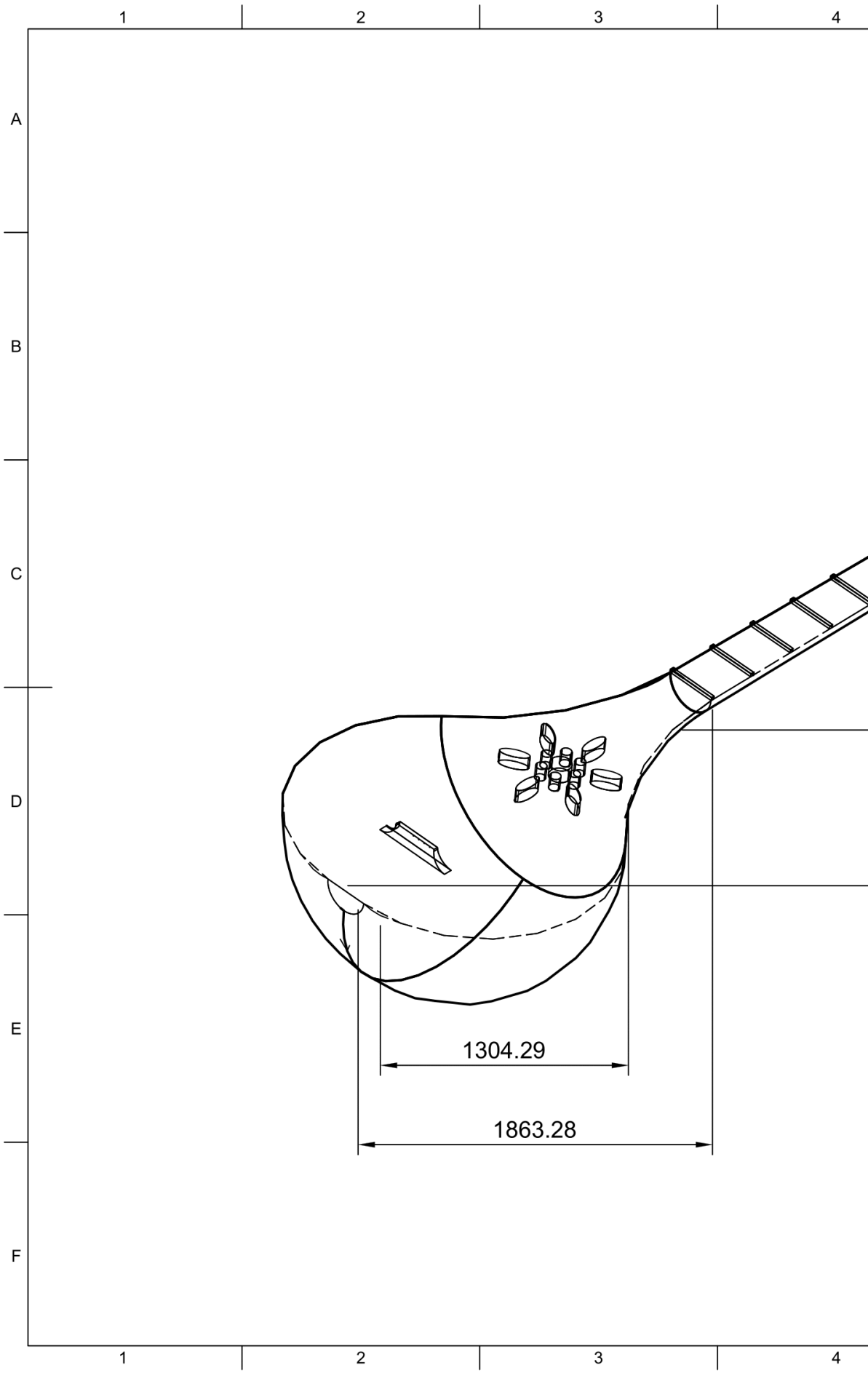
The physical equivalent of the system was a custom-built Setar interface. The interface was designed in the Rhino 7 program with dimensions based on the actual historical dimensions from th e Safavid era (around 90cm long), while keeping the original materiality, but offering an electronic element. Enclosed within the wooden bowl is an Arduino UNO R4 microcontroller, a piezoelectric vibration sensor, a 12V solenoid operating via a MOSFET, and a rechargeable power unit. When the user plucked a string, the piezo sensor registered the vibration caused by the string, sending an analog signal to the microcontroller. The Arduino would interpret that signal and activate a command: the solenoid's movement would result in a soft mechanical tap on the Quest 3 controller inside the bowl and prompt a story-sequence narrative in conjunction with the tap. The end result was hybrid feedback in which the real Setar and the simulated Setar worked together, the unity of which was the conceptual aim of the project: to rejoin physical tradition and digital immersion.

04.2.1 Technical Drawings and 3D Model for the Setar

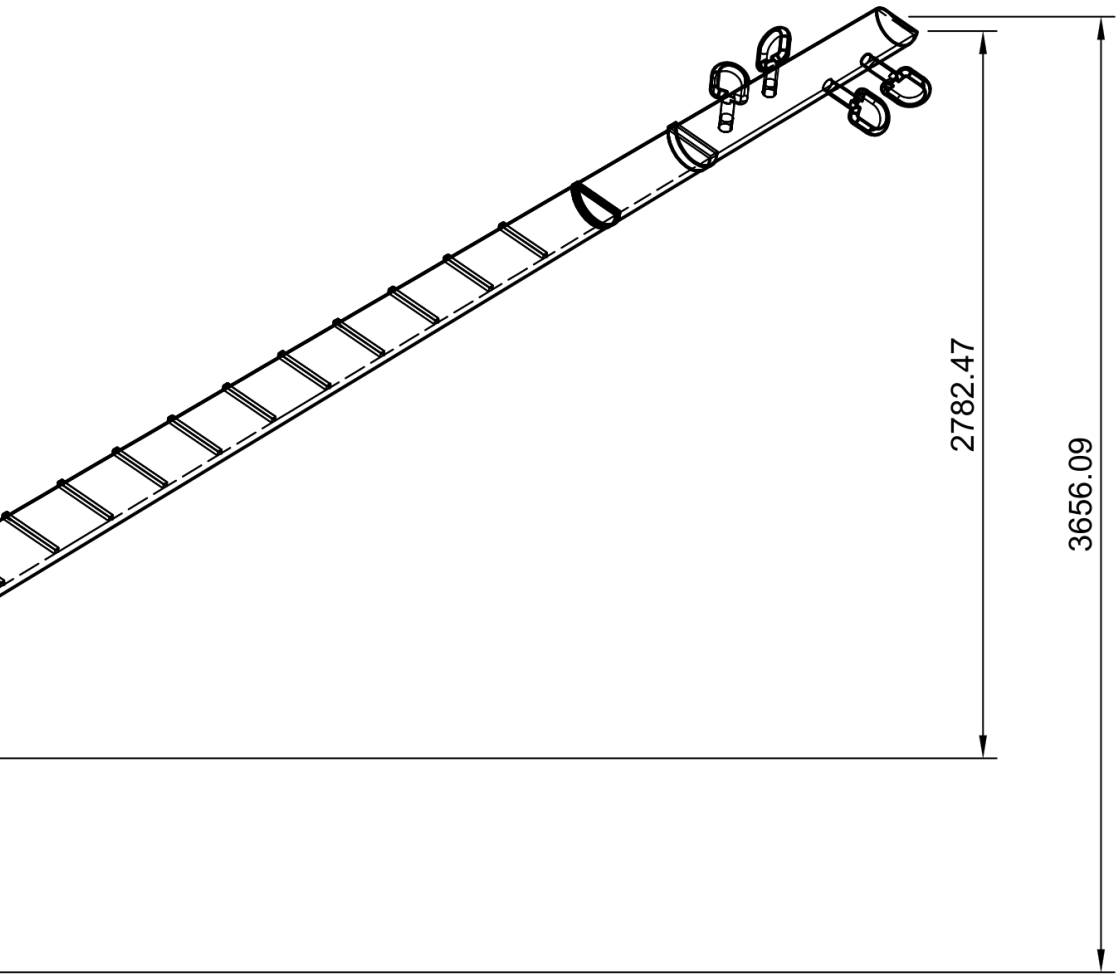
In order to uphold accuracy in the fabrication, a series of technical drawings and 3D renderings were generated in Rhinoceros 7. These provided views from the top, side, and section, with a set of proportional measurements referencing the original Safavid Setar. The 3D model also provided a point of reference to position the controller and solenoid unit to maintain ergonomic balance while being true to the aesthetic.

23. Development setup on MacBook M3 connected to Meta Quest 3 via USB-C during

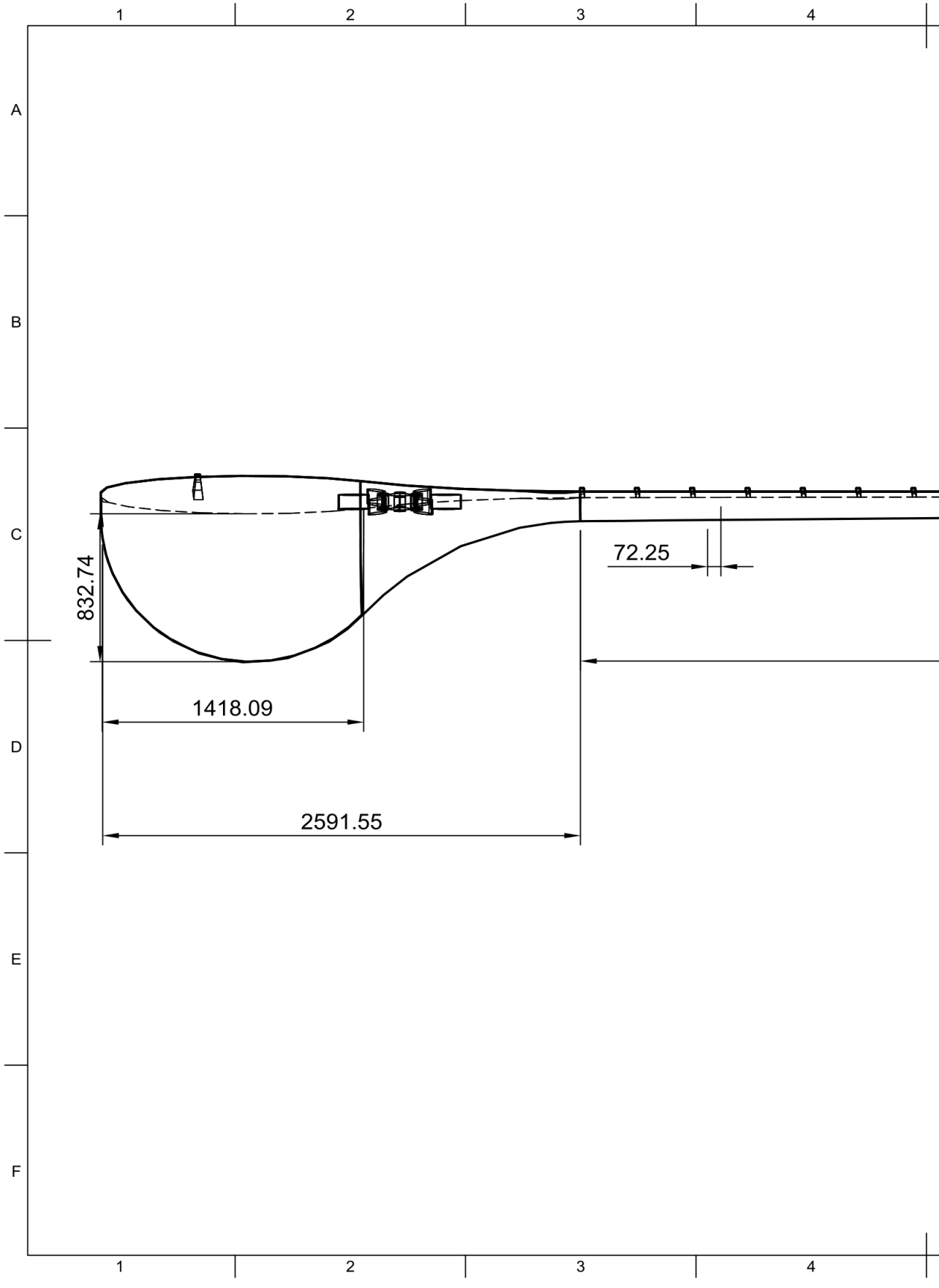
24. Opened Setar prototype showing Arduino UNO R4, piezo sensor, solenoid motor, MOSFET, and controller placement inside the bowl cavity



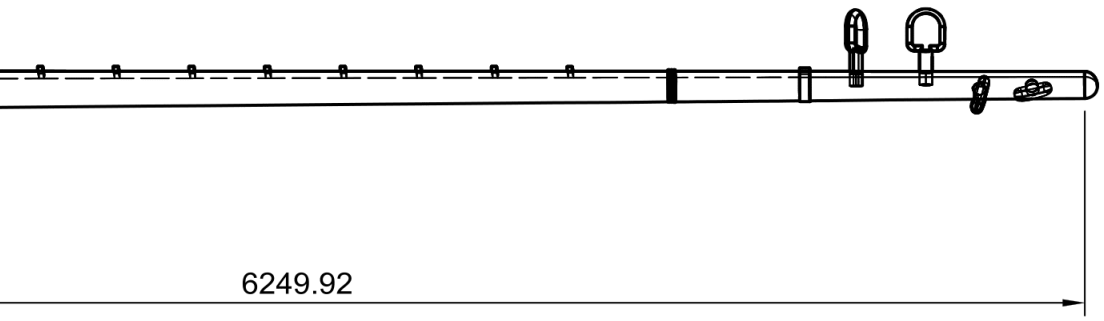
25. The technical drawings of the Setar from perspective view



Dept.	Technical reference	Created by	Approved by
Dept. of Architecture	Master's Thesis	Sina Elyasi 19/10/25	Prof. Chatzigiannakis Prof. Pollini
		Document type: General Arrangement Drawing	Document status: Final Version
		Title: Setar - General Assembly	DWG No.: SE-THESIS-001
			Rev.: A / Date of issue: 19/10/2025 / Sheet: 1/4



26. The technical drawings of the Setar from left side view



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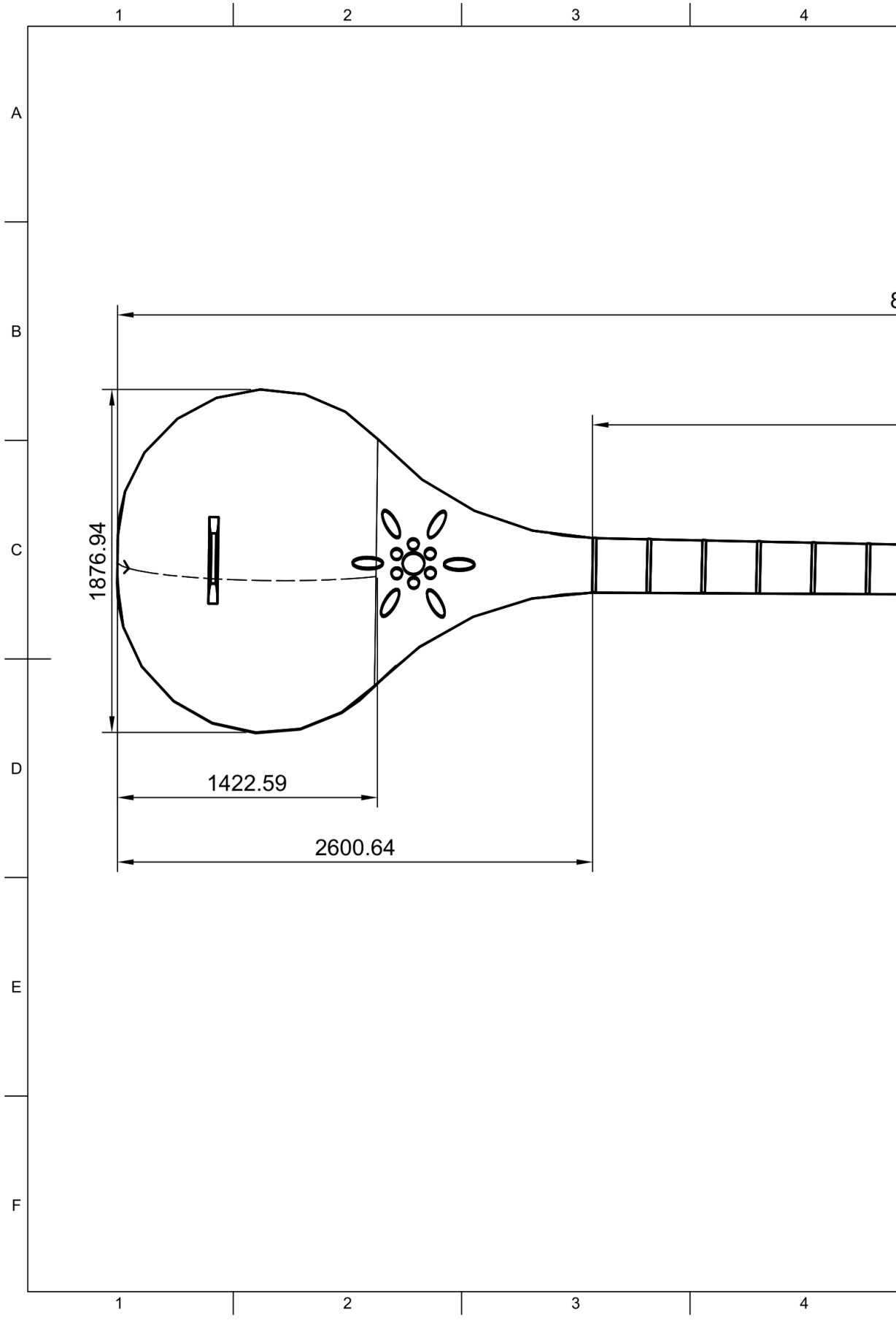
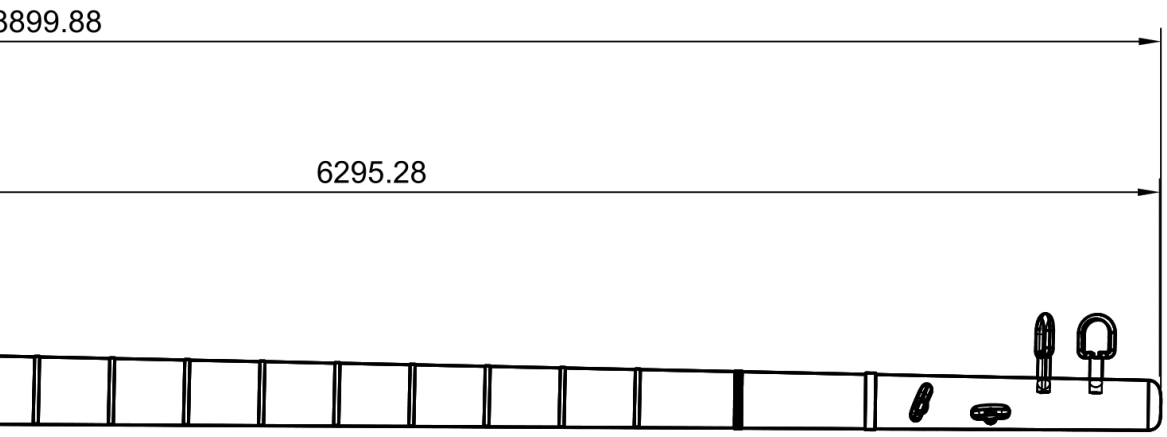


27. The technical drawings of the Setar from front view



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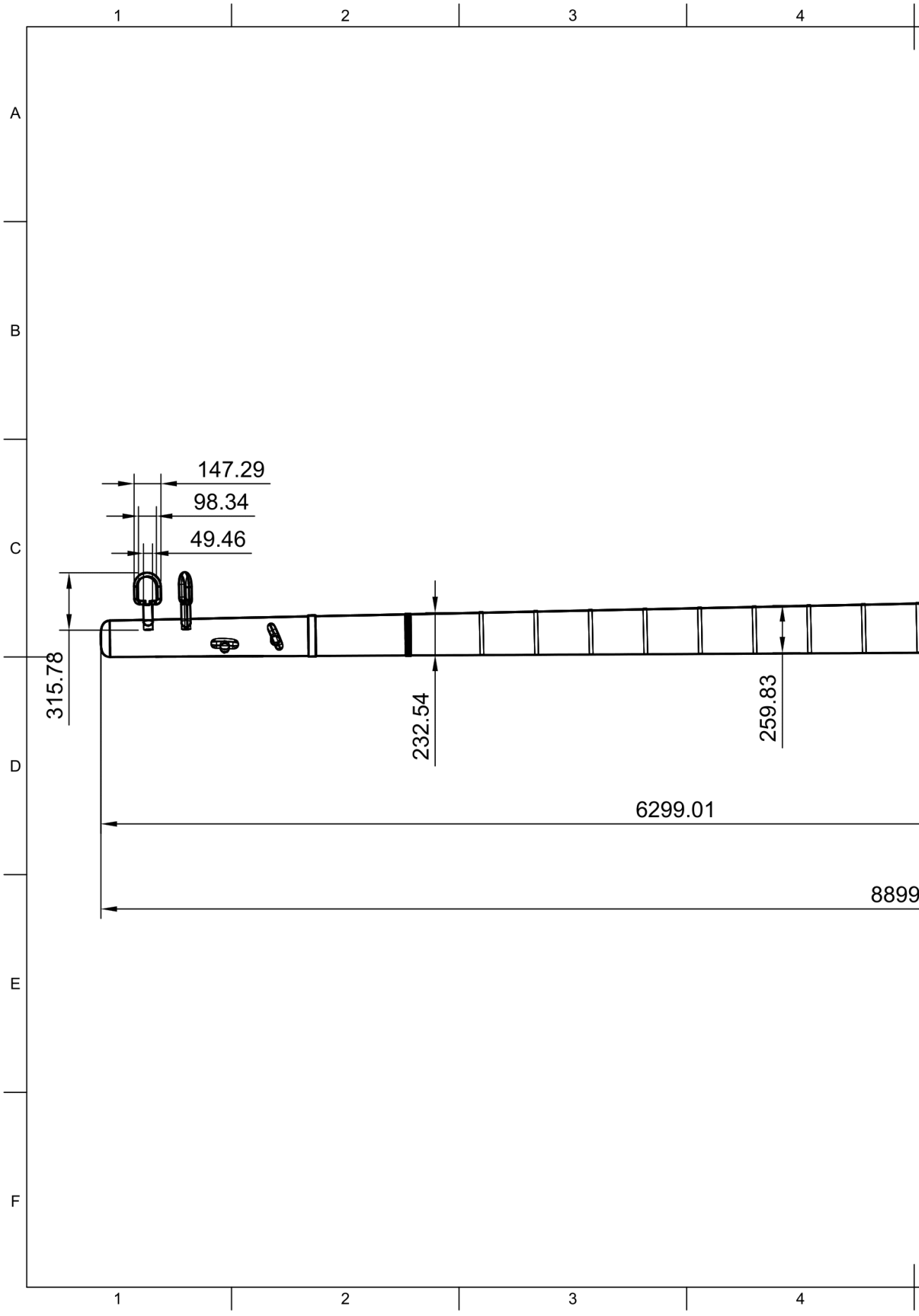
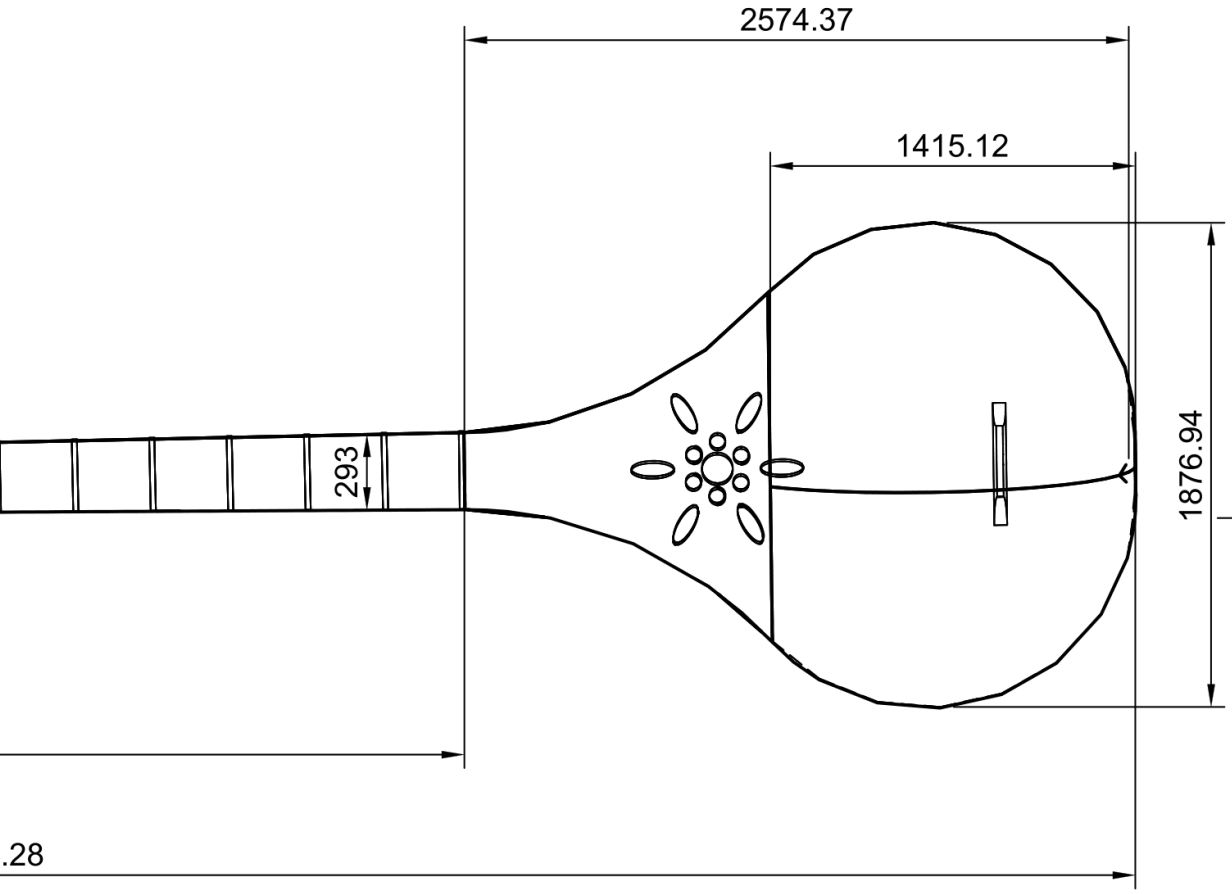
		Document type: General Arrangement Drawing	Document status: Final Version
		Title: Setar - General Assembly	DWG No.: SE-THESIS-003
			Rev.: A | Date of issue: 19/10/2025 | Sheet: 3/4



28. The technical drawings of the Setar from back view



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Dept. of Architecture	Master's Thesis	Sina Elyasi 19/10/25	Prof. Chatzigiannakis Prof. Pollini
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		Title: Setar - General Assembly	DWG No.: SE-THESIS-004
			Rev.: A | Date of issue: 19/10/2025 | Sheet: 4/4

04.3
Software Integration and Optimization

Inside Unreal Engine, software integration operated through a modular work flow created for iterative improvement. The three-dimensional assets were created with Rhinoceros and Blender. Ambient audio recordings were edited in Adobe Audition and then spatialized in Unreal. Unreal Engine 5.5.4, as the environment for all of the assets, rendering, sound, interactions, and optimization, connected all the components using the Blueprint visual scripting system. Cross-device compatibility is maintained, allowing seamless deployment to the Meta Quest devices.

As the Quest 3 is a standalone mobile headset, optimization was a principal consideration. The rendering system was set up for forward rendering without MSAA anti-aliasing, Nanite, and Lumen to minimize particles on the GPU. Lighting was completely baked using stationary and static lights, and reflection captures were placed under the bridge to create realistic reflections of the water. Texture resolutions were constrained to 2k on larger structures and 1k for NPCs. The packaged build size averaged 3.58 GB and consistently output 72 frames per second.

04.4
3D Modeling and Environmental Design

Khaju Bridge's visual reconstruction commenced with extensive field documentation. Particular attention was devoted to recreating Safavid tile patterns with historically accurate blue and turquoise coloration calibrated for VR view. Based on field research and recorded photos and videos, efforts were made to use the right materials for different parts of the bridge as much as possible.

The environment incorporated water, vegetation, and atmospheric elements that immersed the emotional character. I implemented a dynamic water plane with planar reflections, small parallax distortion, and animated ripples to recreate the Zayandeh Rud River. I modeled cypress and plane trees based on botanical reference images and previously sourced information, and procedurally positioned them along the banks. I layered volumetric fog, sky domes, and environmental lighting to create a late-afternoon color palette to evoke the bridge's existing gatherings.

04.5
NPC Design and Animation

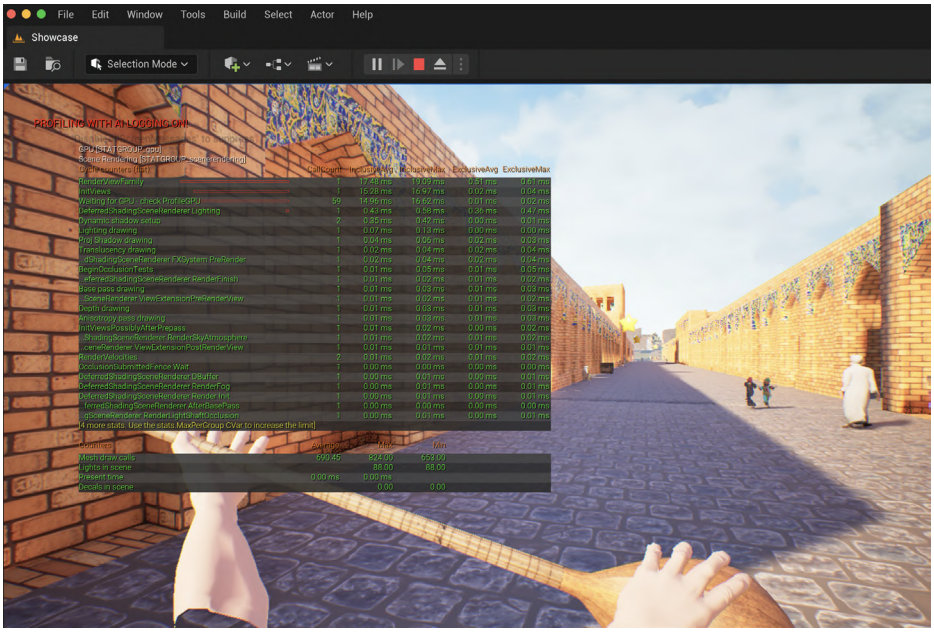
The introduction of humans was done through animated non-playable characters (NPCs) as citizens, men, women, and children of the Safavid period interacting socially, singing, and chatting. Their actions were driven by simple Blueprints based on waypoint movement and idle animations. Each of the non-player characters' animations was initiated to create the perception of mutual awareness that augmented social presence.

04.6
Sound and Lighting Integration

Lighting and sound design were perceived as devices of emotion, not merely a technical detail. The bridge's arches were lit with the warm directional light of the sun. We used a glowing emissive material for the Poem Tablet sequence to provide glowing golden reflections on surfaces, characterizing enlightenment. Transitions were programmed on the blueprints as timelines to blend color temperature transitions, intensity, and fog density of the more emotional aspects smoothly.

04.7
User Flow and Narrative Sequence

The user flow of the VR experience was designed to gradually transition from observation to engagement. When users entered the virtual bridge environment, ambient water and distant human voices were the first stimuli they encountered. The Setar was situated physically before the user, awaiting engagement. The first-time users plucked the strings, and a subtle resonance confirmed the bridge between the physical and digital worlds. Consequent to inducing vibration, each of the subsequent narrative sequences offers layering: The luminescent Poem Tablet, the Elder's story, and the neighborhood Singing Crowd. The narrative succession does not simply serve as a forward-moving function of the story, but serves to strengthen the user's increasing relationship with the spirit of a neighborhood bridge.



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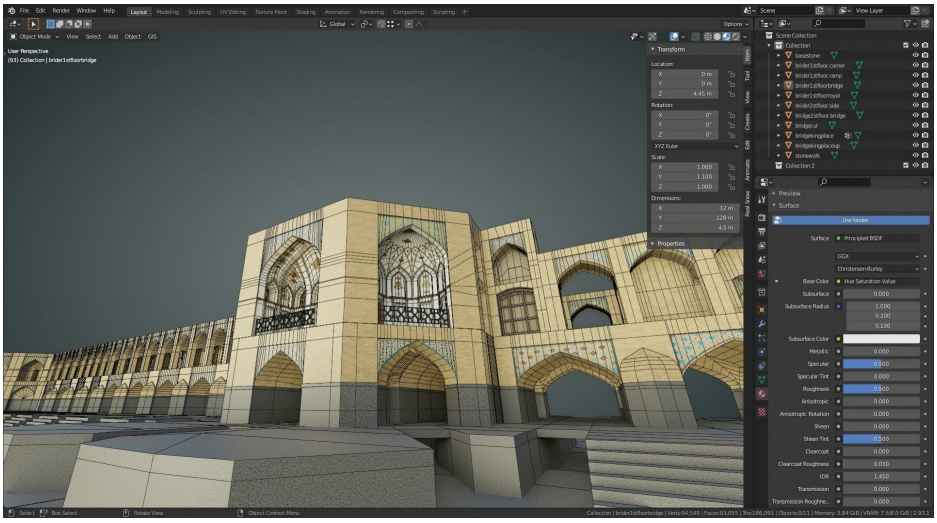

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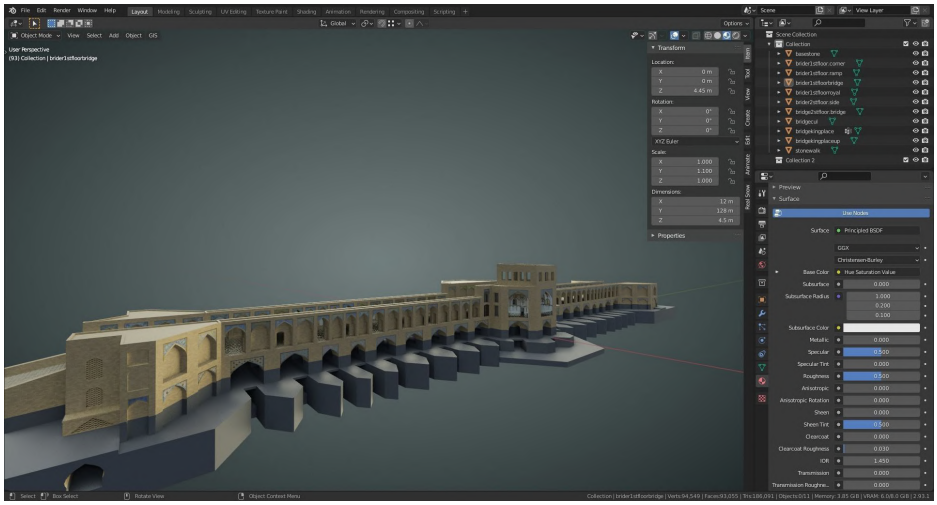

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29. Unreal Engine performance stats: Frame times, GPU cost, rendering, lighting, and lightmap memory.
30. The Bridge modeling
31. Low-poly design of the Bridge

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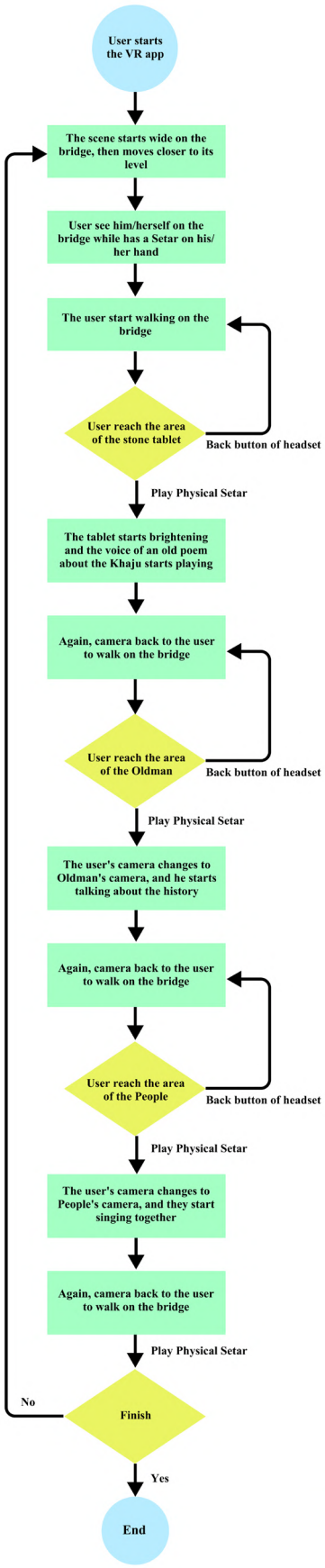
32. Unreal Engine environment overview: water plane and vegetation placement
33. NPC design: Safavid male, female, and child characters
34. Lighting of the Poem Tablet



Flowchart Guide

Symbol	Description
Circle	Start/End
Rectangle	Steps/Levels
Diamond	Decision ara

35. VR user flow diagram (The experience flow)

04.8 Final Prototype and Evaluation

The final prototype represented a culmination of the experience, bringing together all visual, auditory, and interactive systems into a singular experience. The user begins the experience as they stand on the eastern side of Khaju Bridge, facing the sunlit arches and listening to the Zayandeh Rud moving beneath the bridge. As users progressed through the narrative, their actions began to animate the space itself, and the bridge responded back to users through light, voice, and music. The experience duration was approximately five to seven minutes to allow for a complete narrative arc, but not an overly long experience.

Within the Khaju Bridge VR Experience, all interaction logic, event handling, and communication within the system were written within Unreal Engine 5.4 in a visual scripting language called Blueprint. Instead of writing in text-based code, the Blueprint system operates through node-based logic graphs in which functions, variables, and events are visually connected to define behavior in real time. Each gameplay element we created, triggering the poem tablet (see Chapter 8), activating the elder's narration, and initiating the singing crowd, was created as a sequence of events that could be triggered.

The Blueprints managed player movement and interaction, light transitions, and synchronized the audio. The modular and node-based system was very easy to rapidly prototype and debug while still allowing for full control of timing, flow of logic, and interactivity.

Performance profiling validated the prototype's technical robustness, demonstrating a level scene performance of 72 FPS with stable frame delivery timings; CPU load averaged less than 50% per frame, GPU usage stayed stable through level streaming and LOD, and there were less than 25 milliseconds of interaction latency, with locking of haptic, audio, and visual feedback.

Preliminary user trials were undertaken with five participants, three of whom were local residents of Isfahan and two were international students. Each user participated in the VR experience for approximately 10 to 15 minutes before engaging in a brief interview. Users described the Poem Tablet as "spiritually calming," the Elder Narration as "historically alive," and the Singing Crowd as "emotionally moving." Many went on to express how this tapestry of real and virtual Setar created continuity between both aspects of tangible heritage and virtual memory. One user said, "I plucked the strings, and when I heard the poem, it felt like the bridge was answering me." These responses verified the core hypothesis of the project, that embodied interaction and sensory coherence promote emotional presence.

04.9 Technical Limitations and Future Improvements

Although these outcomes were positive, some technical limitations remained. The serial buffer on the Arduino, at times, added very small delays on rapid vibrations, and the memory for textures on the Quest 3 limited the use of higher-resolution textures. Dynamic lighting was pre-baked instead of calculated in real time to prevent performance issues, and there was some compression on the audio that lost some low-frequency clarity in the elder's voice. Future versions could seek wireless communication for the Setar and spatial audio baking for an even more realistic sonic experience.

04.10 Summary and Reflection

The final prototype has dual purposes; it is a proof-of-concept as well as a design manifesto. Ultimately, the final design demonstrates that emotional authenticity in VR Heritage does not depend on visual realism; it is instead based on the manipulation of gesture, sound, light, and symbol. The Khaju Bridge experience successfully transformed a mute monument into a performative event by seamlessly integrating historical architecture and responsive technology. The outcome is a digital ritual in which users participate in the cultural memory, restaging a Bridge that continues to have a voice through the resonance of water, music, and human touch.

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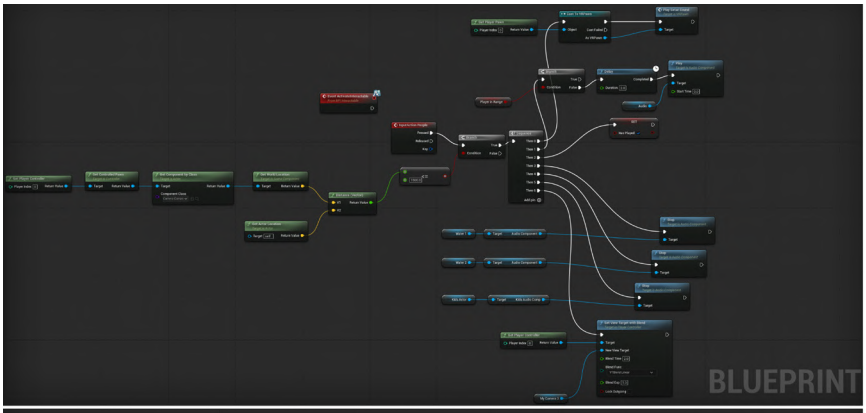

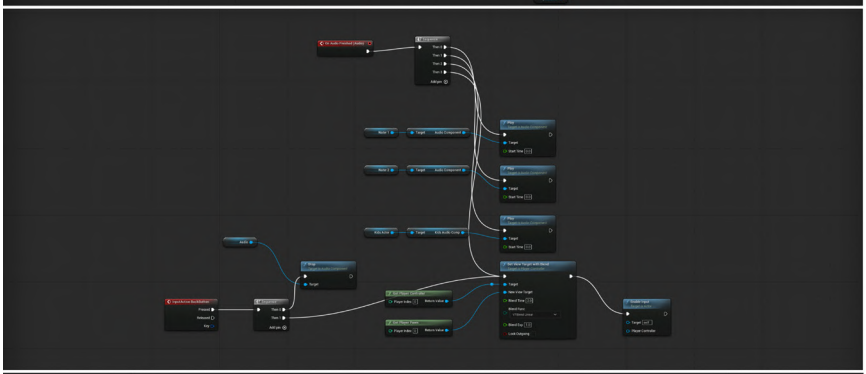

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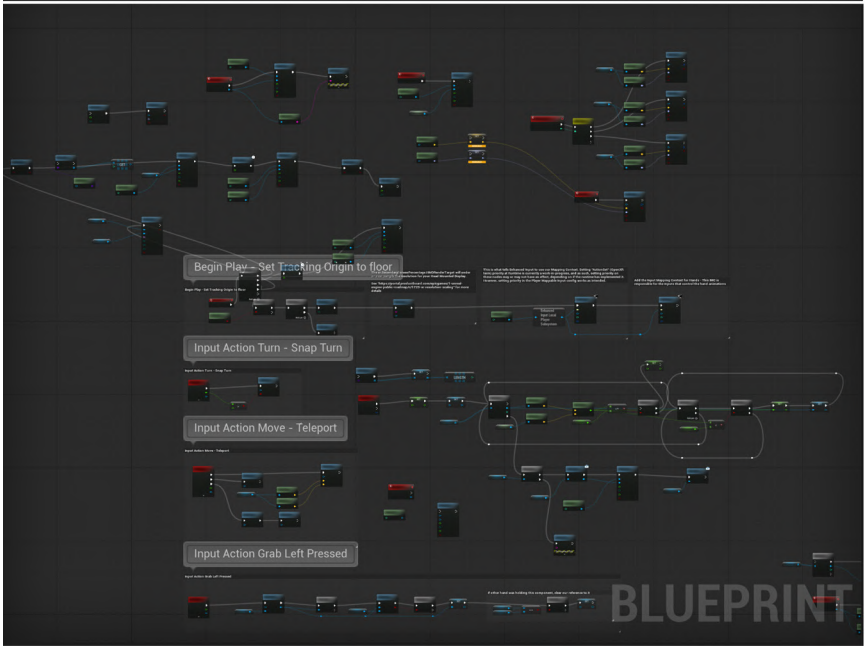
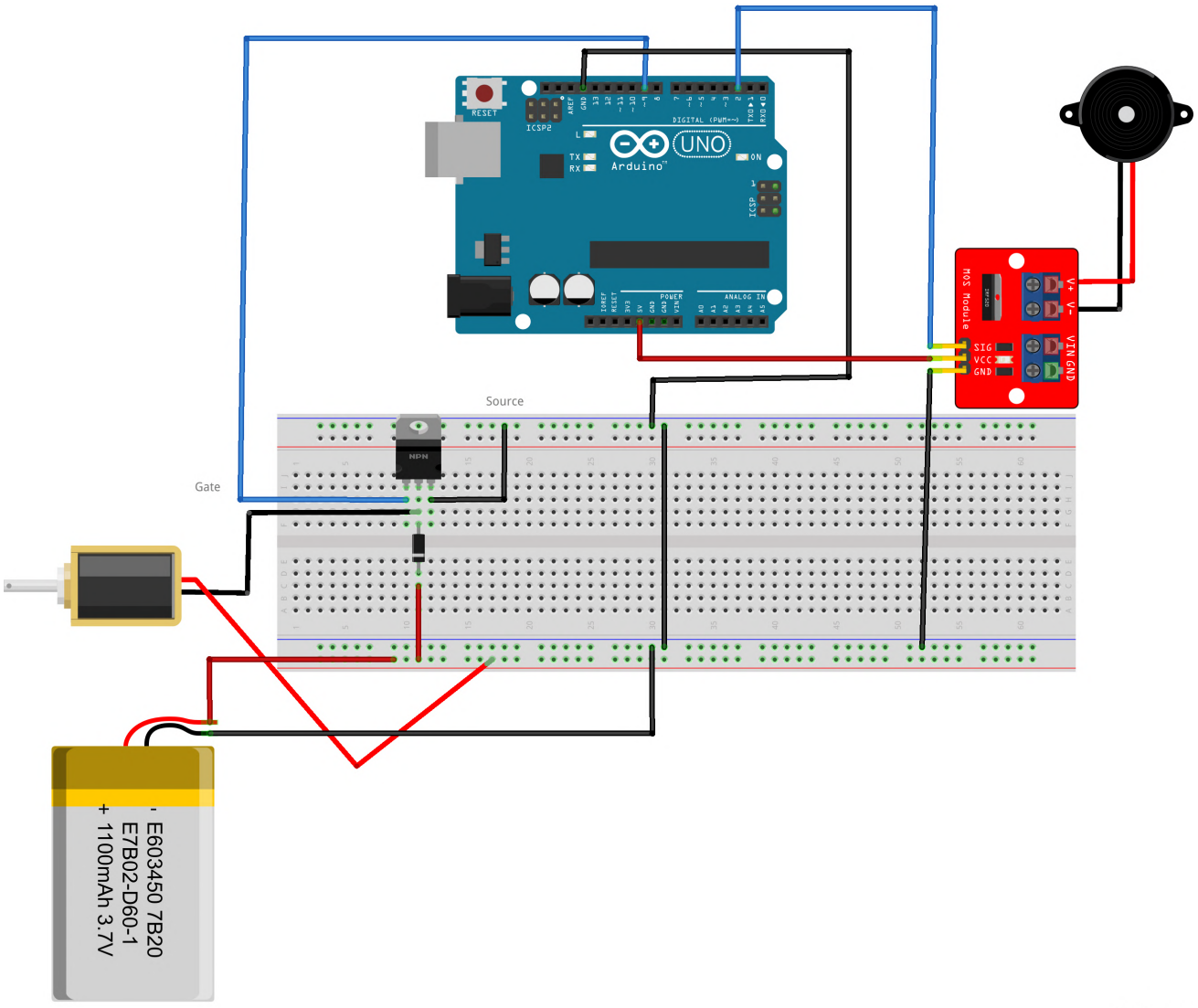


36. VR in-game view from the center of Khaju Bridge
37. Blueprint Event Graph Samples in This Project



38. Arduino circuit wiring: piezo, analog A0, MOSFET, solenoid, 12 V battery + diode protection

39. User testing session: participant holding Setar and wearing Meta Quest 3 headset

05 CHAPTER FIVE

FINDINGS AND DISCUSSION

05.1 Introduction

This section summarizes and interprets the findings of the quantitative and qualitative analyses of participants' experiences with the virtual reality recreation of Khaju Bridge. This experiment aimed to understand the extent to which the virtual environment induced emotional engagement, presence, cultural understanding, and usability, which represent the four key dimensions derived from prior research and validated by adapted questionnaires. Twenty participants completed the VR experience and a mixed-method questionnaire consisting of 18 Likert-scale questions (1-5) and two open-ended questions (Q19 and Q20). Quantitative results offer numerical insights into general patterns among users, while qualitative results provide a richer understanding of emotional, and cognitive, and cultural responses surrounding the experience.

05.2 Evaluation Questionnaire Design

In order to evaluate users' emotional, cognitive, and experiential responses to the Khaju Bridge VR Experience, a questionnaire was developed using a combination of modified items from four previously validated instruments, which have been frequently used in studies examining Virtual Reality User Experience (VRUX) and interaction with Cultural Heritage. The aim of this questionnaire was to address multiple dimensions of user response, emotional engagement, sense of presence, cultural understanding, and usability, and also ensure methodological rigor and comparability to previous research studies.

The instrument ultimately included a total of 18 closed-ended Likert scale items and 2 open-ended questions divided into four primary sections:

1. Emotional Engagement (Items 1–5)
   This tool measured the emotional reactions (e.g., joy, nostalgia, calm, and/or compassion) participants experienced from the immersive experience and auditory landscape based on the Geneva Emotion Wheel (GEW) [42].

   Scale: 5-point Likert (1 = Not at all, 5 = Extremely)

2. Sense of Presence and Immersion (Items 6–9):
   This tool considered how participants, "felt physically and/or cognitively" present in the virtual space (which included naturalness of movement and realism of the environment), based on the Presence Questionnaire (PQ) [43].

   Scale: 5-point Likert (1 = Not immersive at all, 5 = Completely immersive)

3. Authenticity and Cultural Understanding (Items 10–14):
   This section measured cultural identity, historical meaning, and emotional connection to Iranian heritage through the effectiveness of the VR experience by adaptation from prior cultural learning frameworks [7].

   Scale: 5-point Likert (1 = Not authentic at all, 5 = Completely authentic)

4. Usability and Aesthetic Appeal (Items 15–18)
   This section assessed participant evaluations of overall interface clarity, clarity from visual and sound aesthetics, and enjoyment. It was adapted from the User Experience Questionnaire (UEQ) [44].

   Scale: 5-point Likert (1 = Very poor, 5 = Excellent)

To summarize, the questionnaire had two open-ended questions:

- Q19: "What element of the VR experience, for you, was the most emotionally meaningful, and why?"
- Q20: "How would you have changed or improved on the VR experience, if even, to create a more immersive or meaningful experience?"

The resulting responses provided rich interpretive data to complement the quantitative data and facilitate a mixed-methods approach to understand cognitive and affective user experience.

VR Experience Evaluation Questionnaire

This questionnaire aims to evaluate users' emotional engagement, presence, and cultural understanding after experiencing the VR reconstruction of the Khaju Bridge in Isfahan.

1. Emotional Engagement

Instructions:
Please read each statement carefully and check (✓) or mark (✗) the box in the corresponding column that best reflects your experience with VR, based on the following scale:

Not at all - Slightly - Moderately - Very - Extremely

	Statements	Not at all	Slightly	Moderately	Very	Extremely
1	The atmosphere of the VR Khaju Bridge felt emotionally pleasant and calming.					
2	The experience made me feel emotionally connected to the bridge's history.					
3	The music and environmental sounds influenced my mood strongly.					
4	I felt empathy toward the people I saw in the VR scene (musicians, locals, families).					
5	The overall experience left a lasting emotional impression on me.					

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2. Sense of Presence & Immersion

Instructions:
Please read each statement carefully and check (✓) or mark (✗) the box in the corresponding column that best reflects your experience with VR, based on the following scale:

Not immersive at all - Slightly immersive - Moderately immersive - Very immersive - Completely immersive

	Statements	Not immersive at all	Slightly immersive	Moderately immersive	Very immersive	Completely immersive
6	I felt strongly that I was 'on' the bridge rather than in a virtual space.					
7	My movements and exploration in the VR environment felt natural and intuitive.					
8	The soundscape (music, water, voices) made the experience feel alive and real.					
9	The perspective and movement speed allowed me to focus on cultural details like architecture and people.					

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40. Questionnaire test, Page 1, Emotional Engagement Questions
41. Questionnaire test, Page 2, Presence and Immersion Questions

3. Authenticity & Cultural Understanding

Instructions:
Please read each statement carefully and check (✓) or mark (✗) the box in the corresponding column that best reflects your experience with VR, based on the following scale:

Not authentic at all - Slightly authentic - Moderately authentic - Very authentic - Completely authentic

	Statements	Not authentic at all	Slightly authentic	Moderately authentic	Very authentic	Completely authentic
10	The VR representation of Khaju Bridge felt visually authentic compared to the real site.					
11	The lighting, shadows, and textures seemed realistic and culturally accurate.					
12	The VR experience helped me emotionally connect with the cultural meaning of Khaju Bridge.					
13	The experience deepened my appreciation for Iranian heritage and traditional music.					
14	After the VR experience, I feel more motivated to learn about Iranian history and visit similar sites.					

4. Usability & Aesthetic Appeal

Instructions:
Please read each statement carefully and check (✓) or mark (✗) the box in the corresponding column that best reflects your experience with VR, based on the following scale:

Very poor - Poor - Average - Good - Excellent

	Statements	Very poor	Poor	Average	Good	Excellent
15	Navigating and interacting in the VR felt clear and easy.					
16	The VR interface and controls supported my experience rather than distracted me.					
17	The visual and sound design of the VR experience felt aesthetically pleasing.					
18	Overall, the VR experience was exciting and engaging.					

42. Questionnaire test, Page 3, Cultural Understanding Questions
43. Questionnaire test, Page 4, Usability Questions

5. Open-ended Questions

Instructions:
Please take a moment to share your thoughts in your own words.
Your answers will help us understand your personal experience beyond the numerical ratings.

19. What aspect of the VR experience affected you the most emotionally? Why?

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20. What would you improve or change in the VR experience to make it more engaging or meaningful?

Twenty individuals participated in the evaluation of the Khaju Bridge VR Experience and each participant completed a 20-item post-experience questionnaire drive from 18 of which were closed-ended Likert scale items, and 2 were open-ended items all of which were then assigned a numerical score for participants closed-ended response from 1 (Strongly Disagree) to 5 (Strongly Agree). The collected responses were exported and utilized in Microsoft Excel for quantitative processing. The mean (M) and standard deviation (SD) were calculated for each of the four centered dimensions: Emotional Engagement, Presence and Immersion, Cultural Understanding and Authenticity, and Usability and Visual Quality, as a means of summarizing participants' overall ratings and the associated variability in their ratings.

The two open-ended responses were pulled out as an independent qualitative data set. Textual responses were analyzed thematically for common ideas, themes, key terms, and emotional releases. The themes were then categorized into broader themes, indicating the most salient emotional experiences for users (Question 19) and corresponding user suggestions/alterations (Question 20), which will be recorded in greater detail in the subsequent sections.

05.3 Quantitative Results

The quantitative data collected from 20 participants were analyzed through descriptive statistics such as mean and standard deviation (SD) for each group of thematic questions.

Table 3. The quantitative result of the final test

Category	Mean	SD
Emotional Engagement	**4.38**	**0.66**
Presence & Immersion	**4.25**	**0.68**
Cultural Understanding & Authenticity	**4.25**	**0.67**
Usability & Aesthetic Appeal	**4.43**	**0.63**

The outcomes demonstrate that the VR experience attained high scores across all four areas, with averages over 4.0 for all categories. The lowest average fell in the Presence & Immersion area (M = 4.25), and Usability & Aesthetic Appeal reported the highest score (M = 4.43). Standard deviations were similar, varying from 0.63 to 0.68, which indicates fairly similar responses among participants that would convey a similar sense among participants as to the effectiveness of the VR experience.

Emotional Engagement:

Participants indicated a strong affective relationship toward the environment (M = 4.38). Descriptive reflections suggest that for some participants, positive and nostalgic feelings stemmed from the traditional music, sounds of running water, and sights of Safavid architecture, indicating things were 'calming,' and 'created a spiritual connection.' Participants suggested that emotional immersion was one area that had strength for the system.

Presence and Immersion:

Overall, being there, the "being there" experience was moderate to high (M = 4.25). Overall, the spatial design, realistic lighting, and environmental sounds generally contributed in a suitable and appropriate manner to indicate that immersion was solicited. The overall higher SD (0.68) suggests there may have been more variance in perceived realism, and embodiment may have varied due to differing participant familiarity with technology or comfort in headsets.

Cultural Perception and Experience Representation:

This theme (M = 4.25) corresponds to the participants' emotional and cognitive engagement with Iranian heritage. While they enjoyed the historical representation of architectural details and authenticity, some wished for additional interpretation or a story to foster understanding.

Usability and Visual Quality:

This theme was rated the highest across all dimensions (M = 4.43), suggesting well-designed interfaces, interactions, and visuals were all part of the experience; users appreciated the “ease of exploring” and that it was “visually beautiful,” having little frustration or confusion. The consistency (SD = 0.63) also reflects the accessibility and polish of the technology overall.

05.4 Qualitative Results (Open-Ended Responses)

After numerical ratings, participants offered open-ended responses based on their emotional/cultural impressions of the VR experience. The responses went through thematic coding to arrive at themes that were frequently noted in response to sound, nostalgia, interactivity, story, etc.

05.4.1 Qualitative Examination of Open-Ended Responses (Q19)

I used a patterned, inductive thematic approach to analyze the open responses to Question 19 (What part of the VR experience had the most emotional impact on you, and why?). Twenty responses were coded into short semantic units and categorized into recurring emotional triggers that were analyzed as four central theme categories:

Interactive Heritage Rituals (playing the Setar and poem interaction), Restored Natural Soundscapes (river and ambient sounds), Social an Communal Atmosphere (collective singing and everyday life), and Narrative, Local Storytelling (the elder's narration). A fifth, overlapping outcome item identified was Personal Nostalgia and Identity, which appeared across all four theme categories. Among the four aspect categories, a participant indicated the 'Authentic Soundscape' the most often (11 times), thereafter 'Nostalgia and Identity' (10), and then 'Interactive Setar + Poem ritual' (9 times). Only a couple of participants said that they wished there had been more substance in the storytelling.

Theme	Count (out of 20)	Percentage (%)
Authentic soundscape (music + water)	11	55%
Nostalgia / Personal memory	10	50%
Setar + poem (interactive ritual)	9	45%
Participation / unlocking	7	35%
Old-man narration	6	30%
Collective singing	5	25%
Children / daily life	4	20%
Desire for more depth	2	10%

Table 4. Frequency of Theme for Question 19

These findings further substantiate that sound and embodied interaction are the sources of emotional resonance for participants in the Khaju Bridge VR experience.

05.4.2 Qualitative Examination of Open-Ended Responses (Q20)

Responses to Question 20 (“What would you improve or change in the VR experience?”), which were open-ended (N = 20), were analyzed using a thematic approach, highlighting six overarching themes to the responses: (1) Assumption of More Interactive Freedom / Agency, (17 responses); (2) Accessibility / Cultural Understanding, (11); (3) Emotional and Narrative Closure, (10); (4) More Details Related to Sensory / Atmosphere, (9); (5) Local Identity / Everyday Life, (8); and (6) Technical / Comfort Improvements, (4).

The predominant request by participants included more interactive freedom and agency, such as exploring anywhere on the bridge rather than along the guided path, or talking to a character, in which participants valued the increased aspect of presence. Accessibility questions or requests were consistently identified with requests for subtitles or multilingual narration, or cultural context that would build understanding. With regards to emotional closure or narrative closure, some users suggested that the experience discussed end with an emotional reflection that would link the historical or past situational context to the present environmental situation of the bridge. The suggestions to have more sensory realism (sound, lighting, haptics), or including more cues as to local culture (an accent or more daily life experience) reflect the value of authenticity and identity of the immersive heritage.

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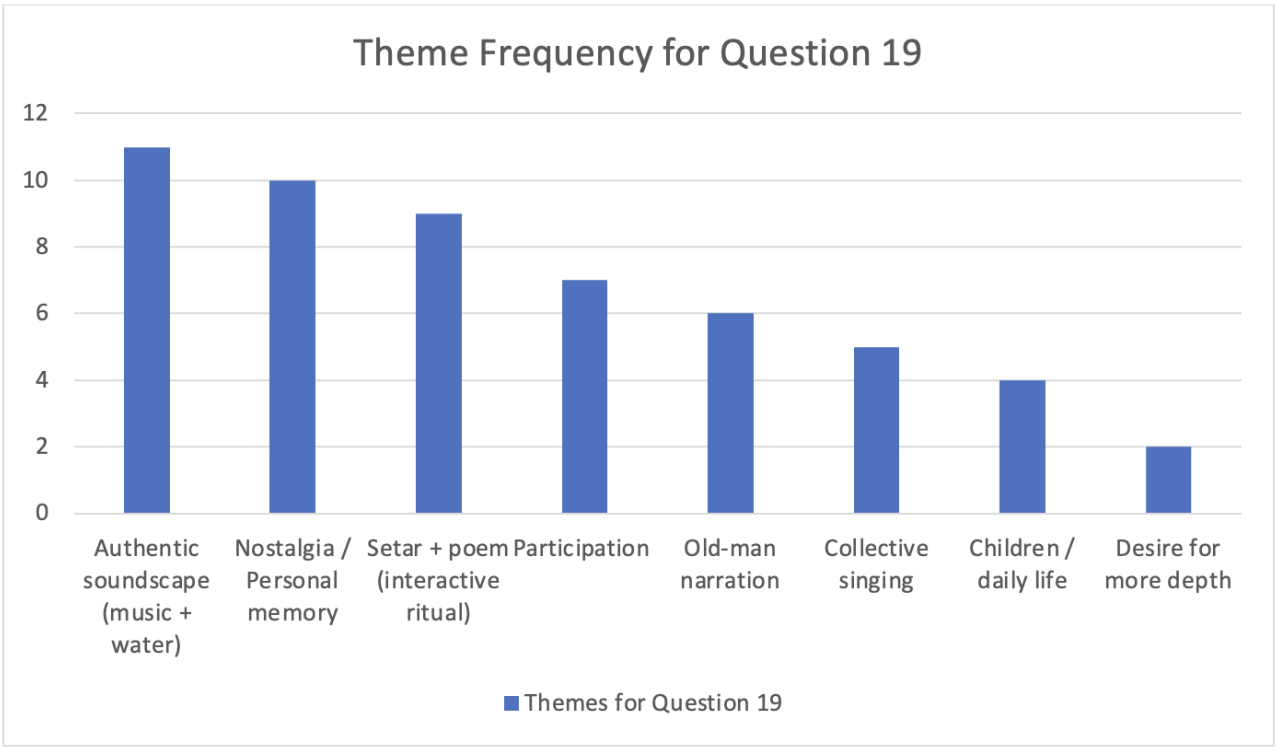

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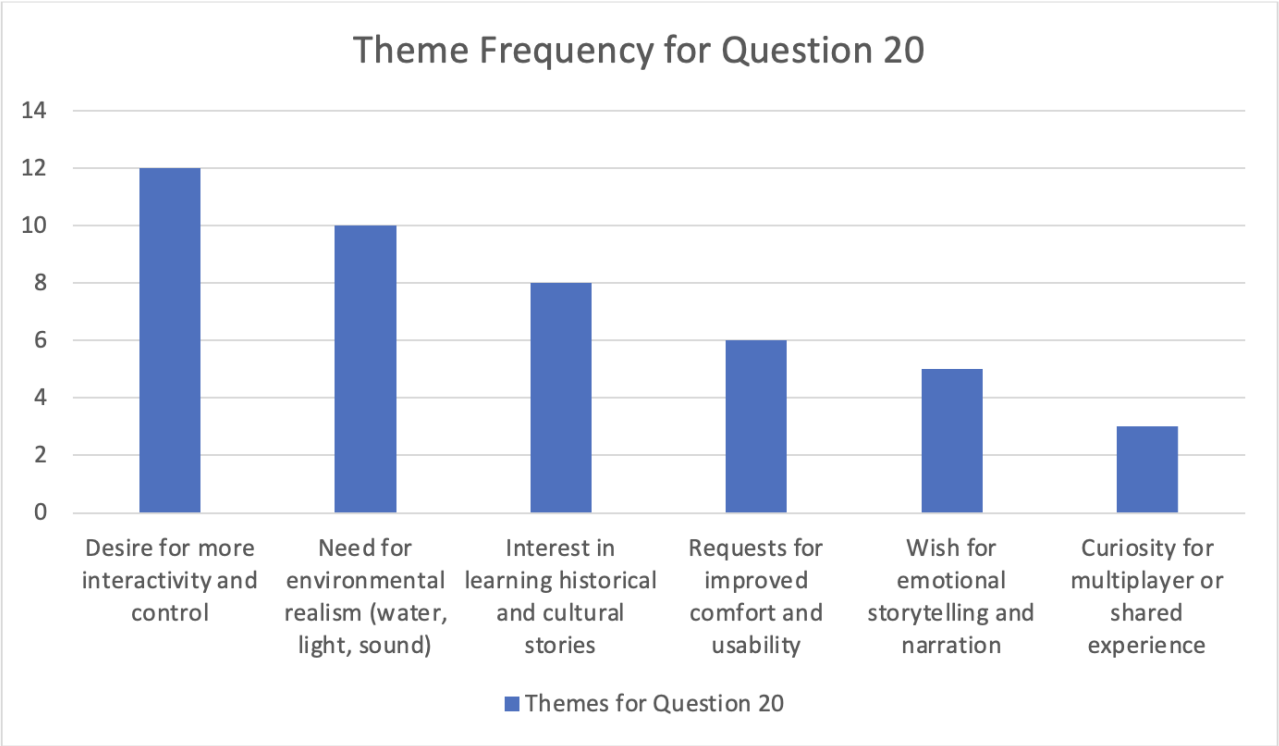

45. Frequency of Theme Chart for Question 19 (Bar chart showing counts for each theme, “Authentic soundscape” was highest, and “desire for more depth” was lowest.)
46. Frequency of Theme Chart for Question 20 (Bar chart representation, "ff. Putting up with less interactivity" is the highest, and "ff. Having curiosity for a multiplayer experience" is the lowest.)

Theme	Count (out of 20)	Percentage (%)
Desire for more interactivity and control	12	60%
Need for environmental realism (water, light, sound)	10	50%
Interest in learning historical and cultural stories	8	40%
Requests for improved comfort and usability	6	30%
Wish for emotional storytelling and narration	5	25%
Curiosity for multiplayer or shared experience	3	15%

Table 5. Frequency of Theme for Question 20

The areas of suggestion reinforce that users conceptualize the next version of the Khaju Bridge VR Experience to be a more open, participatory, and emotionally reflective space.

Themes and Frequencies (Q19 + Q20 Combined):

Theme	Frequency (out of 20)	Percentage (%)
Authentic soundscape (music + water)	11	55%
Nostalgia & personal memory	10	50%
Interactive rituals (Setar + poetry)	9	45%
Sense of cultural continuity	8	40%
Narrative & local storytelling	6	30%
Social & communal atmosphere	5	25%
Everyday life representation	4	20%
Desire for deeper content	3	15%

Table 6. Q19 + Q20 Combined results

The authentic soundscape appeared to serve as the main concept, which shows that participants saw audio as the strongest emotional and cultural aspect. Traditional instruments, Setar, combined with ambient flowing water, produced a sense of "living memory" that could connect users emotionally to Khaju Bridge.

Example quote:
"Listening to the Zayandeh Rud again was like a prayer, it healed the fresh wound attending the dry riverbed in real life."

A number of individuals (half) expressed that they appreciated nostalgia and cultural identity being presented in the experience. To varying degrees, the VR experience evoked memories of family trips or social occasions in Isfahan. It seemed to create not only an idea of pride in one's Iranian heritage but also animated that culture in the VR experience.

For example:
"It was like hearing from a grandparent about the past, the accounts felt intimate."
Activities that were interactive, like playing the Setar or discovering poetry by Sa'eb Tabrizi, were called out as having emotional resonance. They transformed users from observers into participants and increased the engagement level.

Also acknowledged was the narrative and social environment in the VR experience, but there still remained several users who would have liked the narrative to last longer or have more interactions between characters. Children, families, and musicians in the scenes were valuable to have life in the VR experience rather than the scene being a monument.

Lastly, a couple of individuals spoke about wanting more depth, asking for historical facts, or architectural explanations to be integrated without feeling out of place (natural development) of the conversation in the VR experience.

05.5 Discussion and Interpretation

The answers from both sections of the study highlight that the VR reconstruction of Khaju Bridge was successful in furthering emotional and cultural engagement while providing a high degree of usability. Numerous patterns illustrated were found that coincide with the main objectives of the study.

Emotional Connection as Core Value:

The strongest dimension, emotional engagement (M = 4.38), shows that users did not view the experience as simply educational, but as a form of emotional storytelling. This validates findings from similar studies, such as the EMOTIVE study (Antonine Wall) and the Seoul City Wall study, in which both narrative and soundscapes were intriguing facets of user affective immersion.

Emotional engagement and an understanding of culture show thematic overlap, demonstrating that an emotional connection to the physical environment also instills greater intellectual appreciation of Iranian heritage.

The Influence of Sound and Atmosphere:

The overall qualitative data reveal that sound design, specifically the relationship between the water and music, was a key contributor to immersion and nostalgia. This supports existing literature on multimodal sensory experiences in VR heritage, which indicates that aural cues strongly influence notions of authenticity to a location.

Participant comments on the Setar music, as well as the natural bouncing sound of the water under the arches of the bridge, demonstrate how spatial audio helps to create a cultural presence in immersive audio-visual experiences. For many, the sound of Zayandeh Rud had emotional connotations related to loss and memory, adding complexity to the experience that is not accessible in the visual data.

Presence and Realism:

Although the means of presence (M = 4.25) were slightly lower, user comments suggest that the feeling of "being there" was achieved through the scale, light, and movement. However, a few participants brought up their awareness of the headset and some differences in motion, suggesting there is still an opportunity to refine some of the cues of embodiment and the smoothness of head tracking.

Cultural Comprehension and Narration:

While participants appreciated the narrative direction provided by the voice of the elder, there appeared to be an interest in additional historical context; the need for a story narrative still exists, but layered with a choice of either a guided narration or free exploration mode, with the option to utilize hotspots for learning in between emotional, user-driven engagement and educational engagement.

Usability and Visual Aesthetic:

The high usability rating (M = 4.43) and low SD (0.63) show that the system provided intuitive and visually logical navigation among multiple clues and interactions. Participants have free movement in the environment and expectations of interaction without considerable technical challenges or struggles. Together, these link to a refined user experience. The aesthetic qualities of the light, reflections, and materials offered another immersive component for overall participant satisfaction.

05.6 Design Considerations for Cultural Heritage in VR

Through this study, a few positives arise for considering design in developing VR experiences for the heritage space:

1. Emphasize audio and multisensory design:
   Soundscapes (water, music, voice) affect emotional intensity and authenticity, with the opportunity for dynamic mixing depending on user position to en hance presence.

2. Facilitate ritual-based interactions:

Encourage users to employ significant cultural gestures (i.e., playing an instrument or reciting poetry) to change their engagement from passive viewing to active participation through embodiment.

3. Include adaptive storytelling layers:
   Create guided/specific and exploratory/curiosity-driven opportunities for users, which can be differentiated into ways of engaging with a type of learning style.

4. Create a sense of social presence
   Enhancing social presence with NP characters could affirm the collective identity of cultural framing spaces like Khaju Bridge.

5. Create a bridge between then and now
   Investigate narrative approaches that grip Safavid life (the life of the city) to their contemporary emotional realities, a dry river or loss and rejuvenation.

05.7 Limitations and Future Work

Although findings are encouraging, there are some limitations to consider.

The sample size (N = 20) was adequate for exploratory evaluation but not large enough for statistical generalization. Moreover, the sample was predominantly Iranian, which impedes cross-cultural comparison of emotional responses or any generalization of emotional responses outside of the culture represented. Familiarity with the head-mounted display(s) also varied across participants, and participants might carry different perceptions of "presence," which may have affected emotional responses.

Future studies could consider larger, more diverse samples, physiological emotion tracking (heart rate, GSR, etc.), and establish comparative testing outside of this heritage site. A feature that could deepen cultural learning would be an integration of real-time interaction with experts or guides to the virtual environment.

05.8 Conclusion

To sum up, the assessment demonstrates that Khaju Bridge's VR reconstruction positively evoked emotional engagement, presence, and cultural connection among users.

Participants' feedback suggests emotional authenticity through sound and interactivity had the most significant influence on engagement. The experience allowed the participant to not just "see" the bridge but feel its atmosphere and meaning while creating an immersive narrative that closed the gap of time.

These findings confirm the driving hypothesis of the thesis:

Virtual Reality has the potential to meaningfully enhance emotional and cultural engagement with heritage sites when designed using multisensory, narrative, and participatory modalities.

05.9 Future Directions

Even though the Khaju Bridge prototype accomplished several key aims, it opened up a number of avenues for future exploration and extension.

1. Wireless Setar and multi-sensory installation: The next stage would be to replace the wired Arduino shield with a wireless microcontroller (such as ESP32 or BLE module) so that the audience can engage unencumbered, thereby paving the way for use in museums. Furthermore, a multi-sensory installation could involve vibration floors, ambient scent diffusion, and haptic seating to deepen the experience of embodiment.
2. Multi-user collaborative experience: Wouldn't it be fascinating to have scheduled sessions with multiple users, so that they could engage in experiencing the bridge together, while cooperating to sing, play Setar, co-create rituals, and regenerate the social community of the original site?
3. AI-initiated narrative adaptation: Machine learning could examine real-time behavior of user participants (such as motion, gaze, rhythm) in order to adapt the sequence of the narrative, the lighting or soundscape of the experience. In this way the experience could unfold a personally emotional journey, while retaining its cultural continuity.
4. On-site mixed reality version: A mixed reality incarnation at the actual Khaju Bridge may engage both the physical environment with digital overlays to create a "living museum" experience through direct engagement with historic scenes.

47. The Khaju Bridge, a place of reflection and presence

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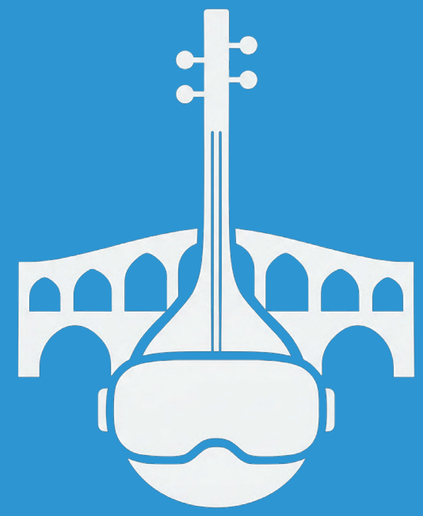
Research Report

Emotive Storyliving

Constructing a Virtual Reality Experience of Khaju Bridge to Enhance Emotional Connections to Cultural Heritage



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Abstract

This article presents Emotive Storyliving, a virtual reality (VR) experience that attempts to create an emotionally engaged connection to cultural heritage through embodied narrative and tangible participation. Discussed here, Emotive Storyliving is cantered around the Khaju Bridge in Isfahan, Iran, and the process of embodied, sound, and narrative design used to create a more emotionally engaging experience around this fleeting temporal site. Using a Research through Design (RtD) research methodology, the project combines ethnographic fieldwork, 3D modelling, Unreal Engine development, and embedded Arduino-based hardware. The findings of the project showcase how VR can serve not only as a representational tool but as a medium for reactivating collective memory, establishing cultural connection, and creating a new form of digital ritual.

KEYWORDS | VIRTUAL REALITY (VR), EMOTIONAL ENGAGEMENT, CULTURAL HERITAGE, RESEARCH THROUGH DESIGN (RTD), IMMERSIVE EXPERIENCE

1. Introduction

There is an increasing awareness that Virtual Reality (VR) is a compelling medium for the preservation, understanding, and emotional storytelling of cultural heritage [1][2]. Unlike traditional methods such as photography, written documentation, or a static 3D scan, immersive media can allow audiences to experience heritage rather than simply observe it. This transition from representation to re-experience introduces new forms of affective engagement, where presence, embodiment, and empathy become active modalities of cultural interpretation [3][4].

More recently, in research related to digital heritage, emotional resonance has emerged as an important aspect of making virtual reconstructions significant for contemporary audiences [10]. Because of sound, gesture, and atmosphere, VR that uses emotional storytelling can support a reconnection to the “sense of place” that is often diminished in technical reconstructions. Multisensory immersion enables a visitor to engage both cognitively and sensorially and emotionally, leading to deeper memory connections and personal reflection [11].

The Khaju Bridge in Isfahan is a case study for a location where architecture, poetry, and social ritual peacefully coexisted during the Safavid era [7]. The bridge was constructed with civic infrastructure and a poetic stage in mind, an assembly point for music and verse in the river's flow. However, Khaju Bridge often stands in silence now, its buzz of sounds quieted by the absence of water and people.

Here, through Design (RtD) research methodology [1][2], we consider how immersive technologies can enact the atmosphere lost at the bridge by replicating the physical form of the site along with its emotional and cultural being. The study seeks to reboot the visitor experience from a passive observer perspective to an active participant, someone who feels, engages, and meditates in the reconstructed setting [8][9]. The study is situated at an intersection of design research, cultural heritage, and affective computing to investigate how narrative-driven interaction, sensory prompts, and embodied engagement may create a new sense of belonging and empathy to the past.

Figure 1. The Khaju Bridge changes over the years.

The study poses three overall questions:

1. How can immersive design encourage an emotional engagement with both tangible and intangible heritage?
2. What is the role embodied interaction having in perceived authenticity and presence?
3. How can mixed material artifacts (physical and virtual) mediate cultural memory through time?

2. Related Works

2.1 Emotional Engagement in Virtual Heritage

Emotional engagement is widely acknowledged as one of the key factors in heritage learning and memory retention [10][11]. The EMOTIVE Project (EU Horizon 2020) showed that storytelling and engaging with

history in VR positively influenced emotional engagement and showed increased empathy for history in this context [12]. Also, Scherer's Geneva Emotion Wheel (GEW) [13] provides an empirical psychological approach to measuring affective intensity during immersive experiences. Researchers often differentiate VR from basic visualization, arguing for the importance of the embodied and experiential narrative that captures emotional and sensory experience as an integral part of our interpretation of the past [27], [43], [44].

In one example of this function, Economou et al. (2021) provides an example, from the EMOTIVE project on the Antonine Wall, of how visitor engagement with digital storytelling techniques using immersive technology elicited emotional responses between visitors/participants and ancient heritage objects, engaging participants in empathetic and personal processes of identification with the past [31]. Choi et al. (2022) offered a similar view by describing VR as a "storyliving" medium that creates active audiences who participate in a co-construction of meaning through embodied action and interaction [6].

2.2 Presence, Authenticity, and Cultural Experience

Presence, the sensation of "being there", is one of the most well-known characteristics of immersive environments [14][15]. The principles of presence, empathy, and engagement provide the psychological foundation for VR experiences that provoke emotional involvement in the context of cultural heritage [46]. Witmer and Singer's Presence Questionnaire (PQ) [16] is one of the most common measurements of VR presence.

In a related work, Chang et al. (2023) extend presence in cultural virtual reality to not merely support realism but to develop empathy and allow users to emotionally cross the temporal and cultural gap between the past and present [47]. Work in cultural VR [17][18] highlights that authenticity arises not just from Visual Realism but from sensory coherence and meaning through the narrative structure.

2.3 Research through Design in VR Contexts

Designing through Design (RtD) has emerged as a legitimate and valued methodological approach within Human-Computer Interaction (HCI) [19][20]. RtD integrates design practice with empirical research as a very particular form of inquiry through iterative prototyping [21][22]. In the context of cultural heritage, this allows designers to investigate experiential hypotheses by testing the extent to which a particular form of embodiment or interactivity generates emotional resonance [23].

2.4 Interaction, Sound, and Hybrid Artifacts

User engagement is the behavioural "marker" of presence and empathy [48]. The incorporation of physical interfaces, such as tools or props, has been found to improve sensory realism and memory encoding [24][25]. Initiatives like “Sonic Palimpsest” [26] and “Re-Live History” [27] demonstrate that soundscapes and gestural interactions evoke feelings, particularly when tied to an authentic cultural context. In addition, Škola et al. (2023) and Chang et al. (2023) found that multimodal feedback, visual, auditory, and haptic, enhanced memory encoding [46], [47].

Table 1. The most related papers summary.

Authors	Year	How Emotion is Defined	Method Used	Actions Used	Emotion Factors Measured	How Measured
Economou et al. [44]	2018	Emotional engagement via affective storytelling	Observation and self-report survey	Interaction with digital VR storytelling	Emotional engagement	Questionnaire (Likert scale)
Yu et al. [45]	2025	Embodied emotion via cultural performance	Motion capture, rigging, user testing	Martial arts gestures, character-driven VR	Anger, rhythm, immersion	Observation, animation quality review
Škola et al. [46]	2020	Presence, engagement, immersion	360° storytelling VR and post-survey	Guided exploration	Presence, engagement, enjoyment	Presence/immersion scale
Chang et al. [47]	2025	Enjoyment, immersion, presence	Pre/post survey and comparative modelling	Digital storytelling in exhibition	Enjoyment, presence, continued intention	Questionnaire and statistical model
Irshad et al. [48]	2020	Triggered emotional response via narrative	Interactive VR app and user study	User choices in narrative	Emotional response, engagement	Self-report and engagement scoring
Choi et al. [43]	2024	Emotional engagement through storyliving	Interactive VR tour and observation	Interactive exploration, narrative triggers	Emotional engagement	Post-experience survey & interviews
Barbara et al. [27]	2022	Emotional learning experience via VR	Story-driven learning in VR and post-survey	Cultural tasks	Immersion, emotional response	Questionnaire and learning impact score

3. Methodology

The research used a Research through Design (RtD) methodology [28]. The research framework cantered on iterative backgrounds of research, ideation, prototyping, and evaluation.

3.1 Field Research and Data Collection

A field ethnography project was conducted at the Khaju Bridge in Isfahan, using a variety of visual, auditory, and narrative documentation techniques to better understand the emotional and cultural meanings of the site. To document the sensory character of the environmental site at different times of day, the fieldwork produced 206 photographs, 21 video clips, and 21 recordings of ambient sound. Short and longer interviews were conducted with local residents, artists, and tourists, to develop better understandings of their memories, attachment to, and interpretation of the bridge as a living heritage [29][30].
The contextual backdrop extends to a sensory ethnography approach in which this work emphasizes first-hand embodied experience rather than a detached object of study. The field notes documenting observations were in a diary style describing both patterned behaviours (e.g., people playing music, crossing the bridge, and resting in proximity to the arches) and responded to environmental sounding cues with the addition of non-static environmental cues such as water flow, echo, and light reflecting off the

water, allowing for rich qualia to develop qualitative data for the foundations of additional scenario-based design development.

3.2 Concept Development and Scenario Design

The field study generated insights that were systematically coded and synthesized with an affinity diagram and persona development to determine patterns of emotional and cultural engagement [31]. Two personas were identified:

1. The Local Resident - motivated by reminiscence and personal memory;
2. The Tourist - motivated by exploration and curiosity;

A storyboard and experience flow diagram were made for each persona to represent the temporal sequence of the VR experience (from arrival and exploration, to contemplation and emotional culmination). The central conceptual theme was the Setar Ritual, where every time the strings of a virtual instrument were plucked, it induced a poetic and visual response: verses appeared as glowing particles, and sound waves danced across the physical bridge. This metaphor of resonance between sound, poetry, and space served as the content and design framework for the project. In this way, the scenario combined tangible interaction, sonic immersion, and cultural meaning as it exemplified the principle of research through design as an iterative discussion and negotiation between concept and making [1][20].

3.3 Implementation

The project was initiated and produced entirely in Unreal Engine 5.4 on a MacBook Pro M3 (2023) and tailored to Meta Quest 3 standalone VR export [32]. The project was realized using Blueprint visual scripting, Unreal's node-based system for designing logic through graphical connections as opposed to text-based code [33].
This method allowed for a rapid way of prototyping, allowing for the real-time iteration of visual, audio, and interaction aspects of the work. Breakthrough Blueprints controlled the Setar interaction logic, narrative sequencing, and dynamic lighting transitions in relation to user engagement. Each group of nodes represented a modular piece of logic (e.g., sound trigger, animation timeline, or user input event) that allowed the creative process to be transparent and flexible.
Haptic feedback and the incorporation of ambient sound cues were also woven into the Blueprints, keeping the development stage aligned with the coherence of the technical organization, together with its aesthetic-intentional design considered in earlier stages. The outcome highlights how visual scripting can function as both a creative and analytical way of expressing in research-through-design workflows.

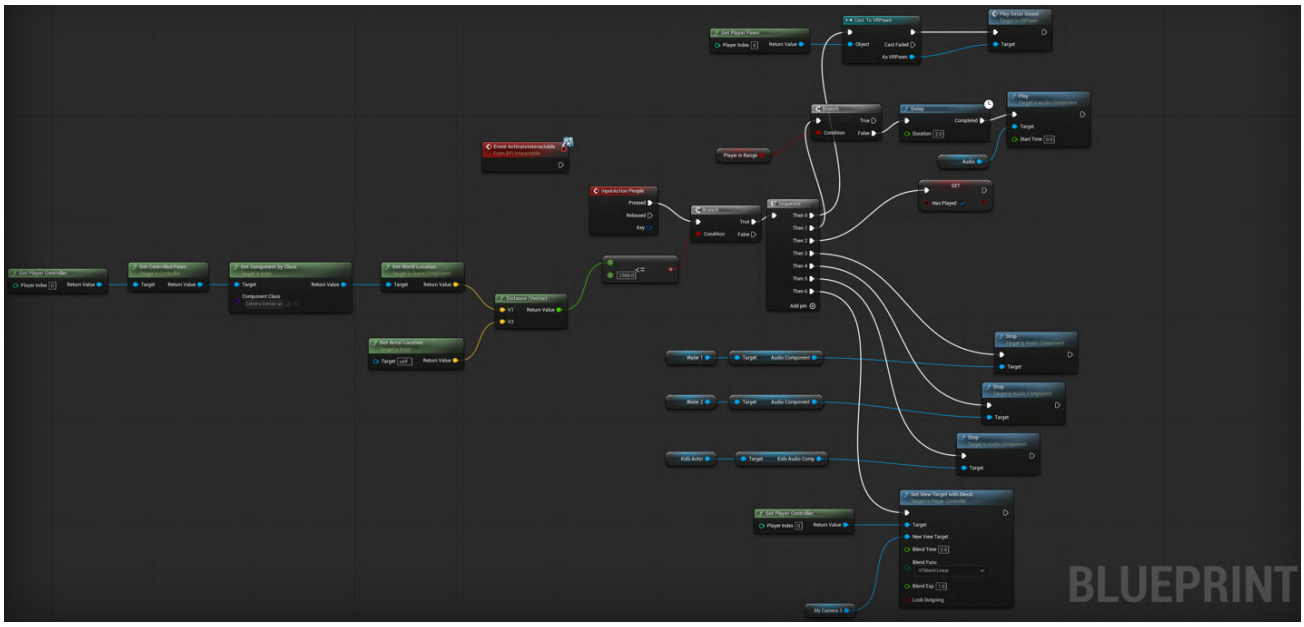

Figure 2. Unreal Engine Blueprint node-based scripting interface.

A physical Setar prototype was built using a body that I modelled in Rhino with an embedded Arduino UNO R4, piezo sensors, and a MOSFET-driven solenoid motor [34]. The piezo sensor converts vibration into a digital trigger to communicate with Unreal Engine over serial to cause a story event.

Figure 3. A physical Setar prototype with the Arduino circuit and its sensors inside.

4. Results and Discussion

4.1 Quantitative Evaluation

Twenty participants (10 traveller and 10 local) engaged with the final VR prototype. Each participant filled out an 18-question combined questionnaire, based on four validated questionnaires:

- *Geneva Emotion Wheel (GEW)* [13]
- *Presence Questionnaire (PQ)* [16]
- *Cultural Learning & Connection* [27]
- *User Experience Questionnaire (UEQ)* [35]

Using a 5-point Likert scale (1-5), each item was scored. Outputs were calculated and analyzed in Excel; means and standard deviations were calculated for each category.

Table 2. The quantitative result of the final test.

Category	Mean	Standard deviation
Emotional Engagement	4.38	0.66
Presence & Immersion	4.25	0.68
Cultural Understanding & Authenticity	4.25	0.67
Usability & Aesthetic Appeal	4.43	0.63

The results showed high levels of emotional engagement (M=4.6, SD =0.42), high levels of presence (M=4.4, SD =0.55), good utilities for cultural understanding (M=4.3, SD =0.48) and high usability (M=4.5, SD = 0.39).

4.2 Qualitative Results

The open-ended questions (Q19–Q20) generated rich emotional information.
Thematic analysis [36][37] revealed emotional triggers for this context that would not fit into other categories of sound triggers: authentic soundscape, nostalgia and identity, interactive ritual and storytelling [38]; sound and music were the most consistent triggers, followed by nostalgia for local heritage.

Participants articulated emotional resonance as “a sense of unlocking history” and “hearing the bridge speak back.” Feedback highlighted the Setar and Poem sequence as the most emotionally impactful.

4.3 Interpretation

Audio was considered the most robust affective media [39]. However, while tangible interaction emphasized both embodiment and agency, visual, auditory, and tactile cues produced authenticity [40][41]. Participants referred to sound as “the emotional glue” that connected them to the space, especially the causal resonance of the setar and sounds of the river in the background. The spatialization of audio enhanced both presence and emotional anchoring, which aligns with previous research illustrating sound as a primary contributor to affective realism in virtual heritage contexts [26].

Moreover, the embodied interaction of engaging with the physical setar asked users to act, rather than observe, changing them from passive visitors to emotional participants. This follows Zimmerman’s perspective that design is a medium for situated meaning-making [1]. Collectively, these multisensory layers created a unified experience where emotion, action, and place intertwined, reinforcing the message that authenticity in the virtual heritage sense is not simply visual fidelity, but embodied, affective engagement, recreating cultural memory.

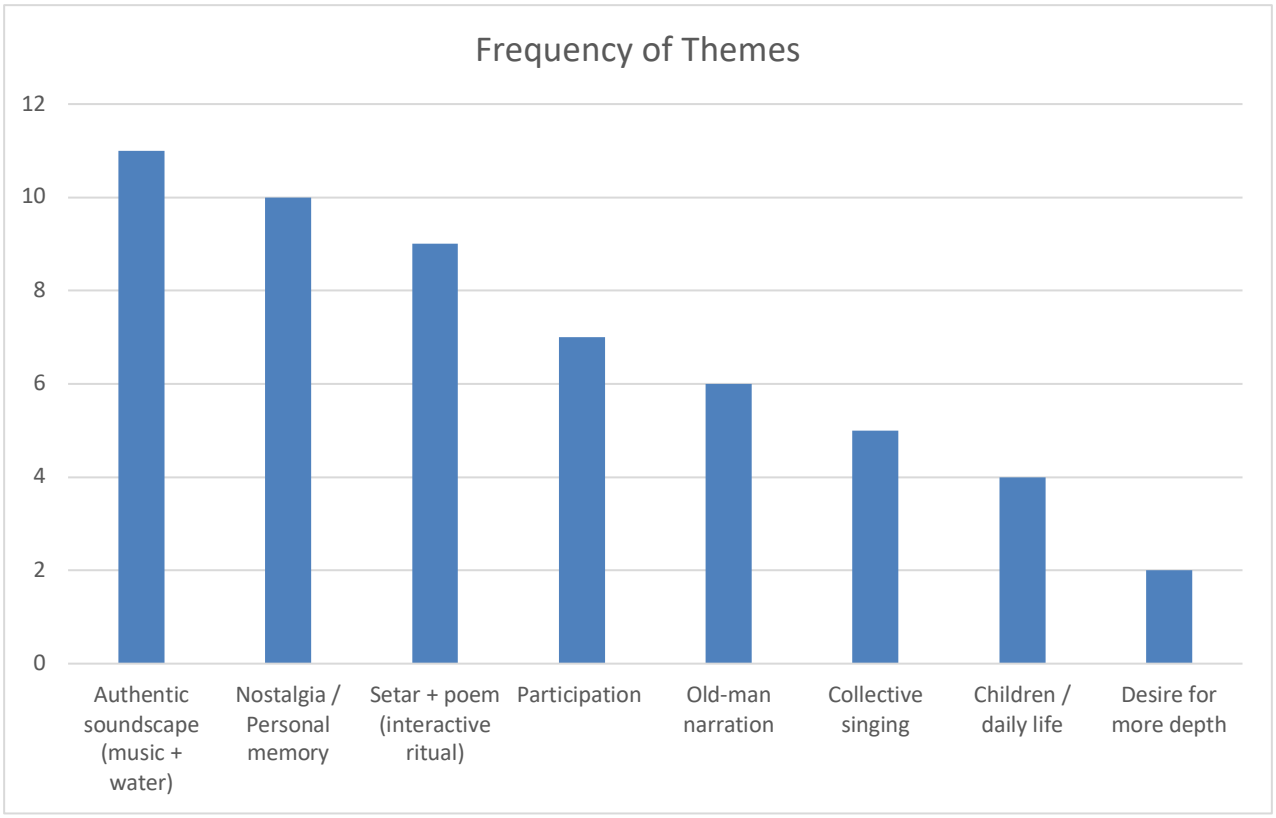

Figure 4. Frequency of Themes (bar chart: soundscape highest, "desire for more depth" lowest).

4. Conclusion

This research showcases the potential of Research through Design (RtD) as a methodological approach for investigating the emotional and cultural reconstitution of heritage in VR settings [1][20]. Blending ethnographic inquiry, scenario-based design, and immersive prototyping, the Khaju Bridge experience represented a historical atmosphere in a multisensory narrative where users could see, hear, and feel traces of the past through embodied experience.

The VR prototype successfully facilitated reconnection with a living memory, engagement in cultural heritage, not as spectators, but as participants in a shared ritual space [42]. Users articulated a sense of nostalgia, awe, and presence that stemmed from tactile engagement with the Setar instrument, embodied sound, and visual poetry. This is indicative of the role immersive environments can play as containers of emotional archives, whereby intangible dimensions of culture, such as rhythm, sound, and ritual, are preserved.

However, there were some technical constraints that arose during implementation. The Meta Quest 3's standalone rendering could only provide limited texture resolution and accurate light, which sometimes resulted in the loss of realism in reflective surfaces. Additionally, the delay of the Arduino's serial communication led to a small lag between physical gestures and corresponding audiovisual feedback. Although these limitations did not inhibit engagement, they present an opportunity for continuation to optimize and synchronize hardware.

In the future, iteration of this research could be facilitated with wireless sensory modules (e.g., ESP32 or BLE), exploring established multi-user experiences, or adaptive storytelling through the use of machine learning to offer personalization of the experience. These changes could evolve the prototype into a living, responsive installation capable of layering digital narratives over the physical story of heritage.

Ultimately, this project is an important contribution to the wider conversations concerning emotional presence and cultural empathy in immersive design for heritage. And supports the position that VR, when

understood as a poetic and embodied medium, can recover the affective quality of places and stories that have long gone quiet through time [43].
The next stages will focus on:

1. Interface for a wireless Setar: the existing Arduino is to be replaced by the ESP32, which will provide the mobility.
2. Multi-user collaborative experience: allowing for shared ritual and co-presence.
3. AI-driven adaptive narrative: modifying light and sound based on the user's emotional experience.
4. On-site Mixed Reality version: users will experience virtual storytelling over the real Khaju Bridge.

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