

# Guardians of Matariki: Evaluating the VisionOS for Māori Storytelling

A research component submitted to  
Auckland University of Technology in  
fulfilment of the requirements for the degree of  
Masters of Philosophy of Creative Technologies

Supervisors

Dr. Rachel Shearer

Assoc. Prof. Stefan Marks

August 2025

by

Thomas K Perese

School of Future Environments: Creative Technologies

# Abstract

This exegesis presents the design, development, and internal evaluation of *Guardians of Matariki*, a spatial storytelling prototype for Mixed Reality, developed specifically for the Apple Vision Pro (AVP). The project addresses the research question:

- *How can immersive spatial storytelling enhance users' engagement with Māori culture through a Mixed Reality application?*

Centred on the Matariki star cluster, the prototype explores how cultural content can be communicated through varying levels of immersive interaction.

A structured methodology was applied using the Research Onion model. The research philosophy combined interpretivism, pragmatism, and kaupapa Māori to support culturally grounded, reflective development. The approach employed abductive reasoning and Design-Based Research (DBR) within a mixed methods framework, with qualitative and quantitative self-assessment, journaling, and heuristic walkthroughs used for data collection and analysis.

Three levels of immersion were developed and evaluated: a 2D windowed interface, a 3D volumetric interface, and a full space immersive environment. NASA Task Load Index (NASA-TLX) and the Technology Acceptance Model (TAM) were used to assess cognitive load, usability, and engagement. Results indicated that increasing spatial immersion correlated with enhanced narrative embodiment, reduced cognitive load, and improved cultural clarity.

The development process followed an Agile (SCRUM) sprint structure, using tools such as Reality Composer Pro, Xcode, SwiftUI, and Meshy AI. Culturally aligned UX heuristics and Apple's Human Interface Guidelines informed design decisions.

Limitations include the absence of external user testing and co-design due to time and hardware constraints. All findings reflect internal evaluation and are not generalisable.

This study contributes to Indigenous digital storytelling, spatial computing, and immersive design. It demonstrates a culturally responsive method for developing immersive applications and proposes a foundation for future work involving user collaboration, cross-platform delivery, and expanded narrative design.

# Table of Contents

<b>ABSTRACT</b> .....	<b>2</b>
<b>LIST OF FIGURES</b> .....	<b>5</b>
<b>LIST OF TABLES</b> .....	<b>7</b>
<b>CHAPTER 1: INTRODUCTION</b> .....	<b>9</b>
<b>CHAPTER 2: LITERATURE REVIEW</b> .....	<b>14</b>
AR 2.1 – MY INTEREST AND MOTIVATION IN AR.....	14
AR 2.1.1 – BACKGROUND OF AUGMENTED REALITY .....	14
AR 2.1.2 – SUBFIELDS, IDEAS AND RELEVANT CONCEPTS .....	15
AR 2.1.3 – CREATIVE AND TECHNOLOGICAL PRECEDENTS .....	17
AR 2.2 – SUMMARY OF LITERATURE AND POSITIONING FOR RESEARCH .....	19
<b>CHAPTER 3: METHODOLOGIES</b> .....	<b>20</b>
3.1 RESEARCH PHILOSOPHY.....	21
<i>Kaupapa Māori</i> .....	21
<i>Interpretivism</i> .....	21
<i>Pragmatism</i> .....	21
3.2 RESEARCH APPROACH .....	22
<i>Abductive Reasoning</i> .....	22
<i>Design-Based Research (DBR)</i> .....	22
3.3 METHODOLOGICAL CHOICE .....	22
<i>Mixed Methods (Qualitative-Dominant)</i> .....	22
3.4 STRATEGIES AND METHODOLOGIES .....	23
<i>Dérive (Drifting)</i> .....	23
<i>Lotus Blossom Technique</i> .....	23
<i>Soundscape Methodology</i> .....	23
<i>Sketching</i> .....	23
<i>Low-Fidelity Prototyping</i> .....	23
<i>Double Diamond</i> .....	23
<i>Agile Methodology</i> .....	24
3.5 TIME HORIZON .....	24
3.6 DATA COLLECTION METHODS .....	24
<i>Qualitative (Self-Reflective) Methods</i> .....	24
<i>Quantitative (Self-Rated) Methods</i> .....	25
3.7 MAORI VALUES.....	25
<i>Whakawhanaungatanga</i> .....	26
<i>Manaakitanga</i> .....	26
<i>Kaitiakitanga</i> .....	26
<b>CHAPTER 4: THE CREATIVE PROCESS</b> .....	<b>27</b>
<i>Overview of Development Frameworks and Methodologies</i> .....	27
4.1 PHASE 1: DISCOVER.....	28
4.1.1 <i>Dérive and Conceptual Drift</i> .....	29
4.1.2 <i>Cultural Foundation: Matariki narrative and Māori values</i> .....	30

4.1.3 Spatial Interaction Frameworks: Augmented Reality and Immersive Design .....	30
4.1.4 Technical Landscape: Apple Vision Pro and iOS Development Ecosystem .....	31
4.1.5 Strategic Visualisation Tools .....	32
4.1.6 Early UI/UX Investigations and Learning Theory Integration.....	33
4.1.7 Emergence of Agile Orientation and User Perspective .....	34
4.1.8 Concept Testing with Tools and Prototypes.....	34
4.1.9 Defining the Problem Space .....	35
Summary of Discover Phase .....	35
4.2 PHASE 2: DEFINE .....	36
4.2.1 Narrative and Immersive Design Architecture .....	36
4.2.2 Technical Feasibility Assessment.....	40
4.2.3 User Story Development .....	40
4.2.4 MoSCoW Prioritisation .....	41
4.2.5 Story Pointing and Complexity Estimation .....	42
4.2.6 Defining the MVP Scope .....	44
Summary of Define Phase.....	45
4.3 PHASE 3: DEVELOPMENT .....	45
4.3.1 Sprint Methodology and Structure.....	46
4.3.2 Sprint 1 – Onboarding and Orientation.....	46
4.3.3 Sprint 2 – Interaction and Immersion (Volumetric Experience) .....	50
4.3.4 Sprint 3 – Fully Immersive Cultural Storytelling .....	53
4.3.5 Sprint 4 – MVP Integration and Completion.....	58
Summary of Development Phase .....	60
4.4 PHASE 4: DELIVER .....	61
4.4.1 Objectives of the Deliver Phase .....	61
4.4.2 Finalisation of the MVP.....	62
4.4.3 NASA-TLX Evaluation: Cognitive Load Analysis .....	62
4.4.4 Technology Acceptance Model (TAM): Perceived Usability.....	64
4.4.5 Cultural Alignment and Kaupapa Māori Reflection .....	65
4.4.6 Visual and Technical Output Documentation.....	65
4.4.7 Limitations and Future Considerations.....	66
Summary of Deliver Phase.....	66
<b>CHAPTER 5: THE ARTEFACT AND FINAL OUTPUT .....</b>	<b>68</b>
5.1 PROJECT VISION AND AIMS.....	68
5.2 TECHNICAL OVERVIEW OF THE ARTEFACT .....	68
5.3 SYSTEM ARCHITECTURE AND FEATURES .....	69
5.4 CULTURAL INTEGRATION .....	70
5.5 EDUCATIONAL AND UX DESIGN FRAMEWORKS .....	71
5.6 REFLECTIONS ON SELF-ASSESSMENT AND EVALUATION .....	71
5.7 LIMITATIONS AND FUTURE SCOPE.....	72
5.8 SUMMARY .....	73
<b>CHAPTER 6: REFLECTIONS ON THE DESIGN PROCESS AND RESULTING OUTCOMES .....</b>	<b>73</b>
6.1 REFLECTIONS ON METHODOLOGIES .....	73
6.1.1 Double Diamond as Structural Framework.....	73
6.1.2 Agile Methodology in Practice.....	74
6.1.3 User-Centered Design and Learning Frameworks .....	74
6.1.4 Māori values as a Design Ethos.....	74

6.1.5 Findings from Immersion-Level Evaluation .....	75
6.2 TECHNICAL AND CREATIVE CHALLENGES .....	80
6.2.1 Learning Curve of VisionOS Development .....	80
6.2.2 Managing Interdisciplinary Demands .....	80
6.2.3 Limitations in Testing.....	80
6.3 KEY SUCCESSES.....	80
6.3.1 Coherence of UI and UX Design .....	80
6.3.2 Preservation of Cultural Integrity.....	81
6.3.3 Self-Assessment Tools Enabled Reflective Practice .....	81
6.3.4 Modular Architecture for Future Expansion.....	81
6.4 SUMMARY .....	81
<b>CHAPTER 7: CONCLUSION AND FUTURE DIRECTIONS .....</b>	<b>82</b>
7.1 PROJECT OVERVIEW .....	82
7.2 SUMMARY OF CONTRIBUTIONS.....	83
7.2.1 Spatial Computing .....	83
7.2.2 Indigenous Storytelling.....	83
7.2.3 Learning Design .....	83
7.2.4 Methodological Rigor .....	83
7.3 FINDINGS FROM IMMERSION-LEVEL TESTING .....	84
Windowed Immersion (2D SwiftUI interface):.....	84
Volumetric Immersion (3D layered interface): .....	84
Full Space Immersive Experience (360° environment): .....	84
7.4 UNRESOLVED QUESTIONS AND LIMITATIONS .....	85
7.4.1 External Testing and User Diversity.....	85
7.4.2 Hardware Accessibility.....	85
7.5 FUTURE DEVELOPMENT PATHWAYS.....	85
7.5.1 Expanded Evaluation .....	85
7.5.2 Story Expansion .....	85
7.5.3 Community Partnership .....	86
7.5.4 Educational Integration .....	86
7.5.5 Cultural Perpetuity.....	86
7.6 FINAL OBSERVATIONS .....	86
7.7 CONCLUSION .....	87
<b>GLOSSARY OF TERMS .....</b>	<b>88</b>
CULTURAL.....	88
METHODOLOGICAL.....	90
TECHNICAL .....	91
<b>BIBLIOGRAPHY .....</b>	<b>93</b>
<b>APPENDICES .....</b>	<b>96</b>
<b>APPENDIX A: MIND MAPS .....</b>	<b>96</b>
<b>APPENDIX B: LOTUS BLOSSUM MAPS.....</b>	<b>101</b>

## List of Figures

FIGURE 1: RESEARCH ONION (AUTHORS OWN).....	20
---	----

FIGURE 2: APPLE IMMERSIVE LEVELS (TIFT, 2024) .....	24
FIGURE 3: MATARIKI MIND MAP (AUTHOR OWN) .....	29
FIGURE 4: LOTUS BLOSSOM, GUARDIANS OF MATARIKI COMPONENT MAPPING (AUTHORS OWN) .....	32
FIGURE 5: PART A) WINDOW EXPERIENCE SKETCHES (AUTHORS OWN) .....	37
FIGURE 6: PART B) WINDOW EXPERIENCE SKETCHES (AUTHORS OWN) .....	38
FIGURE 7: PART A) VOLUMETRIC EXPERIENCE SKETCHES (AUTHORS OWN) .....	38
FIGURE 8: PART B) VOLUMETRIC EXPERIENCE SKETCHES (AUTHORS OWN) .....	39
FIGURE 9: PART A) FULL SPACE EXPERIENCE SKETCHES (AUTHORS OWN) .....	39
FIGURE 10: PART B) FULL SPACE EXPERIENCE SKETCHES (AUTHORS OWN) .....	40
FIGURE 11: PROJECT MANAGEMENT, TRELLO KANBAN (AUTHORS OWN) .....	42
FIGURE 12: PART A) MVP EXPERIENCE SKETCHES (AUTHORS OWN) .....	44
FIGURE 13: PART B) MVP EXPERIENCE SKETCHES (AUTHORS OWN) .....	44
FIGURE 14: INITIAL SKETCHES EXPLORING THE ONBOARDING UI AND NAVIGATION FLOW. ....	47
FIGURE 15: SWIFT PLAYGROUNDS PROTOTYPE OF THE INITIAL UI LAYOUT. ....	47
FIGURE 16: FIRST UI PROTOTYPE IN AVP, SHOWING LAYOUT PLACEHOLDERS WITHOUT CULTURAL IMAGES OR TEXT. THE PROTOTYPE WAS USED TO TEST COMPONENT POSITIONING, NAVIGATIONAL AFFORDANCES, AND SWIFTUI SCENE TRANSITIONS. ....	47
FIGURE 17: UPDATED PROTOTYPE INCLUDING CULTURAL IMAGES AND INTRODUCTORY TEXT. THIS STAGE FOCUSED ON NARRATIVE CLARITY AND VISUAL TONE, INCORPORATING FEEDBACK FROM SELF-LED WALKTHROUGHS. ....	48
FIGURE 18: UPDATED PROTOTYPE WITH INTERACTIVE ELEMENT BUTTONS. THIS UPDATED UI LAYOUT IS SIMILAR TO THE MVP LAYOUT WITH ELEMENT BUTTONS TO INTRODUCE THE EARTH STARS TUPUĀNUKU AND TUPUĀRANGI.....	48
FIGURE 19: UPDATED PROTOTYPE WITH INTERACTIVE ELEMENT BUTTONS. THIS UPDATED UI LAYOUT IS SIMILAR TO THE MVP LAYOUT WITH ELEMENT BUTTONS TO INTRODUCE THE EARTH STARS TUPUĀNUKU AND TUPUĀRANGI.....	48
FIGURE 20: FINALISED WINDOWED INTERFACE OF MATARIKI UI WITH LAYERED Z-STACK LAYOUT FOR INTERACTIVE DEPTH. THIS VERSION INTRODUCED SUBTLE SPATIAL LAYERING TO ALLOW FOR POP-OUT EFFECTS, ENHANCING USER ENGAGEMENT WITHOUT OVERWHELMING VISUAL LOAD. ....	49
FIGURE 21: FINALISED WINDOWED INTERFACE OF TUPUĀNUKA & TUPUĀRANGI UI WITH LAYERED Z-STACK LAYOUT FOR INTERACTIVE DEPTH. THIS VERSION INTRODUCED SUBTLE SPATIAL LAYERING TO ALLOW FOR POP-OUT EFFECTS, ENHANCING USER ENGAGEMENT WITHOUT OVERWHELMING VISUAL LOAD.....	49
FIGURE 22: INITIAL SKETCH OF THE VOLUMETRIC LAYOUT. ....	51
FIGURE 23: EARLY PROTOTYPE USING AN ABSTRACT CUBE OBJECT. THIS MODEL WAS USED TO VALIDATE INTERACTION INPUTS SUCH AS GAZE-TO-FOCUS, PINCH-TO-SCALE, AND DRAG-TO-POSITION. ....	51
FIGURE 24: ANIMATED STAR OBJECTS INTRODUCED WITH ROTATING MOTION. STARS WERE ANIMATED IN ROTATION TO SIMULATE CELESTIAL MOTION, ADDING VISUAL FEEDBACK TO USER PRESENCE AND ENHANCING THE SENSE OF A LIVING COSMOS.....	51
FIGURE 25: ROTATING STARS INTEGRATED WITH THE MEDITATING CHARACTER. THIS VERSION LAYERED CHARACTER AND STARS TOGETHER, ALLOWING FOR PASSIVE INTERACTION AND SPATIAL PROXIMITY TESTING. ....	51
FIGURE 26: ANIMATION OF MĀORI WARRIOR TRANSITIONING FROM KNEELING TO STANDING, WITH ROTATING STARS. ....	51
FIGURE 27: MĀORI WARRIOR STANDING, WITH A SMALL INTERACTIVE UI PANEL POSITIONED IN FRONT OF THE CHARACTER, WHICH DISPLAYED DESCRIPTIVE TEXT ABOUT THE STAR “WAITĀ”. ....	52
FIGURE 28: FINAL VOLUMETRIC PROTOTYPES: WAITĪ WARRIOR ANIMATION, RAIN, ROTATING STARS, AND UI OVERLAY WHICH DISPLAYED DESCRIPTIVE TEXT ABOUT THE STAR. DEMONSTRATING LAYERED SPATIAL STORYTELLING. ....	52
FIGURE 29: EARLY SKETCH OF IMMERSIVE LAYOUT CONCEPTS .....	54
FIGURE 30: IMMERSIVE ENVIRONMENT PROTOTYPE WITH EARTH OBJECT ONLY. THIS WAS THE FIRST VERSION TO FULLY SURROUND THE USER IN FULL SPACE IMMERSION .....	54
FIGURE 31: WAIPUNA-Ā-RANGI WITH STARS AND RAIN EFFECTS. A FEMALE FIGURE REPRESENTING WAIPUNA-Ā-RANGI WAS INTRODUCED ALONGSIDE RAINFALL PARTICLE EFFECTS. STARS HOVERED ABOVE, CONNECTING THE CELESTIAL AND TERRESTRIAL ELEMENTS. RAINFALL WAS SYMBOLIC OF NOURISHMENT AND MANAAKITANGA (CARE), WHICH THE STAR EMBODIES.....	55

FIGURE 32: WAIPUNA-Ā-RANGI IMMERSIVE SCENE WITH INTERACTIVE UI AND AUDIO. AN INTERACTIVE PANEL WAS ADDED, PLACED WITHIN COMFORTABLE GAZE RANGE IN FRONT OF THE CHARACTER. TEXT DESCRIPTIONS, CULTURAL MEANINGS, AND AUDIO WERE TRIGGERED.....	55
FIGURE 33: URURANGI IMMERSIVE SCENE IN PASSTHROUGH MODE WITH SWIRLING CLOUDS. URURANGI’S SCENE FEATURED WIND-BASED MOTION. SWIRLING CLOUD EFFECTS ENVELOPED THE ENVIRONMENT, WHILE THE MĀORI GUARDIAN STOOD GROUNDED IN THE CENTER. AUDIO AND TEXT INTERFACES DESCRIBED URURANGI’S ASSOCIATION WITH CHANGE, JOURNEYING, AND THE WINDS OF TRANSITION. THE USE OF PASSTHROUGH ENHANCED THE BLENDING OF PHYSICAL AND DIGITAL SPACE.....	56
FIGURE 34: WINDOWED IMMERSION, EXPERIENCE RATINGS (AUTHORS OWN).....	75
FIGURE 35: : WINDOWED IMMERSION, TAM SCORES (AUTHORS OWN) .....	76
FIGURE 36:: WINDOWED IMMERSION, NASA-TLX COGNITIVE LOAD SCORES (AUTHORS OWN).....	76
FIGURE 37: VOLUMETRIC IMMERSION, EXPERIENCE RATINGS (AUTHORS OWN).....	77
FIGURE 38: : VOLUMETRIC IMMERSION, TAM SCORES (AUTHORS OWN) .....	77
FIGURE 39: : VOLUMETRIC IMMERSION, NASA-TLX COGNITIVE LOAD (AUTHORS OWN) .....	78
FIGURE 40: FULL SPACE IMMERSION, EXPERIENCE RATINGS (AUTHORS OWN).....	78
FIGURE 41: FULL SPACE IMMERSION, TAM SCORES (AUTHORS OWN) .....	79
FIGURE 42: FULL SPACE IMMERSION, NASA-TLX COGNITIVE LOAD (AUTHORS OWN) .....	79
FIGURE 43: AUGMENTED REALITY MIND MAP (AUTHORS OWN).....	96
FIGURE 44: APPLE VISION PRO APP DEVELOPMENT MIND MAP (AUTHORS OWN) .....	97
FIGURE 45: IOS DEVELOPMENT MIND MAP (AUTHORS OWN) .....	98
FIGURE 46: LEARNING THEORIES MIND MAP (AUTHORS OWN) .....	99
FIGURE 47: UI/UX DESIGN MIND MAP (AUTHORS OWN) .....	100
FIGURE 48: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, ANIMATION NEEDS MAPPING (AUTHORS OWN) .....	101
FIGURE 49: : LOTUS BLOSSOM, GUARDIANS OF MATARIKI, EXEGESES NEEDS MAPPING (AUTHORS OWN) .....	101
FIGURE 50: : LOTUS BLOSSOM, GUARDIANS OF MATARIKI, DEVELOPER ENVIRONMENT NEEDS MAPPING (AUTHORS OWN) .....	102
FIGURE 51: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, SKILL DEVELOPMENT MAPPING (AUTHORS OWN) .....	102
FIGURE 52: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, UI/UX DESIGN MAPPING (AUTHORS OWN) .....	103
FIGURE 53: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, APPLE ECOSYSTEM MAPPING (AUTHORS OWN).....	103
FIGURE 54: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, STORY MAPPING (AUTHORS OWN) .....	104
FIGURE 55: LOTUS BLOSSOM, GUARDIANS OF MATARIKI, FEATURE EXPLORATION MAPPING (AUTHORS OWN) .....	104

## List of Tables

TABLE 1: OVERVIEW OF DEVELOPMENT FRAMEWORKS AND METHODOLOGIES (AUTHORS OWN).....	27
TABLE 2: PROJECT SPRINTS (AUTHORS OWN) .....	43
TABLE 3: MVP FEATURES (AUTHORS OWN).....	62
TABLE 4: NASA-TLX EVALUATION: COGNITIVE LOAD ANALYSIS (AUTHORS OWN) .....	63
TABLE 5: TECHNOLOGY ACCEPTANCE MODEL (TAM), (AUTHORS OWN) .....	64

## Declaration

“I Hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.”

“Generative AI was used in this thesis to improve clarity and expression. Logs of use including dates are available upon request.”



---

Signature of candidate

## Acknowledgments

Ngā mihi nui ki aku kaiārahi, a Dr. Rachel Shearer rāua ko Assoc. Prof. Stefan Marks, mō tō kōrua tautoko, mātauranga, and humbled leadership. Thank you to AUT and the School of Future Environments for the Scholarship and space for growth. Your support made this possible. Ki tōku whānau, me taku hoa rangatira, thank you for your unwavering aroha. And to myself, this is just the beginning. tēnā koutou katoa mō te ū, te māia, te manawanui. This work carries all of us.

*“Ehara taku toa i te toa takitahi,  
engari he toa takitini.”*

# Chapter 1: Introduction

This exegesis investigates the research question:

*How can immersive spatial storytelling enhance users' engagement with Māori culture through a Mixed Reality application?*

This study focuses on the integration of Māori cultural knowledge and storytelling within a spatial computing context, using the Apple Vision Pro (AVP). The project explores how immersive Mixed Reality technologies can be aligned with Indigenous knowledge systems in a manner that is culturally responsible. Central to this research is the development of a prototype application based on Matariki, the Māori name for the Pleiades star cluster and a taonga (treasure) of seasonal, spiritual, and cultural significance.

My personal connection to this work is grounded in both cultural identity and a lifelong passion for storytelling. I am Māori, but also of Samoan, Fijian, and Tongan descent. As a child, I was drawn to stories, not just for entertainment, but for how they helped me make sense of the world. I grew up with a collection of interactive pop-up books, captivated by the way physical layers could be pulled, flipped, or folded to reveal new moments in a story. These books were not just read, they were experienced. That same impulse, to create stories that are felt as much as they are told, has followed me into adulthood, now expressed through immersive technologies such as Augmented and Mixed Reality.

As someone who grew up in Aotearoa New Zealand, Matariki has always been part of my cultural landscape. Before it became a public holiday, it was simply the Māori New Year, an intimate, intergenerational time for reflection, gathering, and renewal. For my whānau, Matariki was about lighting fires, preparing food, remembering those who had passed, and sharing aspirations with whānau and friends for the year ahead. There were no fireworks, parades, or statutory days off, just people coming together with reverence, unity, and hope. When Matariki was officially recognised as a national public holiday in 2022, I felt both pride and concern: pride in seeing our culture uplifted and honoured on a national level, but concern that its deeper meaning could be lost amid commercialisation and recreational excess.

This project emerged from a desire to ensure that Matariki remains more than just a day off from work. By creating an immersive application rooted in Māori values, the goal is to enable users, both Māori and non-Māori to meaningfully engage with the stories, elements, and significance of Matariki in a way that is respectful, educational, and experientially rich.

Cultural storytelling functions as a critical mechanism for preserving Māori knowledge systems and transmitting intergenerational learning. However, contemporary audiences, particularly younger generations, often encounter these narratives through fragmented or highly mediated channels that can diminish their cultural context and depth. Research into immersive storytelling is therefore significant because it examines how emerging technologies can support the continuity of Indigenous knowledge by situating users as active participants within spatial narrative environments. Within this context, spatial computing offers affordances that align with Māori epistemologies of *ako* (reciprocal learning) and *whakapapa* (relational connection), enabling knowledge to be experienced through interaction, embodiment, and relational presence. Immersive storytelling, when developed through culturally grounded design principles, thus provides a framework for exploring how digital tools can extend the reach and understanding of Māori narratives while maintaining their *mana* and integrity.

This application is not only a storytelling tool, but a cultural safeguard and an interactive space where cultural knowledge can meet contemporary technology.

Matariki is known globally as the Pleiades star cluster and has been observed by cultures across the world for thousands of years. It appears in midwinter in the Southern Hemisphere and marks the beginning of the Māori lunar new year. Across cultures, the Pleiades have held symbolic power: the Greeks saw them as the Seven Sisters, daughters of Atlas; in Japan, they are called Subaru, meaning "gathered together"; the Aztecs knew them as Tianquitzli; while in Hawai'i, they are Makali'i, a celestial signpost for seasonal change. Among Aboriginal Australians, the Pleiades appear as the seven sisters across many Dreaming stories (Dowling, 2023). Despite regional differences, the cluster is consistently associated with renewal, navigation, spirituality, and seasonal rhythms, suggesting a profound and shared human connection to this small constellation.

In Māori cosmology, Matariki consists of nine principal stars, each associated with different domains of the natural world and human experience. These are:

- Matariki – the central star, associated with wellbeing and overall health.
- Pōhutukawa – connected to those who have passed away, representing memory and mourning.
- Hiwa-i-te-rangi – the star of aspiration, where people send their wishes for the coming year.
- Tupuānuku – linked to food grown in the ground, such as vegetables and root crops.
- Tupuārangi – connected to food from the sky and forest, including birds and berries.

- Waitī – governs freshwater systems and the life they sustain.
- Waitā – represents the ocean and saltwater food sources.
- Waipunarangi – tied to rain and skyborne water.
- Ururangi – associated with the wind and weather patterns (McGuinness, 2017).

Together, these stars form a cosmic reflection of the Earth's ecosystems, and their rising invites us to pause and acknowledge the interconnection between people, nature, and the cosmos. Each star offers an entry point for reflection and sustainability: Tupuānuku reminds us to nourish the soil, Waitā urges us to protect the ocean, while Pōhutukawa reminds us to honour those whose legacies still guide us.

These celestial associations also mirror a deeply embedded system of sustainability practices within te ao Māori (the Māori world). Kaitiakitanga (guardianship) encourages responsible care for the environment, while manaakitanga (hospitality and care) promotes the equitable sharing of resources. Whanaungatanga (relationship-building) fosters a sense of communal responsibility. These values were traditionally expressed through practices such as seasonal harvesting, careful resource management, and the communal preparation and distribution of food during Matariki. In this way, Matariki is not only a cultural celebration but an environmental one, a recognition of our interdependence with the land, sea, and sky.

This cultural framework resonates with spatial storytelling, where the environment itself becomes a narrative medium. A Mixed Reality (MR) headset such as the Apple Vision Pro offers experimental opportunities for culturally grounded storytelling through its spatial computing capabilities, including gesture-based interaction, passthrough vision, eye tracking, and real-time 3D rendering. These tools can be leveraged to layer narrative into space, allowing users to explore, interact with, and learn from cultural content in ways that go beyond traditional screens. In the context of Matariki, this means enabling users to experience the rising of the stars, hear the stories of each celestial body, and move through virtual environments that reflect land, sea, and sky, inviting not just understanding, but immersion.

The development process for the application draws on a range of methodologies that are further detailed in Chapter 3. The project employs a mixed-methods, practice based research approach grounded in kaupapa Māori, interpretivism, and pragmatism philosophies. The overall structure follows the Research Onion (Saunders et al., 2012), guiding layered decisions across philosophical, methodological, and procedural dimensions. The creative process is informed by Design Based Research (DBR) and abductive reasoning, allowing for theory and practice to develop together through iterative design

cycles. This includes self-reflective design activities, prototyping, and user testing, ranging from observational walkthroughs to user experience surveys and cognitive load assessments.

The design methodology is structured using the Double Diamond framework, which breaks the process into phases of Discover, Define, Develop, and Deliver. Within each phase, specific creative techniques such as Lotus Blossom ideation, Six Thinking Hats, *dérive*, Agile (SCRUM) method, and low-fidelity prototyping were applied to manage, generate, and evaluate concepts. These methods ensured the design process remained both exploratory and culturally responsive, engaging with Māori knowledge systems while drawing upon best practices in spatial design.

The final application comprises three stages of immersion:

1. Windowed prototype using a 2D SwiftUI interface for interaction testing
2. Volumetric scene created in RealityKit to test spatial embodiment
3. Full space immersive experience integrating all visual, auditory, and interaction layers for assessing emotional and cultural engagement

Each stage was developed through Agile sprints, user testing, and reflective evaluation. Cultural values, including *manaakitanga*, *whakawhanaungatanga*, and *kaitiakitanga*, were embedded throughout the design, influencing not only the content but also the interaction models and narrative tone.

Educational scaffolding was structured using Cognitivism, Constructivism, and Bloom's Taxonomy, allowing users to move through a progressive learning model as they engage with the content.

This exegesis is organised into seven chapters that collectively articulate the research journey, design process, and outcomes of the project. Chapter 2 presents a review of relevant literature, with a focus on the fields of Augmented Reality and related technological and pedagogical frameworks. Chapter 3 outlines the methodological foundation of the study, detailing the research philosophy, strategic approach, and data collection methods employed. Chapter 4 traces the creative development process, documenting the progression from initial ideation through to prototyping and delivery. Chapter 5 introduces the final application output, describing its technical architecture and cultural integration. Chapter 6 provides a reflective analysis of the development process and resulting outcomes, incorporating both qualitative and quantitative evaluations. Finally, Chapter 7 concludes the

exegesis by synthesising the study's key findings and proposing future directions for research and development.

Ultimately, this project seeks to contribute to the evolving conversation around Indigenous digital storytelling, immersive storytelling, and the ethical application of emerging technologies within cultural contexts. It asks not just what we can build with new tools, but how we can build in a way that honours our ancestors, educates the present, and protects the future. The work is not finished, but it has begun.

## Chapter 2: Literature Review

This section explores literature relevant to my project, focusing on augmented reality (AR). Section 2.1 will examine spatial computing in the context of AR, followed by Section 2.2 which will summarise the literature and position the key concepts in support of my research.

### AR 2.1 – My Interest and Motivation in AR

My interest in Augmented Reality (AR) began with a desire to move beyond screen-based digital storytelling and into environments where users could experience cultural stories in more embodied, spatial ways. As a Māori creative technologist working at the intersection of culture and emerging media, I saw AR as an opportunity to foster deeper engagement, not just through visuals and interactivity, but through environmental context and presence. The launch of Apple's Apple Vision Pro device introduced a new paradigm in AR that I felt offered an immersive experience the other devices fall short on delivering.

I had previously used other hardware like the meta Quest 3, but the Apple Vision Pro felt significantly more immersive to me. Its visual clarity and depth made a noticeable difference, and I felt it would provide a much more engaging experience for this type of project. This form of interaction introduced a new medium for Māori storytelling that captured my interest to research further into to understand its potential effects on our cultural storytelling traditions.

#### AR 2.1.1 – Background of Augmented Reality

The origins of augmented reality (AR) can be traced back to the 1950s, when Morton Heilig's vision of immersive cinema led to his creation of the Sensorama, which he patented in 1962 (Carrilho & Costa, 2021). In 1968, Ivan Sutherland built the first head-mounted display and demonstrated an early AR system commonly called 'Sword of Damocles (Sutherland, 1968). The next milestone was Myron Krueger's Videoplace, which furthered the field by allowing users to interact directly with virtual objects (Krueger et al., 1985).

In 1990, the term "augmented reality" was coined by Tom Caudell and David Mizell at Boeing (Caudell & Mizell, 1992), and in 1992, L. B. Rosenberg developed Virtual Fixtures, one of the first fully functional AR systems (Rosenberg, 1992). A few years later, Paul Milgram and Fumio Kishino's 1994 Reality–Virtuality Continuum established a theoretical framework distinguishing AR from other concepts such as Augmented Virtuality and Virtual

Reality (Skarbez et al., 2021), while Ronald Azuma conducted a survey in 1997 (Azuma, 1997), he defines AR systems to have three characteristics:

- Combines real and virtual
- Interactive in real time
- Registered in 3-D

which offered the first widely accepted definition of AR.

Entering the early 2000s, prototype mobile AR applications such as ARQuake demonstrated AR's potential outside laboratory settings (Thomas et al., 2000), and the 2005 Horizon Report predicted AR's imminent rise in mainstream use (Johnson et al., 2010). By 2008, consumer-focused apps like the Wikitude AR Travel Guide had begun to bring AR into everyday contexts, blending location-based content with smartphone cameras (Madden, 2011). These milestones chart the evolution of AR from experimental prototypes to a mature technology capable of seamlessly overlaying interactive digital content onto the physical world (Carmigniani et al., 2011).

Together, these developments contributed to the evolution of contemporary AR platforms, including devices such as the Apple Vision Pro.

## AR 2.1.2 – Subfields, ideas and relevant concepts

A study by Thandu (2019) identifies two AR features that are worth noting for this project: marker-based AR and mixed reality. Marker-based systems detect specific images or objects, whilst MR takes this a step further by enabling seamless interaction between the real and virtual elements. In the context of my project within the Apple Vision Pro, these features could allow a user to physically interact with a 3D representation of the Matariki constellation, manipulate it, and explore each star's narrative in their own space.

Other core ideas in AR development that align closely with my research are environmental anchoring, embodied interaction, and spatial UX design.

Environmental anchoring refers to the technique of placing digital content in specific, persistent locations within the physical environment. Anchoring is crucial for storytelling, particularly in my project where celestial elements like Matariki stars need to appear in culturally meaningful and consistent positions. Anchoring helps foster a sense of stability and believability, enabling users to navigate the experience as they would a real-world site of significance.

Embodied interaction is another key concept, especially with Vision Pro's sensor suite. It enables natural interaction through eye movement, similar to the quest 3 it utilises hand tracking, head position, and voice input. This enhances immersion, but also aligns with Māori values like *kanohi ki te kanohi* (face-to-face connection), which privileges relational presence and gestures in communication.

Finally, spatial UI/UX design is emerging as a new design field within AR. In contrast to flat interfaces, spatial UX involves designing within a 3D environment, considering depth, gaze direction, volume, and user comfort (Jiboku & Obarayi, 2024). Spatial UX requires designers to rethink metaphor and interaction, using subtle cues like lighting, scale, and sound to guide users through immersive narratives.

Apple's spatial design philosophy complements this approach. Apps are meant to be "part of the room," which encourages experiences that unfold around the user rather than on a 2D screen (Apple, 2025). This aligns beautifully with Māori storytelling, where stories are often grounded in specific landscapes, constellations, and ritual spaces.

AR and VR design research provides additional validation for the spatial and interaction design decisions underpinning this project. According to Kruijff, Swan, and Feiner (2010), effective AR experiences rely on stable environmental anchoring to reduce spatial disorientation and cognitive load, as consistent registration between digital and physical space improves user trust and immersion. Billinghurst (2015) likewise emphasise that spatial consistency and robust alignment are key to sustaining presence in mixed reality environments.

Interaction design research supports the use of natural, embodied inputs such as gaze and hand tracking. A review by Billinghurst et al. (2015) shows that intuitive, direct manipulation techniques (e.g., gaze-directed targeting, gesture/hand selection) can lower interaction effort and help users focus on content rather than interface mechanics; Kruijff et al. (2010) further note that minimising perceptual conflicts between visual focus and interaction targets reduces cognitive load.

Text and interface legibility have been studied extensively in immersive contexts. Gabbard, Swan, and Hix (2018) and Rehman and Liu (2015) report that larger, high-contrast text and adaptive scaling improve readability and reduce visual fatigue, particularly when text is layered at depth in outdoor or variable-lighting AR conditions. These findings inform decisions in this project regarding text size, placement, and depth layering to ensure comfort and accessibility across varying focal distances.

Collectively, these studies establish an empirical foundation for the project's interaction and spatial layout choices, demonstrating alignment with recognised AR/VR design principles in addition to kaupapa Māori values.

### AR 2.1.3 – Creative and Technological Precedents

Research on AR in cultural and educational contexts highlights its potential to improve engagement, comprehension, and emotional connection. Although at the time of writing, only few studies focus exclusively on Vision Pro due to its recent release, related research provides valuable precedents.

One of the most relevant studies is *Whispering Tales: Using Augmented Reality to Enhance Cultural Landscapes and Indigenous Values* by Marques et al. (2019). This research, developed in partnership with Ngāti Kahungunu ki Wairarapa, employed a bicultural design framework that merged pōhiri (Māori welcoming protocols) with Girot's (1999) four-trace method of landscape interpretation to reimagine Māori oral narratives through AR. Using mobile devices and the HP Reveal platform, the team overlaid imagery, voice recordings, and sketches onto real sites around Wairarapa Moana, transforming the landscape into an interactive storytelling environment. Users could experience stories such as Te Ika-a-Māui (Māui's fish), where the lake represented one of the fish's eyes, thereby reinforcing spatial and cultural connections between story, place, and identity.

Critically, Marques et al. (2019) found that AR can operate as a cultural interface bridging the tangible and intangible layers of Indigenous landscapes by revealing, rather than replacing, Māori presence. Their methodology highlighted key ethical principles including community verification, cultural consent, and the treatment of digital artefacts as taonga (treasures) linked to whakapapa (genealogy) and mauri (life force). These insights directly inform this research's commitment to kaupapa Māori values of manaakitanga, whanaungatanga, and kaitiakitanga within a spatial computing framework.

From a technological perspective, their use of marker-based AR exposed several challenges, such as lighting variability and dependence on visual triggers that can limit user immersion outdoors. The current project extends this work by adopting Vision Pro's markerless spatial anchoring and gesture-based interaction, enabling cultural narratives like Matariki to unfold through volumetric space rather than flat-screen overlays. Thus, *Whispering Tales* provides both a methodological precedent and a conceptual foundation for embedding Indigenous storytelling within advanced AR ecosystems.

Similarly, Brown (2008) argues that AR and VR technologies, when developed within a Māori paradigm, can carry essential cultural qualities such as mana, tapu, and wairua. Her work reinforces the idea that immersive media can serve as contemporary taonga, provided they are created with cultural integrity. For example, in the Virtual Patu project, Brown and her collaborators digitised a traditional Māori weapon using augmented reality, embedding it with cultural narratives and protocols. This digital artefact was treated not merely as a replica, but as a living taonga demonstrating how virtual objects can embody Māori values when developed through bicultural consultation and tikanga-aligned processes

A study by Gunn et al (2021) demonstrated how volumetric AR could be used to create intimate, culturally respectful encounters between Māori and non-Māori through the installation First Contact – Take 2. Their work placed a Māori woman, captured in 3D using DepthKit software and an Intel RealSense depth camera setup, across from the viewer at a dining table in a virtual encounter. This volumetric capture enabled a realistic, spatially anchored representation that maintained direct gaze and relational presence. The project exemplifies how spatial computing can foster cultural dialogue and immersive storytelling principles that directly inform the Guardians of Matariki project.

Loyd -Jones et al. (2023) demonstrated how immersive VR can be used to scaffold understanding and confidence in Māori cultural practices, specifically through a virtual pōwhiri (formal Māori welcoming ceremony) experience. Their findings reinforce the value of spatial immersion and culturally grounded design in enhancing user engagement with tikanga Māori (Māori cultural practices).

A relevant precedent in the use of AR for cultural storytelling is the development of the AWAR app by Ilish (Samin, 2019), which used mobile augmented reality to guide visitors through the cultural heritage sites of Langkawi Island in Malaysia via a fictional narrative. The app combined location-aware AR with storytelling to deepen user engagement with local myths. This approach aligns with the goals of Guardians of Matariki, where spatial computing is used to anchor Māori cosmological narratives in immersive environments, with the goal of enhancing both emotional connection and cultural understanding.

Similarly, the work by Park et al. (2022) on a mixed reality storytelling system co-developed with Te Rau Aroha Marae community in Bluff highlights the importance of cultural co-design and presence in immersive environments. Their system allowed users to virtually enter a reconstructed whareniui (meeting house) and experience stories told by elders through volumetric video, reinforcing the value of kanohi kitea (a face seen) and whanaungatanga

(relationship-building) in digital spaces. This precedent directly informs the Guardians of Matariki project's emphasis on spatial presence and cultural integrity.

Collectively, these studies reinforce that AR especially when grounded in natural interaction and environmental cues enhances story presence, cultural understanding, and personal meaning. These are all central to my project's goals.

## AR 2.2 – Summary of Literature and Positioning for Research

The literature demonstrates that augmented reality offers a unique opportunity to design culturally grounded immersive experiences. AR's ability to integrate digital content into real-world contexts combined with embodied, intuitive interaction makes it particularly suited to Indigenous storytelling.

These findings validate the foundation of my research question and suggest that immersive storytelling in MR has the potential to meaningfully deepen user experience with Māori culture. As development tools mature and community partnerships expand, this approach could support broader cultural education, tourism, and preservation initiatives in Aotearoa and beyond.

# Chapter 3: Methodologies

This chapter outlines the layered methodological framework that guided the development of the immersive cultural storytelling application focused on Matariki for the Apple Vision Pro (AVP). Organised using the Research Onion model (thephdclub, 2024), as shown in Figure 1, the chapter structures methodological decisions across six concentric layers: research philosophy, research approach, methodological choice, strategy, time horizon, and data collection methods.

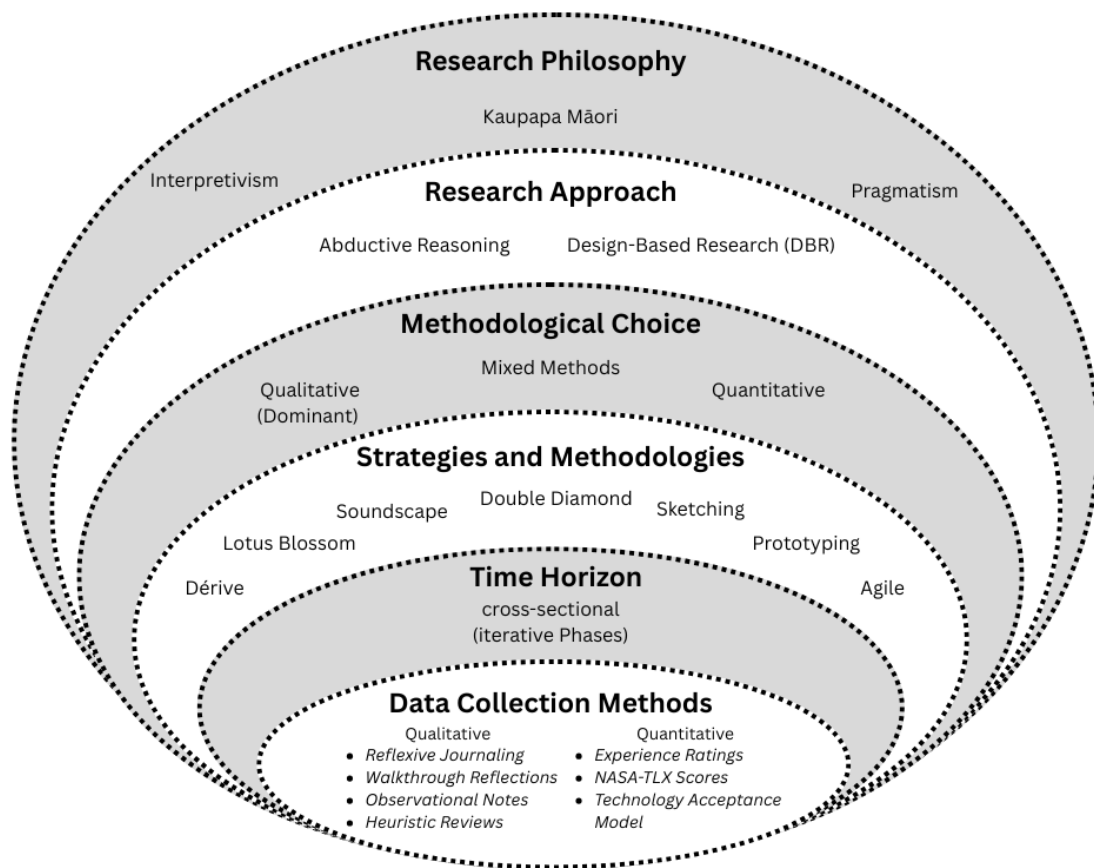


Figure 1: Research Onion (Authors own)

Framing the project through the Research Onion provided a structured approach for contextualising and justifying methodological decisions. Each layer demonstrates how kaupapa Māori values, creative design methods, learning theory, and iterative prototyping were integrated into a self-directed, reflective process to produce a culturally aligned, user-centred spatial experience.

## 3.1 Research Philosophy

### Kaupapa Māori

Kaupapa Māori values served as both ethical foundation and a cultural framework. As noted by Pihama et al (2002), The core of Kaupapa Māori is: The affirmation and legitimation of being Māori. Identifying as Māori myself, I embedded Māori values such as manaakitanga (care), kaitiakitanga (guardianship), and whakawhanaungatanga (relationship-building) into every stage of design and reflection to this project. These values shaped not only interface and narrative decisions but also the protocols for assessing cultural alignment, even in the absence of formal community co-design sessions.

As Smith (2015) articulates, Kaupapa Māori research is defined as research by Māori, for Māori, and with Māori. This framework asserts the validity of Māori knowledge systems and supports research that uplifts Māori aspirations, language, and culture. While Kaupapa Māori outputs can be accessed and engaged with by non-Māori, their integrity relies on Māori retaining leadership and oversight of the work. Guardians of Matariki adheres to these principles by being Māori-led and grounded in Māori values. However, given the evolving role of Matariki as a national public holiday, this project also extends kaupapa Māori toward a wider audience. Through values such as manaakitanga (care) and kaitiakitanga (guardianship), the project seeks not only to protect cultural integrity but to share its depth respectfully with all who now encounter Matariki. This reflects a contemporary evolution of kaupapa Māori practice — open yet grounded.

### Interpretivism

This research adopts an interpretivist stance, valuing subjective meaning and cultural context over generalisable data. As discussed by Alahara. and Pius (2020), interpretivism recognises reality as socially constructed and best understood through lived experience. This aligns with kaupapa Māori (Māori way of doing and thinking), allowing the project to explore Matariki through personal reflection, emotional resonance, and symbolic interpretation. The solo nature of development supported a deeply introspective process, where cultural meaning was shaped through journaling, design iteration, and situated engagement with the narrative.

### Pragmatism

Pragmatism guided this project as a flexible, practice-based philosophy that values action, reflection, and adaptation. Informed by Simpson's (2018) view of Pragmatism as a dynamic and socially grounded approach, it supported iterative decision-making under real-world

constraints. Rather than seeking fixed truths, the project embraced emergent knowledge shaped through design, testing, and cultural reflection, aligning well with kaupapa Māori values and the evolving nature of immersive storytelling.

---

## 3.2 Research Approach

### Abductive Reasoning

The research followed an abductive logic, moving cyclically between theory and personal experience. Initial design directions were informed by literature, mātauranga Māori (Māori knowledge), and interaction models, but were revised through reflective evaluation. Interface sketches, sound design, and narrative pacing were adjusted based on observations and insights gained during solo testing, development, and journaling.

### Design-Based Research (DBR)

Design-Based Research supported a practice-led and reflexive approach. Each iteration of the prototype functioned as a testbed for evaluating learning, cultural engagement, and interaction flow, using my direct experience as the primary mode of assessment. While DBR traditionally involves participant cycles, in this study it was applied to my own development sprints as retrospective feedback, mirroring the cycles of design, reflection, and refinement found in comparable literature (Park et al., 2022; Samin, 2019).

---

## 3.3 Methodological Choice

### Mixed Methods (Qualitative-Dominant)

A mixed methods approach was adopted with an emphasis on qualitative techniques, but all data were self-generated. Cultural reflections, design insights, and usability notes were recorded through reflexive journaling, walkthrough logs, and interface critiques. Quantitative data such as the NASA-TLX scores (Hart & Staveland, 1988), usability ratings, and the Technology acceptance model (Masrom, 2007) were estimated and logged by myself to evaluate relative cognitive load and design performance across prototype stages.

---

## 3.4 Strategies and Methodologies

### Dérive (Drifting)

Adapted to a digital setting, the *dérive* (Debord & Knabb, 2014) methodology encouraged unstructured exploration of each prototype build. The application of this method was used to explore spatial storytelling from different angles, to identify moments of engagement, confusion, or emotional resonance.

### Lotus Blossom Technique

Used as a personal ideation tool, the lotus blossom method (Riley, 2025) helped expand cultural themes into interactive elements. Mapping subtopics and providing branching structures for content layers within the experience.

### Soundscape Methodology

Authentic and atmospheric soundscapes (Perese, 2020) were layered into the application and evaluated in-situ. These were assessed for emotional tone, scene coherence, and alignment with traditional environments from personal cultural memory and design intention.

### Sketching

Sketching was used to translate conceptual ideas into visual layouts and interaction flows. These sketches helped prototype interface transitions, scene compositions, and narrative pacing in a low-fidelity stages of development.

### Low-Fidelity Prototyping

On-paper walkthroughs were used to test basic flow and button structure before developing interactive 2D and 3D builds. The effectiveness of these low-fidelity (Amsterdam, 2016) tests was assessed directly by myself.

### Double Diamond

The development followed the Double Diamond model: Discover, Define, Develop, and Deliver (Humble, 2021). Each stage was individually navigated and documented, using reflective tools such as whiteboarding, journaling, and critique. This structured the progression from problem definition through prototyping and final build.

## Agile Methodology

Agile (Abrahamsson et al., 2017) development was adapted to a solo workflow. Development was divided into sprints with defined tasks (e.g., build UI components, test sound triggers, refine animations). Each sprint concluded with a reflective evaluation using internal checklists and experience ratings. This method drew inspiration from solo creative technology practices described by Footit (Footit, 2016), Gunn (Gunn et al., 2021), and Samin (Samin, 2019), who also iterated on culturally embedded prototypes using reflective cycles.

---

### 3.5 Time Horizon

The study followed a cross-sectional time horizon across three main immersion levels:

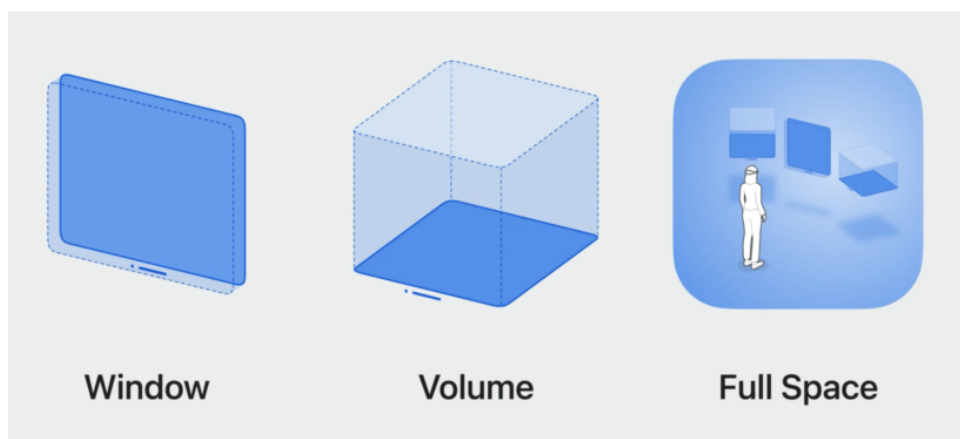


Figure 2: Apple Immersive Levels (Tift, 2024)

windowed, volumetric, and full space. Each stage was developed, tested, and evaluated sequentially through structured personal walkthroughs and journaled observations. The staged structure enabled comparative reflection on learning, interaction, and engagement.

---

### 3.6 Data Collection Methods

#### Qualitative (Self-Reflective) Methods

- *Walkthrough Reflections*: Internal observations while navigating each prototype build.

- *Reflexive Journaling*: Recorded insights on cultural tone, design challenges, and decision rationales.
- *Observational Notes*: Captured gestures, focus shifts, and attention patterns during immersive self-tests.
- *Heuristic Review*: Applied existing UX heuristics and Apple's Human Interface Guidelines to evaluate design choices.

## Quantitative (Self-Rated) Methods

- *Experience Ratings*: Researcher-generated Likert-style ratings of usability, narrative clarity, and emotional response.
- *NASA-TLX Scores*: Used to self-assess perceived cognitive load after each prototype level.
- *Technology Acceptance Model (TAM)*: Applied post-hoc as a framework to consider perceived usefulness and future audience adoption, based on personal assessment.

---

## 3.7 Maori Values

Māori values informed the design of content and experience logic. While many values exist within te ao Māori, the scope of this project drew specific guidance from three: whakawhanaungatanga (relationship-building), manaakitanga (care), and kaitiakitanga (guardianship). In this context, these values also operated as design principles, actionable guides that shaped decision-making across the design, development, and evaluative phases. Whakawhanaungatanga directed the creation of interactions that fostered trust and connection; manaakitanga informed choices that ensured the experience was welcoming and intuitive; and kaitiakitanga guided the responsible representation and protection of cultural narratives and designs. I also drew from personal cultural knowledge developed through my earlier Matariki mobile AR project to ensure these principles were meaningfully embedded in both content and interaction design.

## Whakawhanaungatanga

Whakawhanaungatanga, the process of establishing and nurturing relationships, was applied internally to frame the relationship between designer, user, and story as interconnected. Although there was no external co-design, this principle informed the care and intention with which cultural elements were introduced.

## Manaakitanga

Manaakitanga, the value of showing care, respect, and hospitality toward others, guided the application's design to feel inviting, respectful, and emotionally safe, reflecting the mana (authority, prestige) of both host and guest. Attention to tone, colour, and scene transitions reflected this intent, and these elements were assessed subjectively for alignment with manaakitanga values..

## Kaitiakitanga

Kaitiakitanga, which refers to guardianship and the responsibility to protect and care for cultural and environmental knowledge, underpinned the project's commitment to cultural stewardship. This included avoiding the commodification or simplification of Matariki, reflected in development choices and internal criteria for cultural appropriateness.

This methodological framework aligns with bicultural digital design principles outlined by Marques et al. (2019) and Brown (2008), who emphasise respectful internal reflection, protocol adherence, and Indigenous-led design even in small-scale or prototype-based contexts. While this project was self-contained and reflective, it established practices that may guide future collaborative or scaled-up iterations.

# Chapter 4: The Creative Process

This chapter outlines the creative process behind the development of the immersive cultural storytelling application for the Apple Vision Pro (AVP), centered on the Matariki narrative. It illustrates how the Double Diamond framework structured the overall development, how Agile sprints supported iterative design, and how cultural values drawn from Mātauranga Māori shaped creative decisions. Tools, platforms, and methodologies ranging from Apple’s development ecosystem to co-design and self-assessment techniques were employed to ensure a culturally grounded and user-centric experience.

## Overview of Development Frameworks and Methodologies

Table 1: Overview of Development Frameworks and Methodologies (Authors own)

Methodology/Framework	Applied Phase	Contribution to Project
Double Diamond	Whole Process	Macro structure guiding four main phases
Agile (SCRUM)	Development Sprints	Iterative and flexible development
User-Centered Design (UCD)	All Phases	Ensured design prioritised real user needs
Mātauranga Māori	All Phases	Cultural grounding and narrative ethics
Lotus Blossom Technique	Discover & Define	Expanded key ideas and themes
Six Thinking Hats	Discover & Define	Facilitated multi-perspective reflection
Sketching & Lo-Fi Prototypes	Define & Develop	Visual exploration of concepts
Learning Theories	Develop & Deliver	Informed educational content and interactions
Technology Acceptance Model	Deliver	Framed post-evaluation of usability and adoption

NASA-TLX	Deliver	Informed self-assessment of cognitive load
----------	---------	--

---

## 4.1 Phase 1: Discover

### Step 1 Exploration of Narrative, Technical, and Design Domains

The Discover phase functioned as the foundational research stage in the project's development lifecycle. Aligned with the first quadrant of the Double Diamond framework, this phase involved expansive, exploratory thinking to survey the landscape of relevant cultural, technological, and methodological domains. Its objective was not to define a solution, but rather to uncover themes, requirements, and potential barriers. This approach was informed by divergent thinking principles and guided by creative and analytical tools including the Dérive method, Lotus Blossom technique, and Six Thinking Hats. The outcomes of this phase directly influenced sprint planning, design direction, and eventual MVP scope in the Define phase.

## 4.1.1 Dérive and Conceptual Drift



Figure 3: Matariki Mind map (Author own)

The phase began with a period of creative wandering using the Dérive method. Traditionally used in psychogeography to explore urban space, in this context the dérive was adapted as a thematic and methodological drift across diverse conceptual territories. Rather than charting a single linear path, the dérive allowed for associative, reflective navigation through various interrelated sources, including academic literature, technical documentation, tutorial resources, and previous AR experience.

By engaging with materials non-linearly, this method exposed underexplored areas such as indigenous UI/UX design heuristics, educational frameworks in immersive media, and cognitive affordances in spatial interfaces. Key emergent domains were then categorized

into three primary pillars: Matariki narrative and Māori values, Augmented Reality design frameworks, and the Apple iOS development ecosystem.

---

#### 4.1.2 Cultural Foundation: Matariki narrative and Māori values

Matariki was chosen as the central narrative framework due to its accessibility, celestial structure, and cultural significance. A mind map was created to break down each star and its corresponding associations (e.g., Hiwa-i-te-rangi with aspirations, Tupuānuku with food from the earth). This visual mapping helped surface thematic threads appropriate for educational storytelling and informed how visual elements might be structured spatially within immersive environments.

The narrative exploration was embedded within the following Māori values:

- Whakawhanaungatanga: relationship-building through early consultation with Māori advisors, lecturers, and whānau.
- Manaakitanga: designing interactions that embody care, accessibility, and cultural empathy.
- Kaitiakitanga: ensuring narrative integrity through continual cultural reflection, even in solo-authored decisions.

This cultural framework provided an ethical foundation that guided both content selection and interface behaviours throughout the later stages of the project.

---

#### 4.1.3 Spatial Interaction Frameworks: Augmented Reality and Immersive Design

A parallel track of exploration focused on the literature and precedents in Augmented Reality (AR). A second mind map charted various design challenges and opportunities relevant to immersive experiences, particularly in the context of cultural storytelling. Topics included:

- Embodiment and presence

- Cognitive load in spatial UI
- Cultural semiotics in interaction
- Narrative pacing in non-linear environments
- Emotional resonance in 3D storytelling

Sources reviewed included AR development guides, research on presence and immersion, and case studies involving indigenous XR projects. The analysis identified a need for scaffolded, user-specific interaction design. For instance, a novice user might be overwhelmed by full immersion, while an experienced user could benefit from increased interactivity and spatial freedom. These insights later shaped user story generation and learning pathway design.

---

#### 4.1.4 Technical Landscape: Apple Vision Pro and iOS Development Ecosystem

Given that the prototype would be developed for the Apple Vision Pro, a substantial portion of this phase was dedicated to technical exploration of the Apple development environment. This included:

- Programming languages: Swift, SwiftUI and RealityKit
- Development environments: Xcode, Reality Composer Pro, Blender and Reality Converter.
- Interaction systems: hand gestures, gaze tracking, and volumetric placement

A third mind map was created to chart out the relationships among tools, libraries, and frameworks. Early experimentation revealed the need to learn Apple's declarative UI framework (SwiftUI), volumetric asset placement conventions (using anchors and entities), and model import workflows using USDZ file types. These findings illuminated a significant departure from Unity-based AR workflows, requiring a bottom-up relearning of technical fundamentals.

The exploration also surfaced critical constraints. A full-featured immersive VisionOS application with animations, audio, and responsive interactions would likely require 6 to 8 months of skill development. This exceeded the MPhil program’s timeline and thus shaped later decisions on defining a scalable MVP with emphasis on an app with partial windowed, volumetric, fully immersive modes.

#### 4.1.5 Strategic Visualisation Tools

3D models	Sound	Triggers	Design	UX	Interfaces	Educational	Narative	Value
Sketches	<b>Animation</b>	Texturing	Affordances	<b>explore apps</b>	features	Engaging	<b>Story</b>	Meaning
Rigging	Story board	guides	Interactions	Haptic feedback	UI layout	Interactive	Intuitive	Story board
Apple design	Xcode	Swift swiftUI	<b>Animation</b>	<b>explore apps</b>	<b>Story</b>	Cognitivism	Constructivism	Behaviourism
VisionOS SDK	<b>apple ecosystem</b>	ARkit RealityKit	<b>apple ecosystem</b>	Guardians of Matariki	<b>UI/UX Design</b>	Kaitiakitanga	<b>UI/UX Design</b>	Bloom taxonomy
Tutorials	Reality Converter	Reality composer pro	<b>Skill development</b>	<b>Exergesis</b>	<b>developer environment</b>	Manaakitanga	Apple design	Learning theories
Apple design	Bloom taxonomy	Swift swiftUI	Research	Literature	Methodology	Hardware	wifi	Software
VisionOS SDK	<b>Skill development</b>	ARkit RealityKit	Docs	<b>Exergesis</b>	Data collection	Laptop	<b>developer environment</b>	Xcode
Animation	Xcode	Reality composer pro	APA 6th references	Synthesise	Practice based	Apple vision pro	iPhone pro	Reality composer pro

Figure 4: Lotus Blossom, Guardians of Matariki component mapping (Authors own)

To make sense of these overlapping domains, I applied the Lotus Blossom technique. This allowed me to segment the core components of the project (e.g., UI/UX, 3D modelling, animation, programming, sound, narrative) and assess each area in terms of:

- Tools required
- Skill familiarity
- Learning curve
- Time estimates

The resulting matrix highlighted priority areas that needed immediate attention, particularly SwiftUI, interaction design, and asset pipelines. Simultaneously, a self-assessed SWOT analysis (Gurl, 2017) was conducted to evaluate:

- Strengths (e.g., prior 3D modelling and animation experience)
- Weaknesses (e.g., unfamiliarity with Apple development tools)
- Opportunities (e.g., use of AI-based animation tools like Meshy AI)
- Threats (e.g., steep learning curve of VisionOS and time constraints)

Together, these tools provided a structured understanding of what was feasible within the timeframe and what could be deferred or minimized.

---

#### 4.1.6 Early UI/UX Investigations and Learning Theory Integration

While investigating VisionOS design constraints, I concurrently began exploring UI/UX design principles, with a focus on applications for cultural learning. This led to the integration of learning theories (Ertmer & Newby, 1993) as design frameworks, with the following models shaping later interaction logic:

- Constructivism: Emphasised learning through doing which was key for an interactive story.
- Cognitivism: Directed attention to mental load and clarity of information architecture.
- Behaviourism: Highlighted the role of immediate feedback in reinforcing exploration.
- Bloom's Taxonomy (Armstrong, 2010): Provided a scaffold for content escalation, from knowledge recall to synthesis.
- Scaffolded Learning (Dirksen, 2015): Influenced the flow from windowed → volumetric → immersive experiences.

I captured these insights in sketchbooks and Miro boards, translating theory into low-fidelity interaction diagrams, which began to shape early ideas for user flow, menu systems, and user engagement pacing.

---

#### 4.1.7 Emergence of Agile Orientation and User Perspective

As the research phase progressed, it became evident that a linear development plan would not be viable. Skills acquisition, asset development, and interaction design would all need to progress in iterative cycles, leading to the adoption of Agile methodology (SCRUM).

At this stage, I drafted a preliminary product backlog informed by user perspective. I generated 40 user stories that reflected varying levels of user experience and interest in cultural engagement. These stories were categorized by:

- First-time users unfamiliar with XR
- Curious learners of Māori culture
- Experienced or returning users seeking deeper exploration

Each user story helped illuminate the types of features and interface designs that should be considered. These later informed MoSCoW prioritisation (Kravchenko et al., 2022) and the Fibonacci story point estimation sequence (Cohn, 2024) in the Define phase.

---

#### 4.1.8 Concept Testing with Tools and Prototypes

To test emerging hypotheses and build confidence in technical feasibility, I engaged in early experimentation using a modular approach:

- Swift and SwiftUI: Created simple UI layouts, tested toggles, text fields, and navigations.
- RealityKit: Experimented with basic scene anchoring and physics properties.
- Reality Composer Pro: Imported static 3D models and applied animations.

- Reality Converter: Validated OBJ-to-USDZ conversions from Blender.
- Meshy AI: Tested auto-rigging and animation of humanoid models.

These early prototypes were not intended for final use but served as validation points, helping determine which pathways would be feasible. Technical notes and screenshots were archived and reviewed during each Agile sprint retrospective.

---

### 4.1.9 Defining the Problem Space

By the end of the Discover phase, several key conclusions emerged:

- A tiered interaction model (windowed → volumetric → full space) would better align with skill constraints and learning theory.
  - A minimum viable proficiency model would be required for Swift and SwiftUI.
  - Cultural fidelity must be ensured through self-reflection, value alignment, and advisor feedback.
  - Agile development, with structured sprint planning, was the optimal method for ongoing progress and adaptability.
- 

### Summary of Discover Phase

The Discover phase established the interdisciplinary foundation required for the Guardians of Matariki prototype. Through a blend of creative exploration, methodological structuring, and critical self-assessment, this phase achieved the following:

1. Thematic clarity around the cultural narrative of Matariki and its spatial storytelling potential.
2. Technical orientation toward Apple's VisionOS tools, pipelines, and interaction models.

3. User-informed insights through emerging user stories and engagement models.
4. Learning framework alignment through the integration of cognitive and constructivist principles.
5. Prioritised development targets, shaped by the Lotus Blossom analysis and SWOT findings.

This phase did not solve the project's core challenges but provided the necessary intellectual scaffolding, cultural grounding, and technical context to define what was possible, valuable, and achievable. The insights gained here directly informed the focused planning activities of the Define phase.

---

## 4.2 Phase 2: Define

### Step 2 – Synthesise and Prioritise

The Define phase marks the transition from divergent exploration to convergence of findings. Following the broad discovery of technical requirements, cultural narratives, and design theories, this phase aimed to establish a clear and feasible direction for prototype development. Activities in this phase included defining the narrative architecture, aligning educational strategies with design decisions, assessing immersive feature feasibility, and planning actionable sprints. The Define phase adhered to the Double Diamond's "Define" quadrant, employing a convergent thinking process to refine goals and identify viable development targets.

### 4.2.1 Narrative and Immersive Design Architecture

One of the primary tasks in the Define phase was to rearticulate the Matariki narrative within the specific constraints of the Apple Vision Pro (AVP) environment. The Matariki story, though familiar from previous undergraduate work, required reinterpretation to suit AVP's new modes of user interaction and spatial computing. Apple's documentation identifies three tiers of immersive experience within VisionOS:

- Windowed experience - (2D applications in the user's space),
- Volumetric experience - (3D elements coexisting with the real world),

- Full Space immersive experience - (360° spatial takeover).

In response, I created a series of low-fidelity storyboards, one for each level of immersion. These storyboards aimed to test the feasibility of delivering the Matariki narrative progressively, matching the complexity of the interaction to the degree of immersion. For example, the windowed storyboard focused on static text and iconography, while the volumetric version introduced manipulable 3D objects, and the fully immersive design included an atmospheric environment and animated elements. These sketches clarified not only the technical ambitions for each experience tier but also their educational and cultural implications.

### Window Experience:

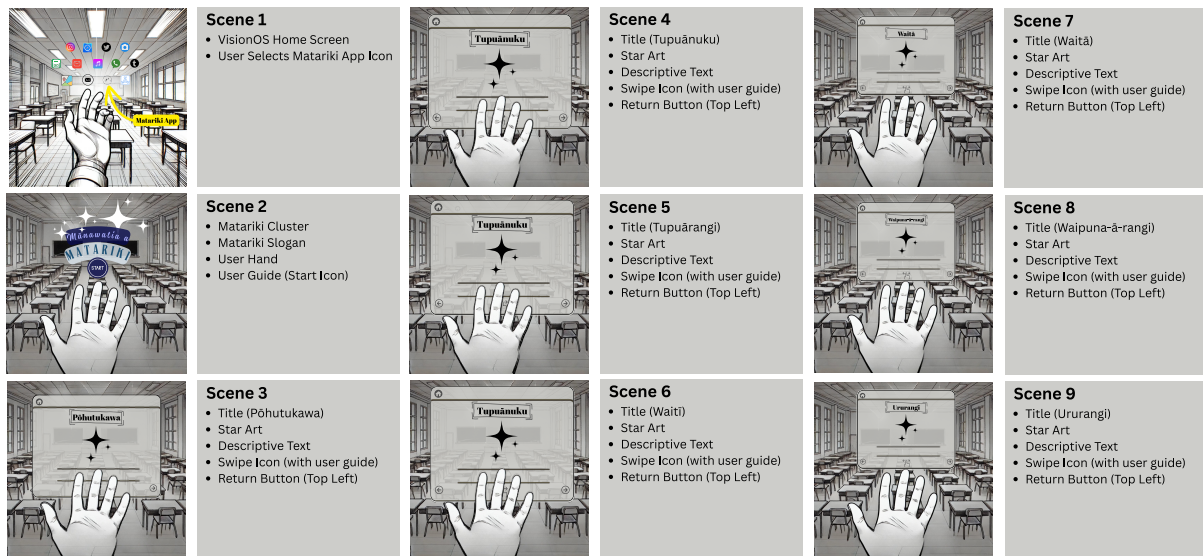


Figure 5: Part A) Window experience sketches (Authors own)

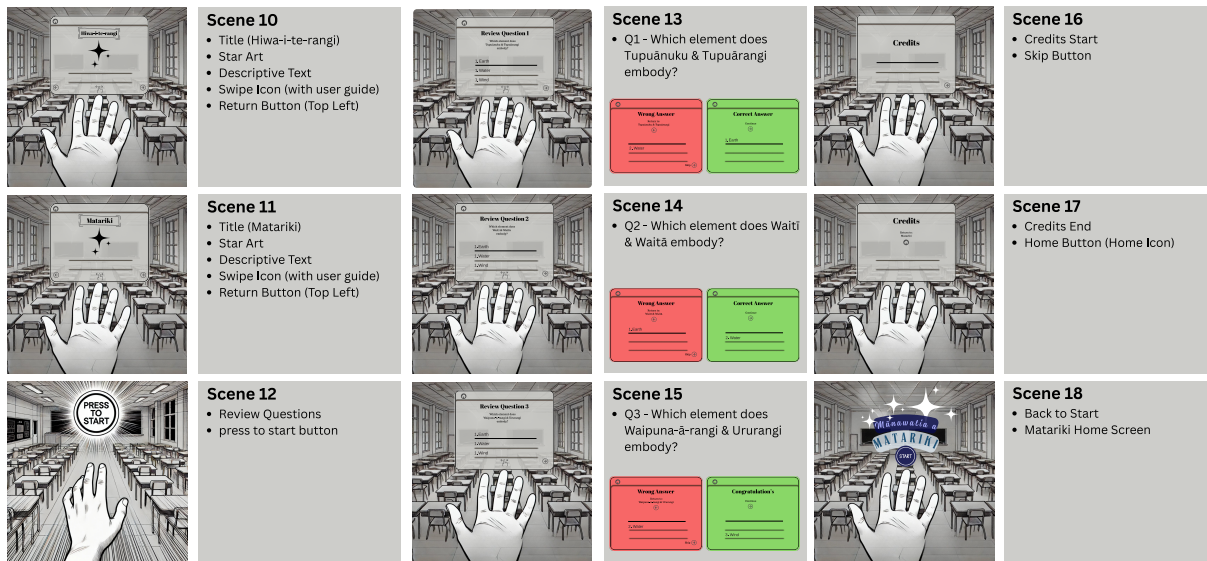


Figure 6: Part B) Window experience sketches (Authors own)

### Volumetric Experience:

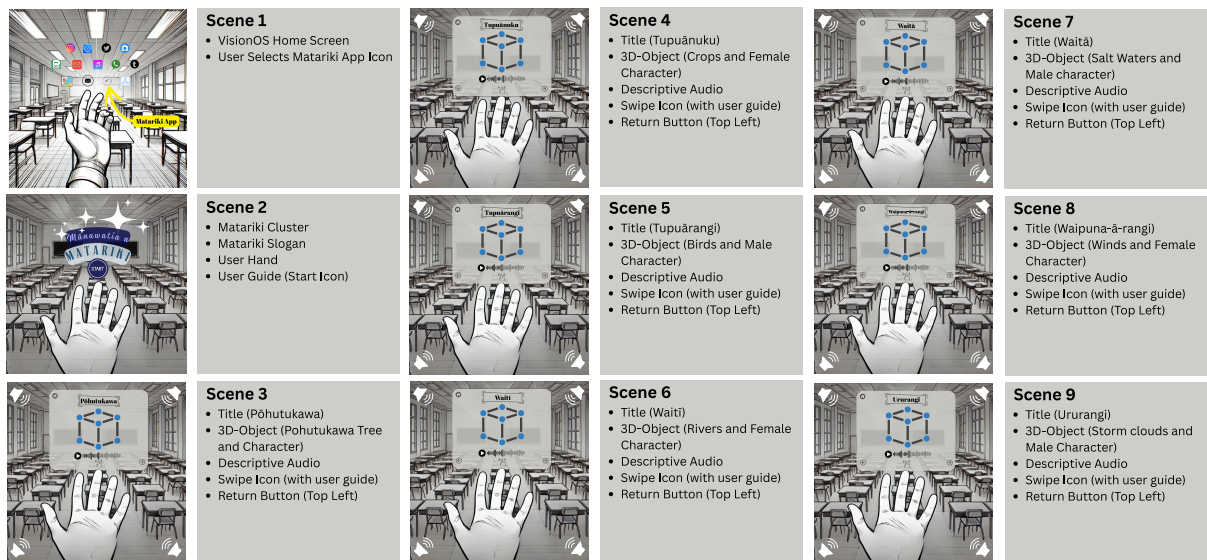


Figure 7: Part A) Volumetric experience sketches (Authors own)

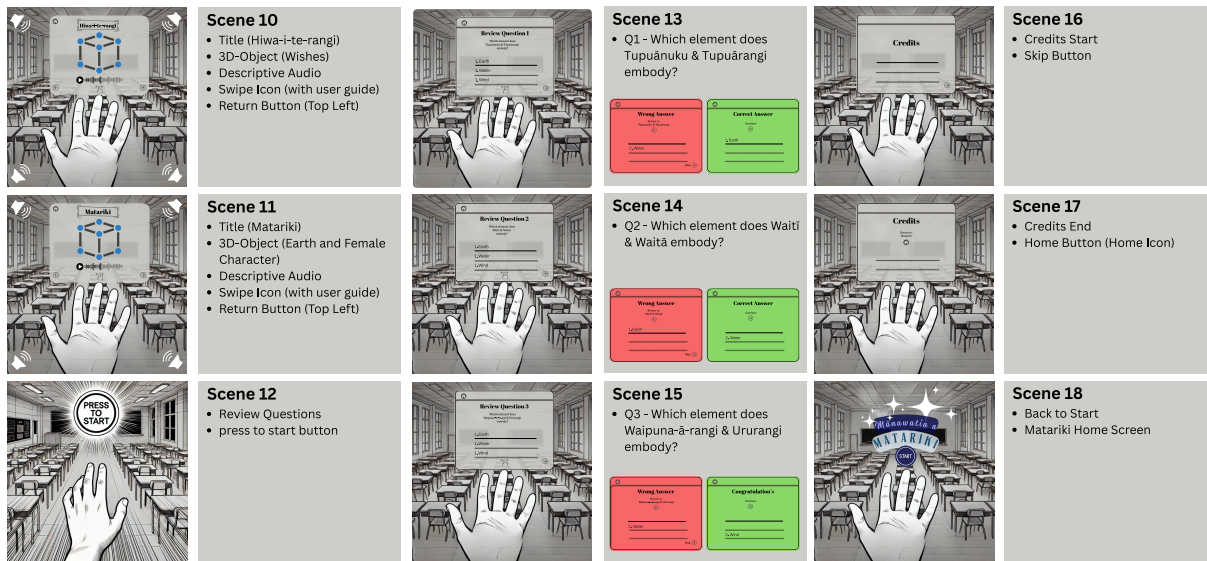


Figure 8: Part B) Volumetric experience sketches (Authors own)

Full Immersion Experience:

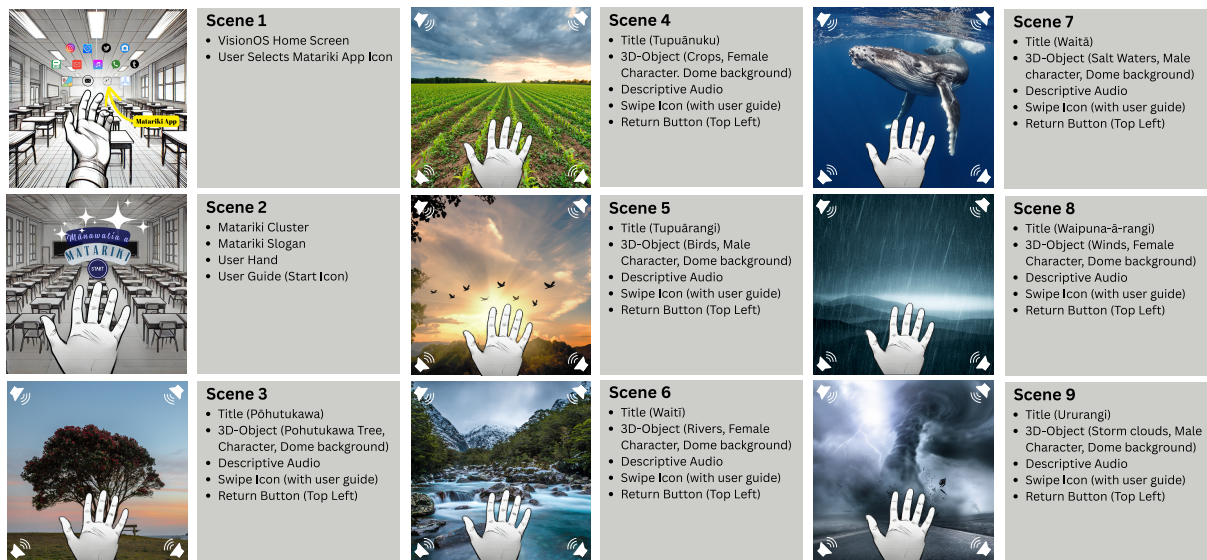


Figure 9: Part A) Full Space experience sketches (Authors own)

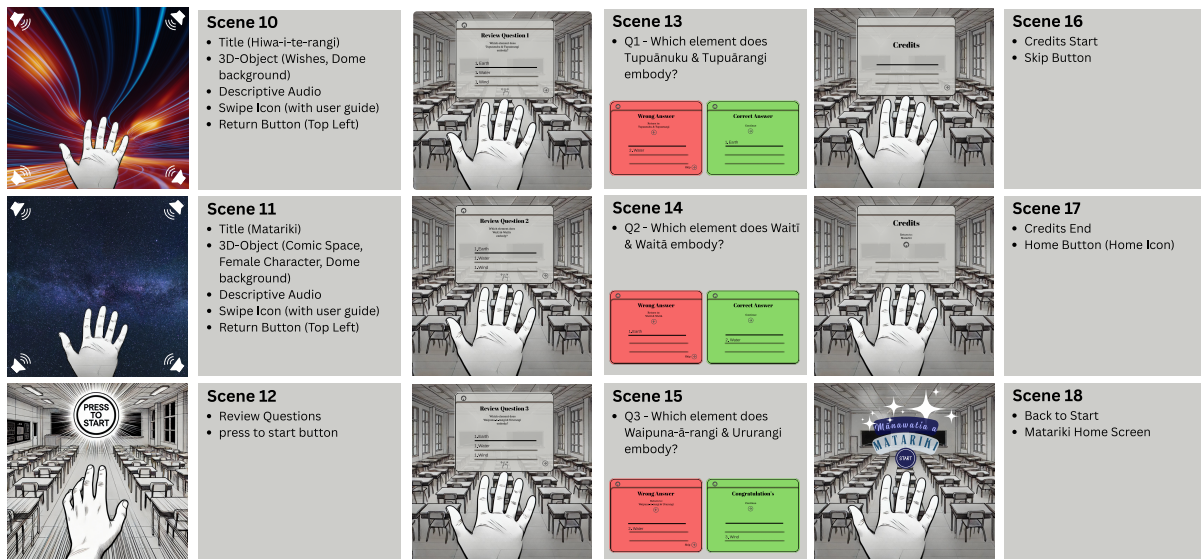


Figure 10: Part B) Full Space experience sketches (Authors own)

This design stratification became essential when aligning narrative moments to scaffolded users experience. Applying Bloom’s Taxonomy, narrative segments were structured so that each new level of immersion increased user engagement and ease of use.

#### 4.2.2 Technical Feasibility Assessment

Parallel to narrative structuring, I engaged in technical testing to determine the viability of each immersive mode. Based on earlier discoveries, I had already developed a minimalist roadmap for Swift, SwiftUI, and VisionOS fundamentals. During this stage, I extended that roadmap with practical exercises.

Using Apple’s boilerplate “Hello World” examples, I successfully deployed a windowed experience then expanded this to include a volumetric and fully immersive experience, where users could manipulate 2D and 3D object using AVP’s built-in eye-tracking and hand-gesture systems. This phase included importing assets via Reality Composer Pro and Reality Converter, validating the OBJ-to-USDZ pipeline from Meshy AI and Blender.

These findings informed subsequent planning decisions and helped to define the scope of a minimum viable product (MVP).

#### 4.2.3 User Story Development

With a clearer understanding of platform capabilities and narrative goals, I created a structured set of user stories using an Agile approach. These stories articulated potential user interactions and experiences across three types of users:

- New or beginner users, focused on onboarding and basic interaction.
- Curious or experienced users, interested in exploring cultural content and immersion.
- Proficient or fast users, looking for deeper, interactive engagement.

Each user story followed the format:

“As a [user type], I want to [action or experience] so that I can [goal or benefit].”

For example:

- *“As a beginner user, I want to see a clear start button so I can easily begin my journey.”*
- *“As a curious user, I want to tap on each Matariki star to learn more about its meaning.”*
- *“As a pro user, I want to interact with volumetric representations of the stars so I can explore the cosmological structure.”*

These user stories were logged and analysed to identify essential application features and informed the structuring of the sprint backlog.

#### 4.2.4 MoSCoW Prioritisation

Following the creation of user stories, I applied the MoSCoW prioritisation framework (Kravchenko et al., 2022) to categorise features into four levels:

- **Must Have:** Critical features required for the app to function and meet core objectives.
- **Should Have:** Important features that enhance usability or immersion but are not essential.
- **Could Have:** Optional enhancements that may improve the user experience.
- **Won't Have (for now):** Features deemed out of scope due to time or technical complexity.

Each user story and associated feature was evaluated using this model. The classification criteria included:

- Development feasibility (based on current skill level)
- Alignment with core learning goals
- Cultural and narrative fidelity
- Importance for onboarding or progression

For instance, the ability to manipulate a 3D star in the volumetric space was classified as a Should Have, while a fully immersive night sky simulation was assigned to Won't Have, given its technical demands. Basic UI elements (such as the home interface, Matariki intro text, and star selection) were marked as Must Haves.

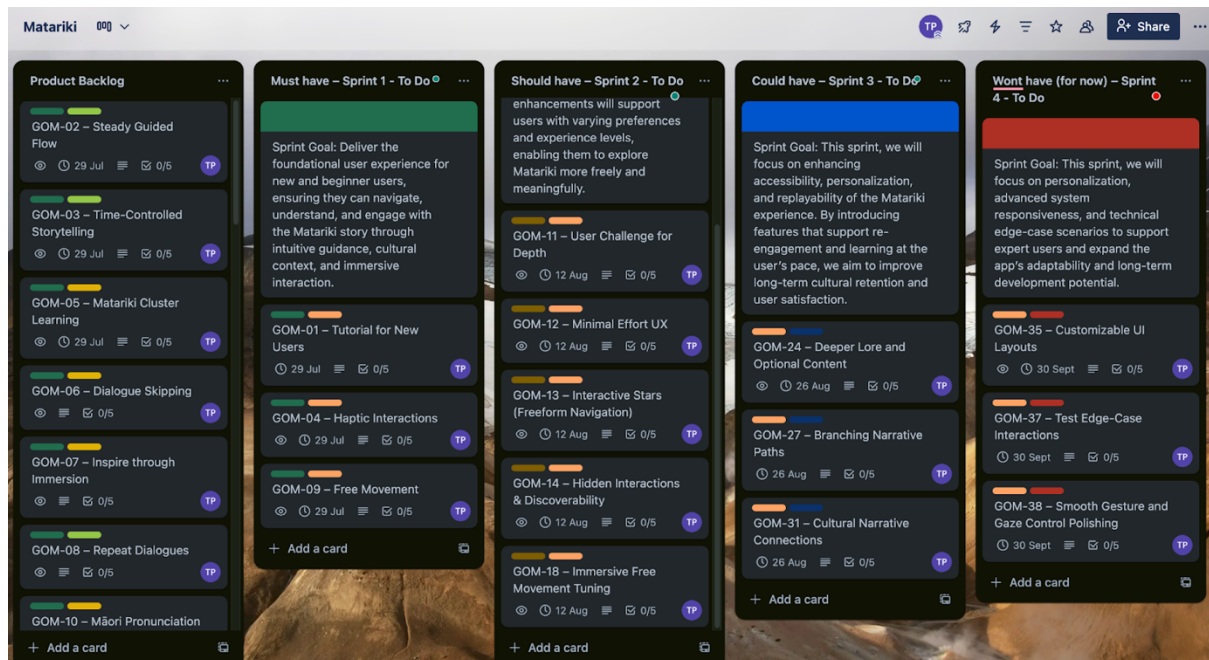


Figure 11: Project management, Trello Kanban (Authors own)

This prioritisation enabled the focusing of development resources on the features most likely to support a complete and functional MVP while leaving room for later expansion if time allowed.

#### 4.2.5 Story Pointing and Complexity Estimation

To manage sprint planning more effectively, I applied the Fibonacci story point method (1, 2, 3, 5, 8, 13, ...) to each prioritised feature. This Agile estimation technique allowed me to quantify the relative effort and complexity of implementing each item in the sprint backlog.

For example:

- Creating a basic windowed text UI was scored as 1 story point (simple and quick).
- Developing a volumetric star interaction feature was 3 story points (moderately complex).
- Attempting a real-time animated constellation sequence was 8 story points (high complexity).

This method provided a pragmatic way to schedule realistic goals per sprint. Each sprint was capped at 5 story points, reflecting a sustainable workload while allowing for time spent on debugging, design adjustments, and cultural review.

The combination of MoSCoW filtering and story point estimation yielded the first complete sprint plan for the development phase. Features were grouped into upcoming sprints by story point weight and aligned with immersion levels.

Table 2: Project Sprints (Authors own)

<b>Sprint</b>	<b>Focus</b>	<b>Feature</b>	<b>MoSCoW</b>	<b>Story Points</b>
Sprint 1 – Windowed Setup	Onboarding UI and cultural introduction	Home screen, narration, and gesture-based overlays	Must	1
Sprint 2 – Volumetric Interaction	Interactive 3D character + basic gestures	Manipulable 3D object, gaze/pinch/drag/scale interactions	Must	3
Sprint 3 – Full Space Immersive Experience	Embodied spatial scenes with narrative characters and environment	Rain/star world scenes, animated characters, ambient audio immersion	Must	2
Sprint 4 – MVP Integration	Final integration of all immersion levels + Matariki video	Combined UX flow, transitions, full testing, bonus video feature	Could	3

## 4.2.6 Defining the MVP Scope

The analysis from this phase ultimately informed a refined definition of the storyboard for a Minimum Viable Product.

MVP experience:

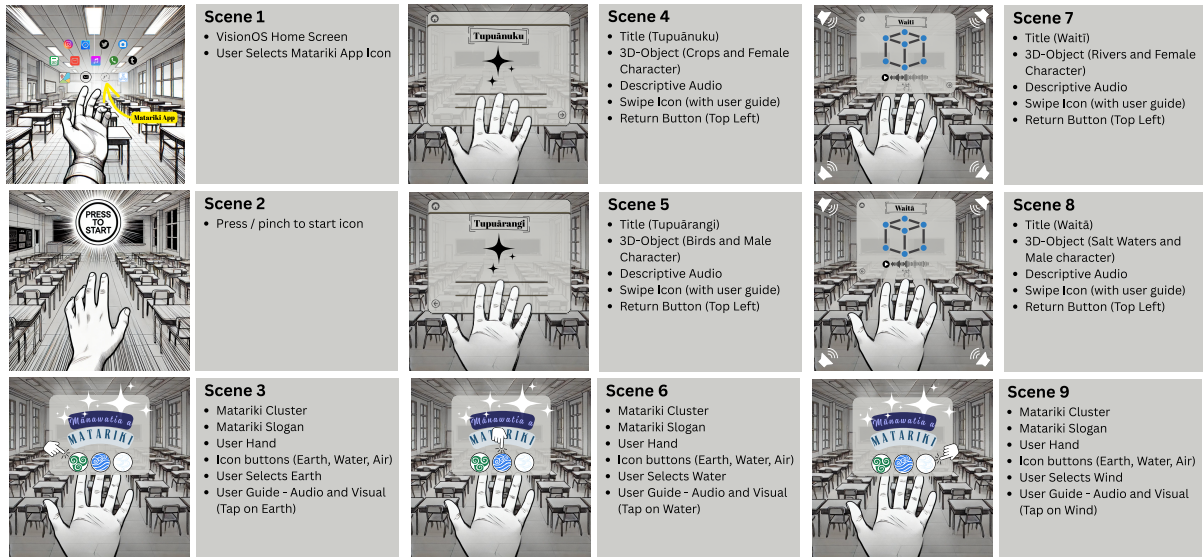


Figure 12: Part A) MVP experience sketches (Authors own)

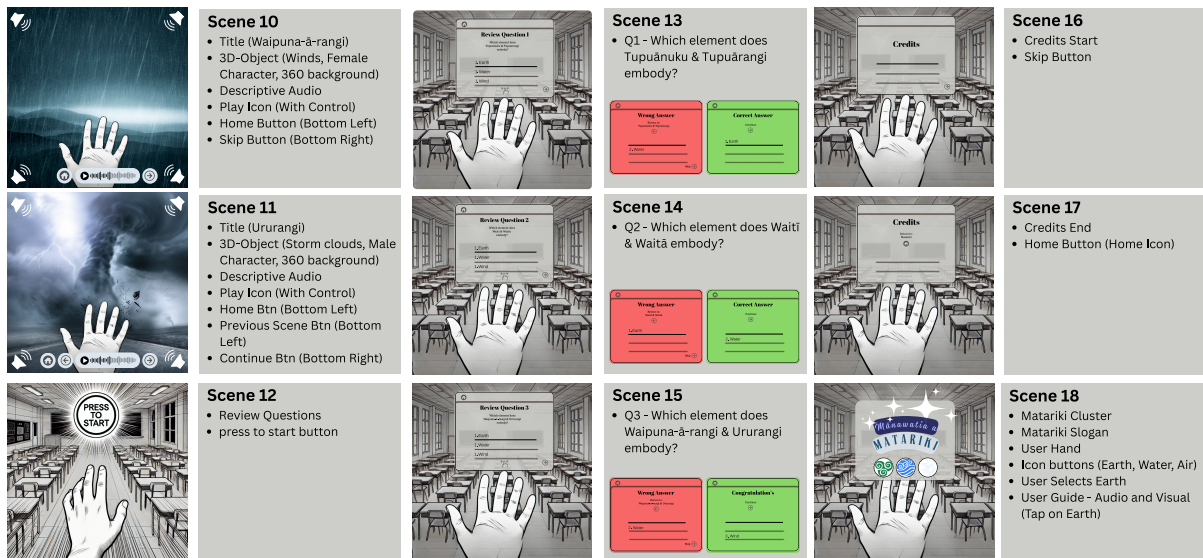


Figure 13: Part B) MVP experience sketches (Authors own)

The MVP would include:

- A windowed interface introducing the earth elements of the Matariki narrative through 2D UI.

- A volumetric scene where the user can select and manipulate 3D Models.
- A fully immersive scene where the user is immersed in environments.
- Culturally appropriate design elements, reflecting manaakitanga and kaitiakitanga.

This decision was influenced by three major inputs:

1. Learning theories (Scaffolded learning).
2. User story insights.
3. Technical constraints and feasibility analysis.

The MVP served as a practical boundary for the project, enabling a focus on delivering a coherent, functional, and culturally respectful experience within the project timeline.

---

## Summary of Define Phase

The Define phase synthesised the exploratory findings from the Discover phase into a clear development plan. It accomplished the following:

- Translated the Matariki narrative into tiered immersive experiences appropriate to VisionOS.
- Applied learning theories to structure narrative and interface design.
- Established a prioritised feature backlog, guided by Agile SCRUM methods including MoSCoW and story points.
- Defined a MVP, balancing innovation with time and skill constraints.

By grounding creative goals in both educational theory and iterative design practice, this phase positioned the project for focused development in the subsequent phase.

---

## 4.3 Phase 3: Development

### Step 3 – Build and Iterate

The Development phase marked the point of transition from planning to execution. It built directly on the foundations laid during the Discover and Define phases, translating narrative, interaction, and technical ambitions into working components of the Guardians of Matariki prototype. Guided by Agile SCRUM methodology, this phase was structured into a series of sprints aligned with the project's prioritised backlog. Each sprint represented an iterative

development cycle, targeting specific features and user stories mapped to the three levels of immersion: windowed, volumetric, and fully immersive.

### 4.3.1 Sprint Methodology and Structure

The SCRUM process began with a clear Product Backlog derived from MoSCoW prioritisation and story point estimation conducted during the Define phase. The backlog included 42 unique user stories, each representing a different type of user (new, beginner, curious, experienced, fast, pro, and engaged) and was segmented into four sprints:

- Sprint 1: Onboarding and Orientation (Windowed Experience)
- Sprint 2: Interaction and Immersion (Volumetric Experience)
- Sprint 3: Fully Immersive Cultural Storytelling (Full Space and Pass through Experience)
- Sprint 4: MVP Integration and Completion (Mixed Modes Experience)

Each sprint was scoped at approximately 5 story points based on the Fibonacci scale, balancing complexity with feasibility over the MPhil timeline. Sprint goals were clearly articulated in advance, and each cycle concluded with a retrospective to reflect on lessons learned, technical hurdles, and alignment with user needs.

### 4.3.2 Sprint 1 – Onboarding and Orientation

Sprint Goal: To establish the foundational user interface and experience, introduce the Matariki narrative, and guide users through the app's navigation in a 2D windowed mode.

This sprint focused on easing new users into the application. Key user stories included:

- "As a new user, I want to take my time through the story, so that I don't miss anything."
- "As a beginner user, I want to experience new immersive capabilities so that I feel inspired to share what I learn."

Tasks included:

- Creating the home screen in SwiftUI.
- Designing the introductory Matariki sequence using text, audio narration, and static images.
- Integrating onboarding overlays with simple gesture prompts.
- Applying accessibility principles to ensure pacing and clarity.

The completion of Sprint 1 resulted in a usable interface that functioned as the app’s entry point. It also set the narrative tone, introducing users to key Māori values such as manaakitanga (care) and whakawhanaungatanga (relationship building). The onboarding sequence was refined through multiple test iterations, prioritising clarity and minimal cognitive load. Bloom’s Taxonomy was employed to scaffold user learning from basic recall (text and narration) to comprehension (summarised cultural meaning of each star).

To support the development of the windowed experience, a sequence of low- to high-fidelity prototypes was created. This visual progression reflects the iterative design process from early sketches through to functional UI deployment, aligning with Agile development practices and user-centered design principles.



Figure 14: Initial sketches exploring the onboarding UI and navigation flow.

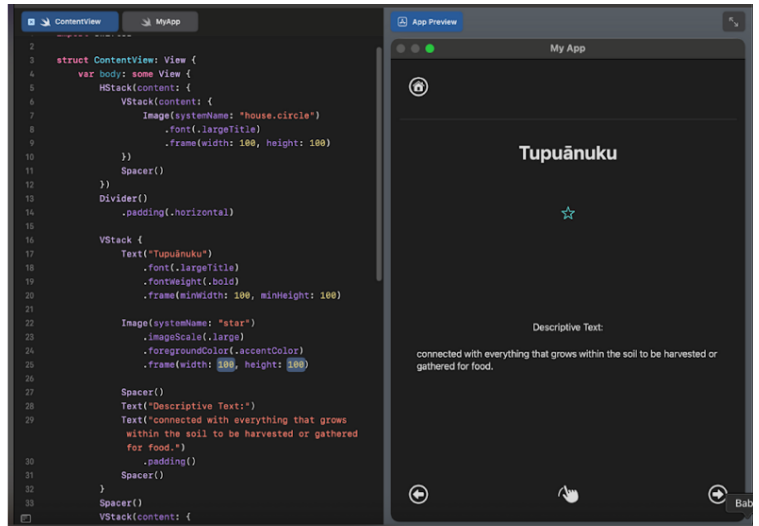


Figure 15: Swift Playgrounds prototype of the initial UI layout.

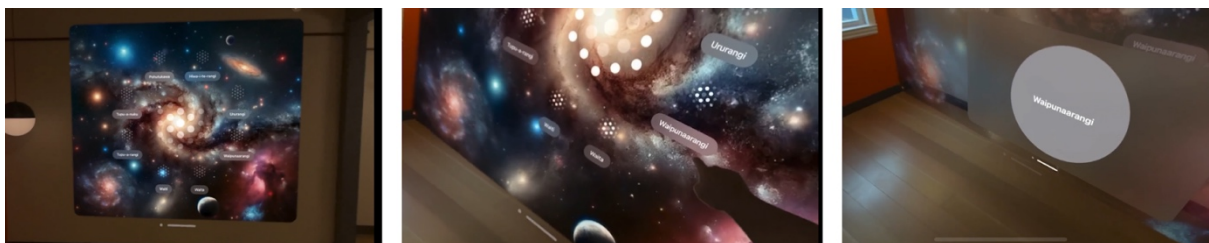


Figure 16: First UI prototype in AVP, showing layout placeholders without cultural images or text. The prototype was used to test component positioning, navigational affordances, and SwiftUI scene transitions.

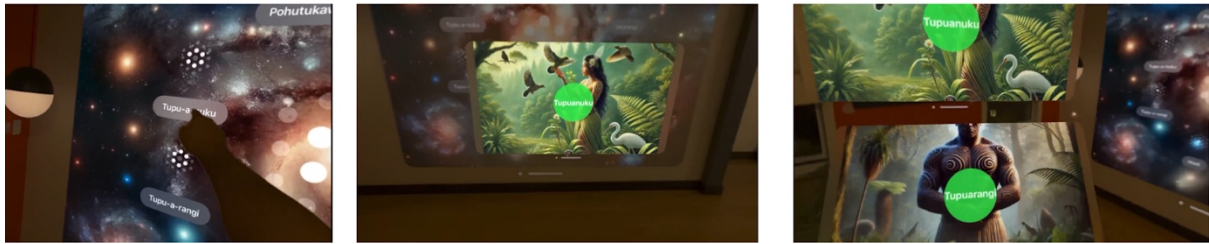


Figure 17: Updated prototype including cultural images and introductory text. This stage focused on narrative clarity and visual tone, incorporating feedback from self-led walkthroughs.

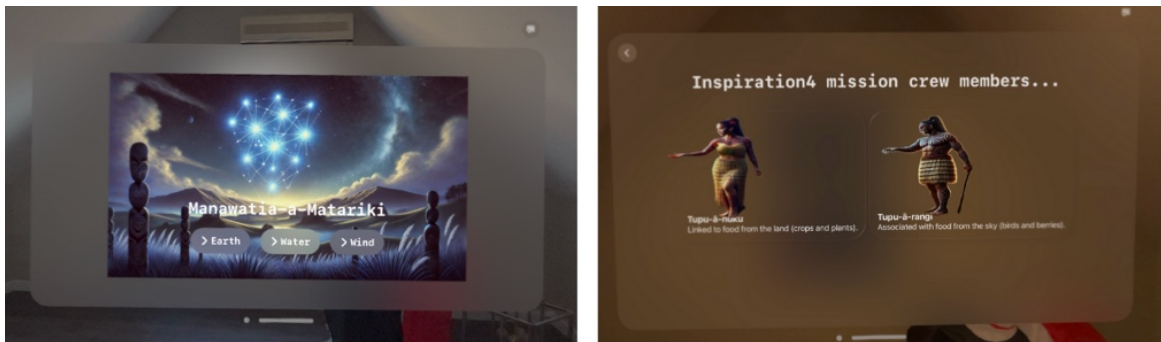


Figure 18: Updated prototype with interactive element buttons. This updated UI layout is similar to the MVP layout with element buttons to introduce the earth stars tupuānuku and tupuārangi.



Figure 19: Updated prototype with interactive element buttons. This updated UI layout is similar to the MVP layout with element buttons to introduce the earth stars tupuānuku and tupuārangi.

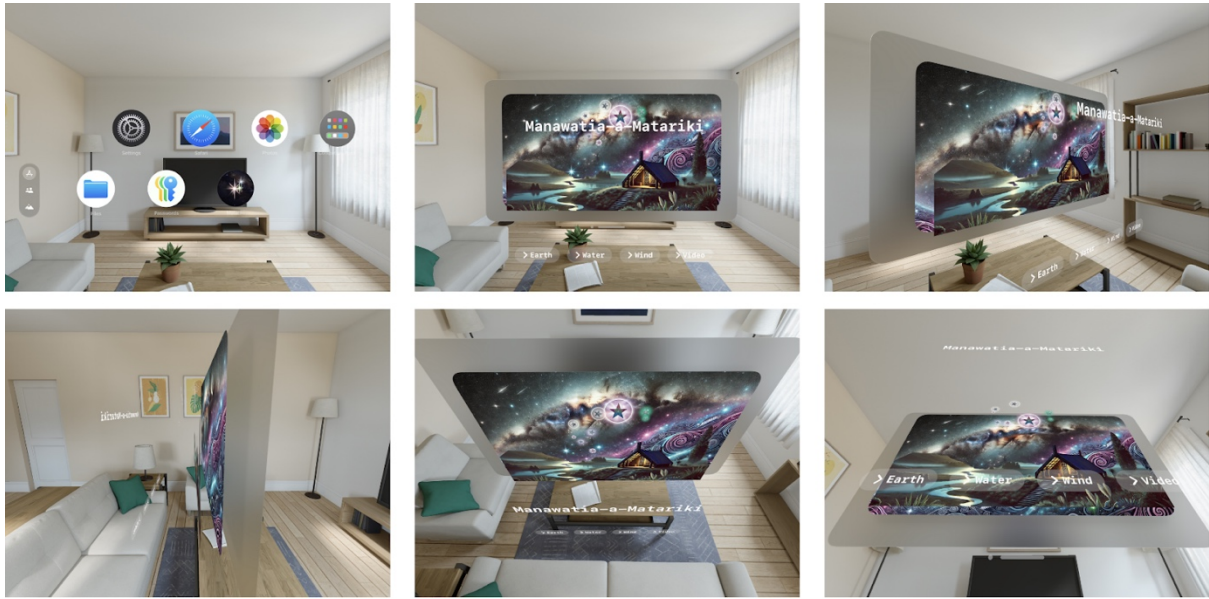


Figure 20: Finalised windowed interface of Matariki UI with layered Z-Stack layout for interactive depth. This version introduced subtle spatial layering to allow for pop-out effects, enhancing user engagement without overwhelming visual load.



Figure 21: Finalised windowed interface of Tupuānuka & Tupuārangi UI with layered Z-Stack layout for interactive depth. This version introduced subtle spatial layering to allow for pop-out effects, enhancing user engagement without overwhelming visual load.

This visual series illustrates how iterative prototyping was critical to shaping an interface that was both technically feasible and culturally respectful. Each stage informed refinements in layout, gesture mapping, and storytelling sequence.

### 4.3.3 Sprint 2 – Interaction and Immersion (Volumetric Experience)

#### **Sprint Goal:**

To develop a volumetric interaction layer enabling users to manipulate 3D objects through basic spatial input methods, specifically gaze, pinch, drag, and scale and to prototype culturally resonant experiences aligned with the narrative of Matariki.

This sprint marked a significant progression from windowed interaction to spatially embodied engagement. Volumetric immersion allowed users to interact with 3D models positioned in the user's space, creating deeper engagement through spatial awareness, proprioception, and kinaesthetic input. The iterative nature of this sprint was shaped by technical experimentation and continuous design refinement across multiple prototypes.

Key user stories for this sprint included:

- *“As a curious user, I want to gaze at a 3D object to trigger a response, so that I can intuitively explore the experience.”*
- *“As a beginner user, I want to pinch and drag objects, so that I can interact without needing to learn complicated controls.”*
- *“As a fast user, I want the interaction to respond to natural gestures, so that it feels fluid and seamless.”*
- *“As an experienced user, I want to scale and reposition stars in 3D space, so that I feel a greater sense of agency in the experience.”*

Volumetric Interaction Iteration Process:

The development began with conceptual sketching to establish a spatial layout that reflected the radial formation of the Matariki cluster. From there, eight iterative prototypes were produced to test, refine, and evaluate the responsiveness of volumetric interactions and narrative anchoring.

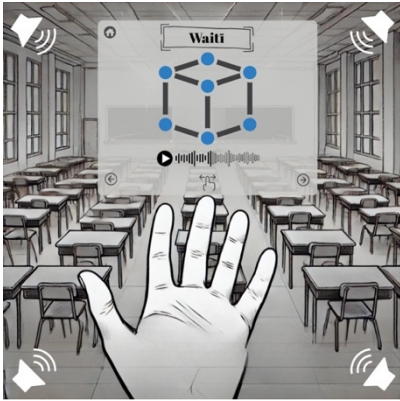


Figure 22: Initial sketch of the volumetric layout.

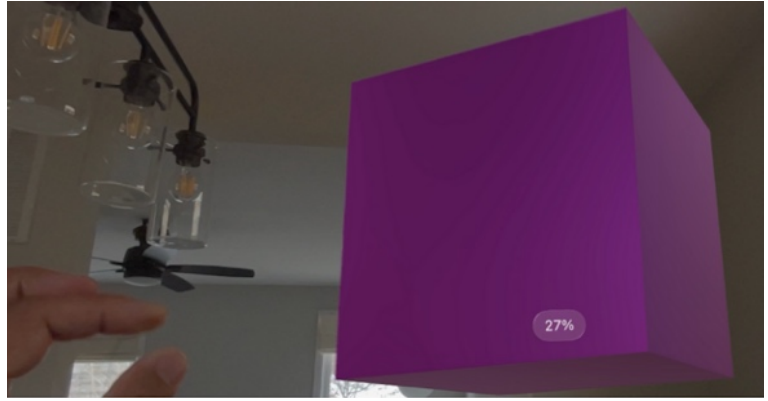


Figure 23: Early prototype using an abstract cube object. This model was used to validate interaction inputs such as gaze-to-focus, pinch-to-scale, and drag-to-position.



Figure 24: Animated star objects introduced with rotating motion. Stars were animated in rotation to simulate celestial motion, adding visual feedback to user presence and enhancing the sense of a living cosmos

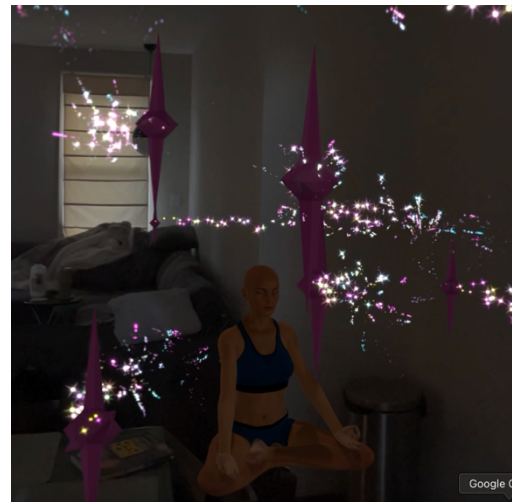


Figure 25: Rotating stars integrated with the meditating character. This version layered character and stars together, allowing for passive interaction and spatial proximity testing.

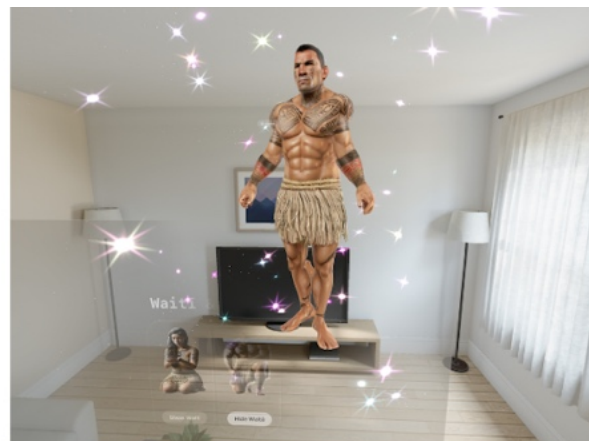
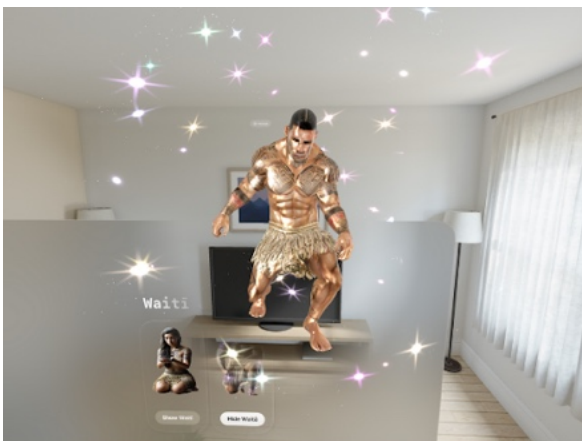


Figure 26: Animation of Māori warrior transitioning from kneeling to standing, with rotating stars.



Figure 27: Māori warrior standing, With a small interactive UI panel positioned in front of the character, which displayed descriptive text about the star “Waitā”.



Figure 28: Final volumetric prototypes: Waitā warrior animation, rain, rotating stars, and UI overlay which displayed descriptive text about the star. Demonstrating layered spatial storytelling.

#### Technical Development and Tools Used:

- Reality Composer Pro was used to position and animate assets using anchor-based configurations.
- RealityKit handled gesture recognition and model transformations including scaling, rotation, and translation.

- Xcode + SwiftUI were employed to build the interaction logic and render content responsively inside the AVP environment.
- Meshy AI assisted in auto-rigging character models to streamline animation workflow.

The layered design logic of the scene allowed for the user to start with minimal interaction (gazing at objects) and progress to full manipulation (pinch and drag), thereby following a constructivist approach to learning by doing.

---

#### Theoretical and Design Considerations:

- Constructivist learning principles informed the non-linear spatial design, encouraging users to discover meaning through interaction rather than linear progression.
  - Cognitive Load Theory guided the pacing of animations, the simplification of interactions, and the restrained visual environment.
  - Māori values, particularly *kaitiakitanga*, underpinned the narrative integration of the Māori warrior figure as a guardian of cultural knowledge.
- 

#### Outcomes

This sprint produced a working volumetric prototype featuring animated 3D assets, gesture-based input, and narrative overlays. The progression from abstract shape manipulation to culturally meaningful character animation illustrated the evolution of both technical skill and cultural intentionality. Most importantly, the sprint validated the feasibility of deploying a volumetric experience using basic gesture inputs and set the stage for further narrative layering in future development.

### 4.3.4 Sprint 3 – Fully Immersive Cultural Storytelling

#### **Sprint Goal:**

To deliver a fully immersive spatial experience that integrates animated environmental elements, Māori cosmological characters, and interactive user interfaces. This sprint aimed to position the user inside a culturally resonant world, where interaction, narrative, and ecological symbolism unfold in real-time through spatial immersion.

Unlike prior sprints, which focused on 2D or volumetric layers, this sprint concentrated on designing a 360° immersive experience in VisionOS. The user is surrounded by interactive

cultural scenes, moving from observer to participant, supported by audio, atmospheric effects, and narrative metaphors aligned with individual Matariki stars.

Key user stories guiding this sprint included:

- “As a curious user, I want to be surrounded by the story so that I feel like I’m inside the Matariki universe.”
- “As a culturally engaged user, I want each star to be presented in a way that reflects its ecological and spiritual meaning.”
- “As a visual learner, I want to explore immersive environments that change with each character so that I understand the unique traits of each star.”
- “As an experienced user, I want to use gestures and gaze to explore scenes without leaving the immersive mode.”

Iterative Development of the Immersive Experience:

The immersive experience was built across five key iterations. Each prototype advanced visual fidelity, interaction design, and narrative delivery. Assets were tailored for two specific stars: Waipuna-ā-rangi (rain and nourishment) and Ururangi (wind and movement).

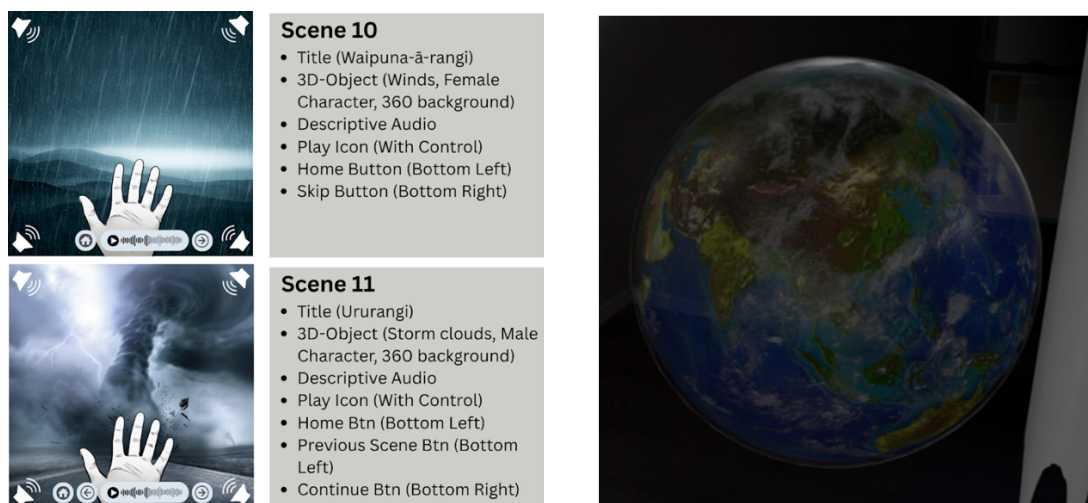


Figure 29: Early sketch of immersive layout concepts

Figure 30: Immersive environment prototype with Earth object only. This was the first version to fully surround the user in Full Space immersion

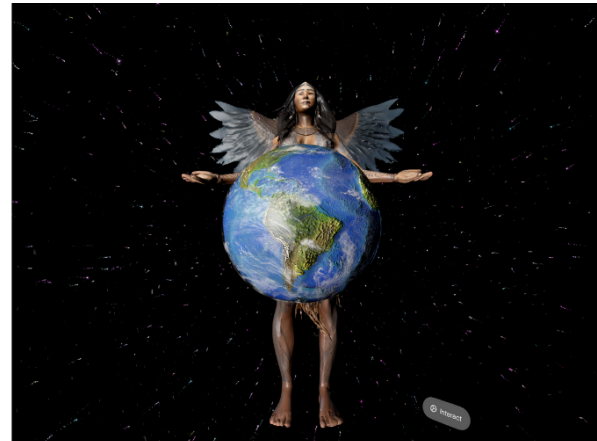
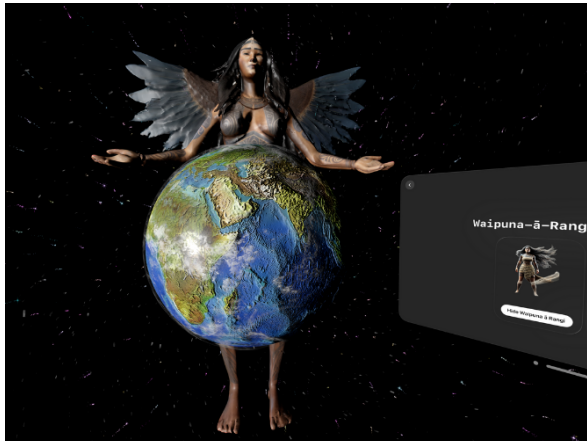


Figure 31: Waipuna-ā-rangi with stars and rain effects. A female figure representing Waipuna-ā-rangi was introduced alongside rainfall particle effects. Stars hovered above, connecting the celestial and terrestrial elements. Rainfall was symbolic of nourishment and manaakitanga (care), which the star embodies.



Figure 32: Waipuna-ā-rangi immersive scene with interactive UI and audio. An interactive panel was added, placed within comfortable gaze range in front of the character. Text descriptions, cultural meanings, and audio were triggered.

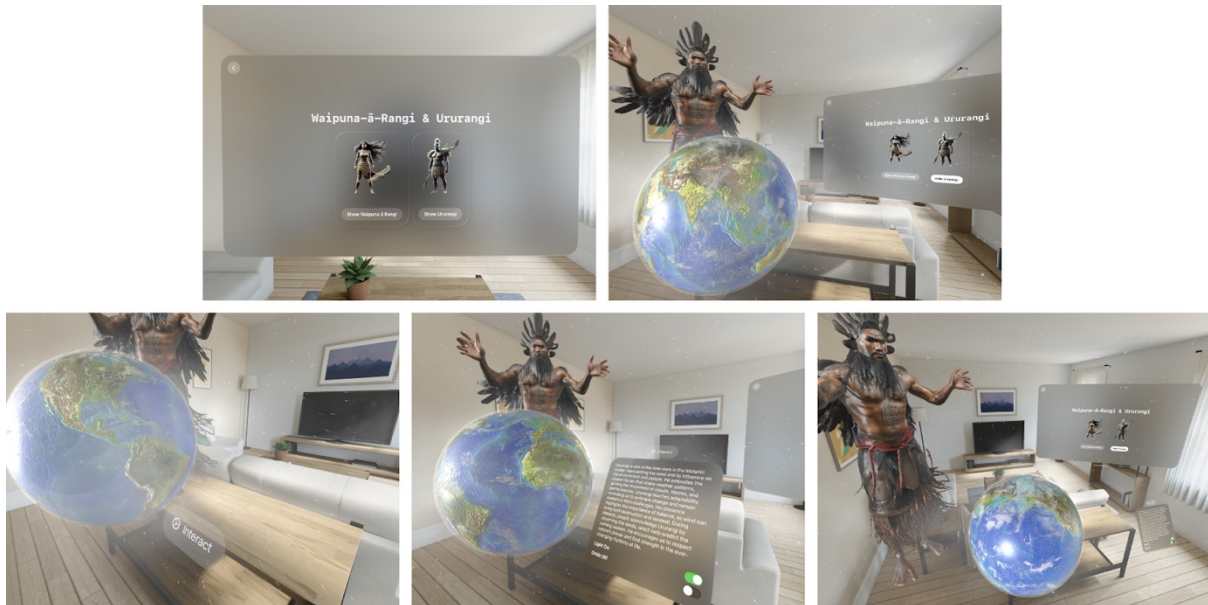


Figure 33: Ururangi immersive scene in passthrough mode with swirling clouds. Ururangi’s scene featured wind-based motion. Swirling cloud effects enveloped the environment, while the Māori guardian stood grounded in the center. Audio and text interfaces described Ururangi’s association with change, journeying, and the winds of transition. The use of passthrough enhanced the blending of physical and digital space.

#### Technical Implementation and Tools:

- Reality Composer Pro was used to build the 360° environmental layers, placing characters, lighting, and effects within a spatially anchored scene.
- RealityKit enabled dynamic animations and gesture-based input, including gaze-based selection, pinch-to-trigger interactions, and UI hover states.
- Particle Systems simulated rain and cloud motion. These were tuned to remain atmospheric without overwhelming the user’s vision or causing disorientation.
- SwiftUI overlays were implemented as flat panels with descriptive content and audio narration, tailored to the story of each star.

#### Cultural Alignment and Design Intent:

Each immersive scene was designed to honour kaupapa Māori by embedding Māori values into interaction design and visual metaphors:

- Waipuna-ā-rangi: Represented *manaakitanga* (care, nourishment), visually symbolised by gentle rain falling on the Earth. Character posture and expression were designed to evoke guardianship and serenity.

- Ururangi: Represented *kaitiakitanga* and movement, depicted through dynamic swirling clouds and a grounded figure ready for transition. The environmental elements shifted continuously, metaphorically echoing the nature of wind.

Scenes maintained the radial star layout for continuity with the volumetric level and respected the astronomical positioning of the stars in the night sky. Soundscapes further reinforced meaning, rain for Waipuna-ā-rangi, and wind for Ururangi, immersing users through auditory cues.

---

#### Educational and UX Considerations:

This sprint marked the transition from passive viewing to active spatial engagement in the prototype's narrative structure. Educational scaffolding was aligned with Bloom's Taxonomy:

- *Remember and Understand*: Through initial observation and audio narration.
- *Apply and Analyse*: By exploring layered meanings and cultural relationships in spatial context.
- *Evaluate*: Through reflection on interconnected ecological and spiritual meanings.

Minimal cognitive load was preserved by limiting visible UI, designing responsive input triggers, and offering optional learning enhancements (repeat audio, description expansion).

---

#### Summary of Full Immersive Sprint:

This sprint successfully delivered a culturally rich, technically stable, and emotionally resonant immersive storytelling experience. Its iterative design process from initial sketching to full deployment in VisionOS demonstrated the feasibility and effectiveness of applying fully immersive environments for Māori cultural education. It also expanded the MVP's spatial capabilities by:

- Offering dynamic, full-surround scenes that respond to natural gestures.
- Embedding narrative-rich characters and environments tied to each star's cultural role.
- Using mixed interaction layers (passthrough and full immersion) to support accessibility and presence.

- Reinforcing te ao Māori through atmospheric and symbolic design.

This immersive mode now stands as a key narrative tier in the Guardians of Matariki prototype and forms a critical component of its user engagement strategy.

### 4.3.5 Sprint 4 – MVP Integration and Completion

**Sprint Goal:** To integrate the Windowed, Volumetric, and Fully Immersive experience layers into a cohesive, functional MVP; and to ensure narrative consistency, usability continuity, and cultural alignment across all interaction modes.

This sprint represented the culmination of prior development cycles. Rather than focusing on speculative or future-facing features, Sprint 4 emphasised structural integration and deployment-readiness. All key features developed in Sprints 1–3 were consolidated into a seamless application experience, designed to guide users from introductory onboarding to immersive spatial interaction while maintaining narrative fidelity and cultural resonance throughout.

Key Integration Objectives:

- Harmonise technical architecture and interface logic across the three main immersion types: Windowed, Volumetric, and Full Space Immersion
- Establish consistent interaction patterns using gaze, pinch, and tap inputs across all scenes
- Ensure cultural concepts such as manaakitanga, kaitiakitanga, and whakawhanaungatanga were reinforced at every level of immersion
- Streamline transitions between immersion modes for performance and user clarity

---

Tasks and Implementation:

#### 1. Multi-Modal Scene Integration:

Using SwiftUI for the entry-level Windowed scenes and RealityKit for both Volumetric and Fully Immersive content, architectural linking was achieved through hand and eye gesture-driven transitions. State bindings and dynamic navigation models allowed users to move from a 2D menu to a volumetric scene, and eventually into fully immersive narrative environments such as the Waipuna-ā-rangi rain world or the Ururangi pass through sky dome.

## 2. Cross-Scene State Continuity:

User actions and progress were retained across immersion modes, allowing users to revisit previously explored stars. This state persistence supported reflective engagement and promoted user autonomy in narrative navigation.

## 3. UI and UX Consistency:

Visual components such as the floating descriptive text UI, animated characters, audio descriptions, and navigational glyphs were implemented with minor stylistic adaptations across immersion levels to preserve familiarity and reduce cognitive friction. Interaction feedback cues (e.g., glow, scale-on-hover, audio haptic feedback) were tested across scenes to maintain usability.

## 4. Cultural Narrative Alignment:

The Matariki story arc was tested across all three layers to ensure that each star's significance (e.g., Waitī, Waipuna-ā-rangi, Ururangi) was represented clearly, without contradiction or redundancy. Each scene used environment appropriate delivery: onboarding narration in the windowed layer, interactive 3D storytelling in the volumetric level, and environmental immersion in full space immersive scene.

## 5. Final Feature Layering:

All working elements including onboarding, star selection, character animation, spatial narration, and ambient sound were combined into a complete user flow. Scene sequencing and transition fluidity were adjusted based on final deployment tests.

---

## Evaluation and Iteration:

As with prior sprints, Sprint 4 involved structured evaluation using multiple reflective and empirical strategies:

- NASA-TLX (Task Load Index):  
Used to evaluate perceived workload during full experience walkthroughs. Results indicated that transitions from windowed to immersive scenes required higher mental effort but were perceived as manageable due to onboarding clarity and visual continuity. Adjustments were made to reduce transition lag and simplify UI during scene entry.

- TAM (Technology Acceptance Model):  
Focused on perceived ease of use and usefulness across the full MVP. The integrated experience scored highest on perceived usefulness, particularly in cultural learning and spatial engagement. Features like character-led explanations and environmental effects were judged by simulated user personas as “highly useful” for emotional and cultural immersion.
  - Experiential Surveys:  
Simulated personas were used to evaluate fluidity of narrative delivery, interface comprehension, and gesture responsiveness across transitions. Personas ranged from first-time cultural learners to fast, pro-level users. Feedback emphasized the need for repeatable UI interactions and consistent visual cues.
  - Reflexive Journals:  
The developer recorded iterative insights after each test session, especially focusing on emotional transitions, cultural tone shifts, and input misalignment. These logs informed interface pacing, gesture recalibration, and scene transition timings.
- 

#### Bonus Feature: Embedded Matariki Video:

As an enhancement, a short educational video on the origins and cultural meaning of Matariki was embedded into a new SwiftUI windowed layer. This video, integrated using AVKit, was positioned as an optional but accessible learning feature for users unfamiliar with the Matariki tradition. It provided a non-interactive entry point to the topic, reinforcing the significance of Matariki in Aotearoa New Zealand .

---

## Summary of Development Phase

The Development phase transformed abstract design goals into a fully functional prototype, culminating in Sprint 4’s integrated MVP. Through iterative sprints grounded in user-centered design, kaupapa Māori values. The Guardians of Matariki prototype achieved the following:

- A windowed onboarding layer introducing Matariki, Tupuānuku and Tupuārangi.
- A volumetric experience of Waitī and Waitā with 2D UI interaction and animated characters.

- Full space immersive scenes of Waipuna-a-rangi and Ururangi.
- Consistent interaction feedback and UI design across all layers
- An embedded Matariki educational video as an inclusive cultural primer

The resulting MVP reflected both technical experimentation and cultural sensitivity, balancing spatial computing innovations with respectful storytelling. The next phase of the exegesis will evaluate this artefact's performance and limitations, drawing on both qualitative and quantitative data.

---

## 4.4 Phase 4: Deliver

### Step 4 – Evaluate and Consolidate

The Deliver phase served as both the culmination of the prototype development process and the evaluative lens through which its effectiveness, usability, and cultural alignment were assessed. Framed by the final quadrant of the Double Diamond methodology, this phase focused on testing, refining, and consolidating the MVP. It emphasised both technical functionality and the project's alignment with educational and cultural goals.

Given the solo nature of this research, formal usability testing with external users was not conducted. Instead, delivery was approached through structured internal testing using self-evaluation models and iterative reflection. The phase also integrated assessments aligned with kaupapa Māori values, ensuring that both the application's mechanics and its cultural delivery remained ethically grounded.

---

### 4.4.1 Objectives of the Deliver Phase

The Deliver phase aimed to achieve five core objectives:

1. Finalise the MVP based on prioritised features and immersion tiers defined in previous phases.
2. Conduct usability evaluations using the NASA Task Load Index (NASA-TLX) and the Technology Acceptance Model (TAM).
3. Apply cultural and learning theory evaluation frameworks to assess effectiveness, user readiness, and value alignment.

4. Document visual and technical outputs, including wireframes, scene architecture, and motion workflows.
5. Reflect on development constraints, user needs, and readiness for future expansion.

The outcomes of this phase provided the basis for evaluating whether the project had met its learning, interaction, and storytelling goals.

---

#### 4.4.2 Finalisation of the MVP

The final Minimum Viable Product (MVP) consolidated the most critical features identified through MoSCoW prioritisation and user story analysis. These features were implemented across three levels of immersion:

*Table 3: MVP Features (Authors own)*

<b>Immersion Level</b>	<b>Features Delivered</b>
Windowed	Onboarding interface, Matariki introduction, user navigation, static cultural text, pronunciation audio.
Volumetric	Interactive 3D character, gesture and gaze controls, contextual overlays, exploration of star-specific stories.
Full Space (Limited)	Concept prototype with ambient starfield and atmospheric storytelling elements and interactive UI.
Video Window	Embedded Matariki descriptive video.

Development was completed using Xcode, SwiftUI, RealityKit, and Reality Composer Pro, with all components tested within the VisionOS simulator. Where features exceeded the defined MVP scope, such as ambient audio layering or immersive AI-led narration. These were scoped for future development and documented accordingly.

---

Because the project was conducted by a single researcher, the NASA-TLX framework was used as a reflective self-assessment tool rather than a formal empirical evaluation. The

results presented in this section are therefore interpretive and based on my own experiences as the designer and user during testing. They provide heuristic insights that guided design refinement rather than statistically validated data.

#### 4.4.3 NASA-TLX Evaluation: Cognitive Load Analysis

To assess cognitive demand across different levels of interaction, the NASA Task Load Index (NASA-TLX) was applied. This model measures six dimensions of workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Each level of immersion was tested individually using a structured walkthrough, followed by scoring and reflection.

Table 4: NASA-TLX Evaluation: Cognitive Load Analysis (Authors own)

<b>Metric</b>	<b>Windowed</b>	<b>Volumetric</b>	<b>Immersive (Prototype)</b>
Mental Demand	3	6	8
Physical Demand	1	4	5
Temporal Demand	2	5	7
Performance	8	6	5
Effort	3	6	7
Frustration	2	3	6

Interpretation:

- The windowed experience had low cognitive load and was appropriate for onboarding and early learning.
- The volumetric mode introduced moderate complexity due to spatial navigation and gesture control, but remained manageable.
- The Full Space immersive prototype showed significantly higher scores across multiple load categories, particularly in mental and temporal demand.

For me as the designer, the analysis highlighted areas where pacing and visual cue clarity could be refined to improve overall usability. Particularly in the volumetric experience, where complexity could become disorienting without appropriate scaffolding.

The Technology Acceptance Model (TAM) was also applied as a reflective framework rather than a formal usability study. Since I was the sole participant, the responses were intended to capture my subjective impressions of the system’s usability and usefulness. These reflections were used to inform design iteration and self-evaluation, not to generate generalisable conclusions.

#### 4.4.4 Technology Acceptance Model (TAM): Perceived Usability

To complement cognitive load findings, the Technology Acceptance Model (TAM) was used to assess perceived usefulness and ease of use. TAM provides two primary constructs:

- Perceived Usefulness (PU): the degree to which a person believes the system helps them perform a task.
- Perceived Ease of Use (PEOU): the degree to which the system is considered intuitive and effortless.

Each immersion level was evaluated via Likert-scale responses based on solo testing and reflective analysis.

Table 5: Technology Acceptance Model (TAM), (Authors own)

Question	Windowed	Volumetric	Immersive (Prototype)
PU: Helped me understand Matariki	7	6	5
PU: Supported my cultural learning	6	6	4
PEOU: Interface was intuitive	6	5	3
PEOU: Felt easy to navigate	6	5	3

Findings:

- The windowed experience was perceived as both useful and accessible, validating its role as a low-barrier entry point to the cultural content.

- In my self-evaluation, the volumetric experience felt useful, though I noticed minor interaction friction likely caused by less precise gesture detection in the simulator.
  - The Full space immersive mode, received the lowest scores, suggesting that additional onboarding and simplification would be needed for real-world deployment.
- 

#### 4.4.5 Cultural Alignment and Kaupapa Māori Reflection

The application was then evaluated against the three key Māori values defined at the outset of the project. These included:

- Manaakitanga (care and support): Measured through tone of narration, responsiveness of design, and inclusive pacing. The windowed experience especially embodied this value, providing a gentle, respectful entry into cultural content.
- Whakawhanaungatanga (relationship-building): Reflected in the emphasis on immersive dialogue, symbolism, and user freedom to explore. Volumetric interactions encouraged personal pathways through the content rather than fixed sequences.
- Kaitiakitanga (guardianship): Central to the selection and presentation of the Matariki narrative. Content was drawn from credible sources, and presentation avoided trivialising spiritual meanings. Animations and interactive behaviours were minimalistic, symbolic, and aligned with the cultural gravity of the stars.

No content was gamified, and no elements sought to reduce the story to metrics or achievements. This restraint was a deliberate expression of cultural guardianship, ensuring the project aligned with both academic and tikanga Māori protocols.

---

#### 4.4.6 Visual and Technical Output Documentation

The final phase of delivery included comprehensive documentation of both the product and the process. Assets and outputs compiled included:

- Storyboard Progression: From hand-drawn sketches to digital prototypes showing evolution of interaction and content layout.
- UI Wireframes: Including variations tested for onboarding, star selection, and glossary access.

- Volumetric Layout Maps: Depicting the spatial positioning of each 3D characters.
- Scene Structure Diagrams: Showing asset integration pipelines, entity hierarchies, and event triggers across SwiftUI and RealityKit layers.
- Learning Scaffold Overlays: Demonstrating the alignment of content with Bloom's Taxonomy across three immersion levels.

These outputs also serve as a future-facing toolkit for potential expansion. In particular, they enable new developers or researchers to pick up from the MVP baseline and build toward full immersion, AI integration, or even co-creation features.

---

#### 4.4.7 Limitations and Future Considerations

Several limitations emerged during this phase, both anticipated and incidental:

- Absence of external user testing limited the breadth of validation. While self-assessment was methodical and consistent, real user feedback, especially from Māori educators or learners would improve reliability and cultural fit.
- Deferred AI integration: Originally conceptualised as a potential feature (e.g., AI-guided navigation, pronunciation feedback), this functionality was not implemented within the project timeline and is reserved for future study.
- Limited accessibility testing: While the UI was designed with simplicity in mind, no formal testing was conducted for users with visual, motor, or auditory impairments.

Despite these limitations, the prototype functioned as a high-fidelity concept demonstrator, validated through multiple reflective and cognitive evaluation methods.

---

#### Summary of Deliver Phase

The Deliver phase evaluated the Guardians of Matariki prototype as a completed, functional, and culturally grounded educational experience. It applied self-assessment frameworks (NASA-TLX, TAM), learning theory reflection, and kaupapa Māori values to gauge the app's performance across immersion levels. Major outcomes included:

- Successful delivery of an MVP that was usable, culturally appropriate, and technically feasible.
- Identification of specific usability improvements and technical constraints for future development.
- Confirmation that scaffolded interaction, cultural narrative fidelity, and design ethics can coexist in immersive environments.
- Thorough documentation of visual, architectural, and procedural workflows, supporting transparency and knowledge transfer.

This final production phase transitioned the project from development into evaluation. The following chapter considers how the creative and technical decisions made throughout the process addressed the original research aims, and reflects on the broader contributions and potential pathways for future investigation.

# Chapter 5: The Artefact and Final Output

This chapter outlines the final artefact developed in response to the research question:

- *How can immersive spatial storytelling enhance users' engagement with Māori culture through a Mixed Reality application?*

A video demonstration of the working prototype has been created to provide a visual complement to the descriptions that follow. It can be viewed here: (Perese, 2025)

This chapter describes the system architecture, cultural integrations, technical execution, and evaluative frameworks applied at each stage of development.

## 5.1 Project Vision and Aims

The aim of the project was to investigate the intersection between spatial computing and Māori cultural engagement through immersive storytelling. The choice of Matariki was based on its broad cultural relevance, previous experience, suitability for representation, and alignment with cosmological space. The vision was not to recreate a traditional ceremony or ritual, but to explore how narrative elements, cultural values, and interaction could be mediated through new immersive technologies.

The intended outcomes were to:

- Design an immersive storytelling experience guided by kaupapa Māori values.
- Develop a prototype for Apple Vision Pro demonstrating spatial interaction.
- Evaluate usability, engagement, and cultural resonance through a iterative review using self-assessment tools (NASA-TLX, TAM) at each immersion level.

## 5.2 Technical Overview of the Artefact

The application is composed of three core components:

1. A 2D window interface that serves as an introductory environment for narrative orientation and onboarding.
2. A volumetric scene containing immersive spatial content, animated sequences, and reactive elements.
3. A fully immersive volumetric scene that leverages 2D and 3D elements for a more immersive experience

Development Tools:

- Swift & SwiftUI – Interface and interaction logic.
- Xcode – Core development and simulation platform.
- RealityKit & Reality Composer Pro – Used for 3D scene design, spatial rendering, and animation logic.
- Reality Converter – Asset format conversion (GLB to USDZ).
- Blender & Meshy AI – 3D modelling and character rigging.
- Canva & Miro – UI design and cultural story boarding.

## 5.3 System Architecture and Features

The artefact's user journey begins with the app icon with distinctive Māori patterns embedded within the designs, when selected a 2D interface presents itself with the title “Manawatia a Matariki” (Celebrate Matariki). Alongside the title a Z-stacked swiftUI 2D background presents the star cluster in the night sky with interactive buttons labelled “earth, water, air” allowing users to explore the Matariki stars in context of the elements they represent. UI affordances guide the user through the narrative flow, offering story fragments, star-specific knowledge, and visuals. This interface acts as the scaffolded entry point for deeper immersion.

Narrative UI Layer:

- Users can select stars representing individual Matariki elements.
- Each selection plays a narrative sequence paired with a visual and auditory interaction.

Volumetric Scene:

- A spatial environment with ambient stars, cosmological colours, and dynamic lighting.
- Users are presented with volumetric representations of selected Matariki stars, e.g., Waitī and Waitā in human form as a Māori warriors.
- The scenes combine soundscapes, animated character gestures, and interactive UI elements.

The architecture was informed by findings from each Agile sprint and the structured evaluation process using apple Guidelines, reflexive journaling, self-assessed experience surveys, NASA-TLX and TAM assessments at each immersion level. Feedback loops from these assessments allowed refinement of features such as UI responsiveness, interaction pacing, and visuals.

## 5.4 Cultural Integration

Cultural values were not isolated features but embedded throughout the design and development process. Māori values of kaitiakitanga, manaakitanga, and whakawhanaungatanga shaped narrative selection, interface tone, character positioning, and interaction design. These values were applied not only to the content but also to the method of implementation.

Design Applications:

- Whakawhanaungatanga: Informed the linear storytelling path and environmental connection to the stars.
- Manaakitanga: Guided the atmosphere of the immersive space, aiming to establish comfort and trust.
- Kaitiakitanga: Drove the structuring of scenes and data to ensure that cultural narratives were respectfully treated.

These values were consistent with findings in other culturally embedded XR projects, including Lloyd-Jones et al. (2023) VR Pōwhiri, which advocated for tikanga-led immersion. They also aligned with Brown's (2008) call for cultural protocols in digital taonga handling.

During development, 3D Māori warrior characters were used to visually embody the celestial figures; however, the use of AI-generated designs highlighted a significant limitation. Given the risks of cultural misrepresentation, all AI-generated character art and voiceovers used during prototyping will be replaced with neutral, non-cultural placeholders until culturally verified assets are co-designed and approved. In practice, this means: (i) generic human silhouettes without culturally specific markings (e.g., no AI-generated moko or attire), (ii) text-to-speech disabled for te reo Māori content during interim builds to avoid mispronunciation, and (iii) any illustrative motifs shown only as abstract forms not associated with specific iwi or taonga. These controls reduce the risk of unintended cultural signalling during early demonstrations and avoid AI artefacts that could undermine cultural integrity. While these assets supported prototyping needs, the patterns lacked cultural specificity and were not created through Māori-led consultation. This underscored the importance of cultural accuracy when representing cultural art. The current characters prototypes functioned as placeholders. Future iterations of the application will require co-designed models and hand-authored art.

## 5.5 Educational and UX Design Frameworks

The application incorporated educational design principles grounded in Bloom's Taxonomy, Cognitivism, and Constructivism. These frameworks were applied across both the UI and immersive scenes to support progressive learning.

Strategies included:

- Cognitive Load Reduction: Simplified menus, minimal clutter, and focused tasks per screen.
- Progressive Disclosure: Information introduced gradually to align with Bloom's hierarchical stages.
- Multi-Modal Input: Users received information through text, visuals, audio, and interaction.

Internal heuristic testing against apple design guidelines and self-evaluation at each stage reinforced these design principles. Using the TAM model, the artefact was reviewed against five core constructs: perceived usefulness, perceived ease of use, attitude toward use, intention to engage, and actual usage behaviour. These were adapted as reflection prompts post-development of each scene.

The NASA-TLX framework was also applied at each immersion stage to assess perceived cognitive load. Results were captured as part of the design retrospective journals. For example, the transition from 2D to volumetric storytelling increased mental demand and effort but also resulted in higher engagement scores in self-assessment, indicating trade-offs that were iteratively addressed through interface and content design.

## 5.6 Reflections on Self-Assessment and Evaluation

Due to the project's solo nature, all usability evaluations were performed through structured self-assessment tools. These tools provided a replicable method for reflection and iteration in the absence of external user testing.

NASA-TLX Findings:

- Windowed Interface: Scored low in mental demand and frustration, indicating successful onboarding and UI clarity.

- Volumetric Scene: Moderately increased effort and temporal demand but was reported as more rewarding in emotional terms.
- Full-Space Mode: Highest on perceived demand but also highest in perceived engagement.

#### TAM Reflections:

- Usefulness and Ease of Use improved with each prototype stage, particularly as interface affordances became more intuitive.
- Attitude and Intention to Use were stable, influenced by cultural alignment and perceived educational value.

These assessments provided actionable insights. For example, high frustration in early volumetric builds led to spacing adjustments and simplified navigation cues. Similarly, temporal demand in the full-space scene informed scene segmentation and animation pacing.

In parallel, interim builds will employ neutral placeholders rather than AI-generated cultural imagery or voices, as outlined in Section 5.4, to maintain cultural safety during iteration.

## 5.7 Limitations and Future Scope

Despite the Artefact's achievements, several constraints remain:

- Limited Scope: Full-space immersion was conceptual but not functionally complete.
- No External Testing: Lack of real-world user testing, particularly with Māori community members, limits generalisability.
- Platform Specificity: Designed exclusively for Vision Pro, which narrows audience reach.
- AI placeholders: Interim use of AI-generated visuals/voices is unsuitable for public release or user testing in a cultural context. Builds will ship with neutral stand-ins only, with culturally authentic assets produced through co-design and voice work by appropriate speakers.

However, the structured self-assessment approach and cultural embedding provide a strong foundation for future development.

## 5.8 Summary

The final artefact represents the cumulative integration of technical skill, design research, kaupapa Māori values, and immersive storytelling theory. The application provides a foundational prototype through which cultural knowledge, spatial computing, and user-centered design converge. Its development reflects the methodological strategies, detailed creative process, and the philosophical positioning. In its current state, the prototype demonstrates not a conclusion, but a starting point, an initial contribution to immersive cultural storytelling that remains open to future exploration and co-creation.

# Chapter 6: Reflections on the Design Process and Resulting Outcomes

This chapter provides a reflective analysis of the methodologies, strategies, and outcomes that emerged from the creative development of the immersive Matariki storytelling application. It considers how methodological frameworks such as Double Diamond, Agile, and specific Māori values shaped the iterative development, and how self-assessment tools informed final design decisions. This chapter explores what was learned through practice, how creative and cultural tensions were managed, and what implications these reflections have for future immersive development.

## 6.1 Reflections on Methodologies

### 6.1.1 Double Diamond as Structural Framework

The Double Diamond framework provided a comprehensive design roadmap across the Discover, Define, Develop, and Deliver phases. In the Discover phase, research and early cultural engagement informed the decision to focus on the Matariki narrative. Initial discussions with lecturers and a review of mātauranga Māori sources aligned with the project's educational aims. This exploration affirmed the cultural appropriateness of Matariki as a shared and publicly accessible story.

During Define, wireframes, storyboards, and immersion level planning narrowed the project scope. Learning theories such as Bloom's Taxonomy and Constructivism were integrated to scaffold content complexity and user engagement. A refined application structure emerged, progressing from 2D interaction to spatial immersion.

In the Develop and Deliver stages, development sprints and internal testing cycles were executed. The structure allowed for iterative design and reflection at each immersion level. As detailed in Chapter 4, self-assessment using NASA-TLX and TAM frameworks anchored these phases, offering insights into interface clarity, emotional resonance, and cognitive load.

### 6.1.2 Agile Methodology in Practice

Agile's sprint-based structure enabled this solo research project to adapt to emerging technical challenges and learning curves. Each sprint targeted specific outcomes like SwiftUI layout, RealityKit scene design, animation testing and was followed by retrospection to assess progress. This modular workflow helped maintain momentum while balancing multiple technical and narrative demands.

In alignment with Footit (2016), Agile allowed development to remain flexible and iterative. Self-review at the end of each sprint supported scope management and problem resolution. Adjustments to tool workflows (e.g., improving file conversion between Blender and Reality Composer Pro) were implemented as direct outcomes of these reflections.

### 6.1.3 User-Centered Design and Learning Frameworks

User-Centered Design (UCD) ensured the experience was grounded in the needs and capacities of first-time VisionOS users. Though formal user testing was constrained, persona modelling, self-assessment, and peer walkthroughs guided UI refinements. Each layer of immersion was designed to support increasing cognitive and emotional engagement.

The application's learning design drew upon:

- Cognitivism: Grouped Matariki concepts to aid memory and comprehension.
- Constructivism: Encouraged exploration through non-linear story sequences.
- Bloom's Taxonomy: Structured narrative arcs to promote deeper engagement across learning levels.

### 6.1.4 Māori values as a Design Ethos

The integration of Māori values was foundational, not only in content but also as a guiding methodology. Māori values shaped onboarding flows, animation tone, spatial placement of content, and interface dialogue.

These values included:

- Whakawhanaungatanga: Encouraged relational proximity through spatial UI.
- Manaakitanga: Supported warmth and care in the interaction flow.
- Kaitiakitanga: Maintained narrative integrity and cultural guardianship.

Like Samin (Samin, 2019), this project treated Indigenous knowledge as a living system rather than static content. This cultural framing was embedded not only in narrative tone but also in iterative decisions about pacing, tone, and inclusion.

Similarly, Brown (2008) positions digital cultural Artefacts as taonga, living carriers of mauri. This framework justified the design decision to avoid gamification and instead frame the application as a meditative, educational experience.

### 6.1.5 Findings from Immersion-Level Evaluation

Through internal testing at each level of immersion, self-assessment tools NASA-TLX, TAM, experience rating surveys and reflexive journaling provided key insights into how immersion affected cultural resonance, cognitive load, and emotional depth.

At the windowed level, the experience was accessible and well-structured but lacked depth and cultural embodiment. Scores were high for usability but low for emotional or spiritual connection.

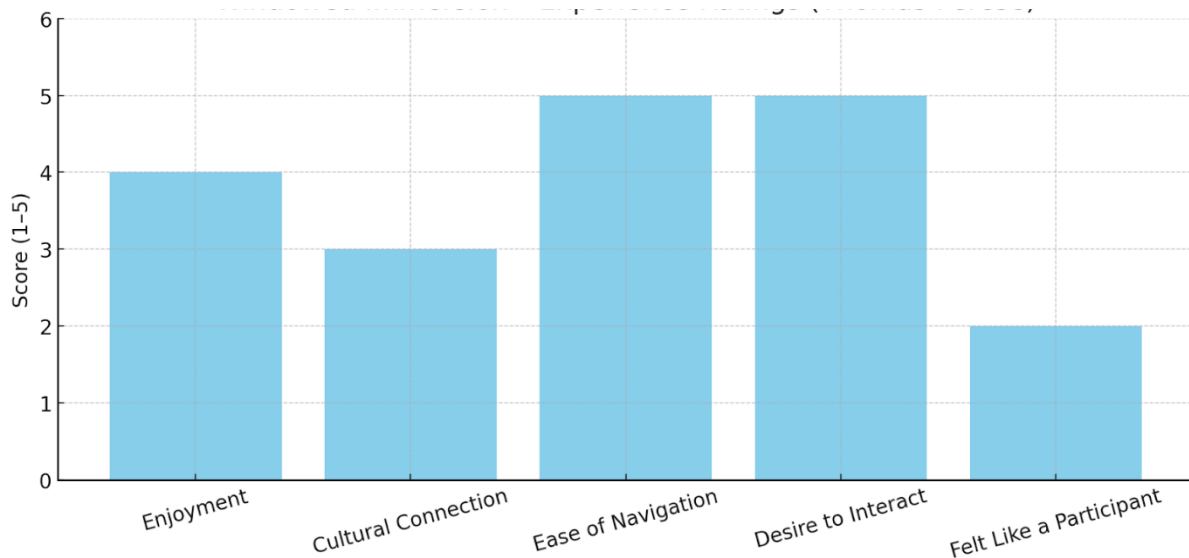


Figure 34: Windowed Immersion, Experience Ratings (Authors own)

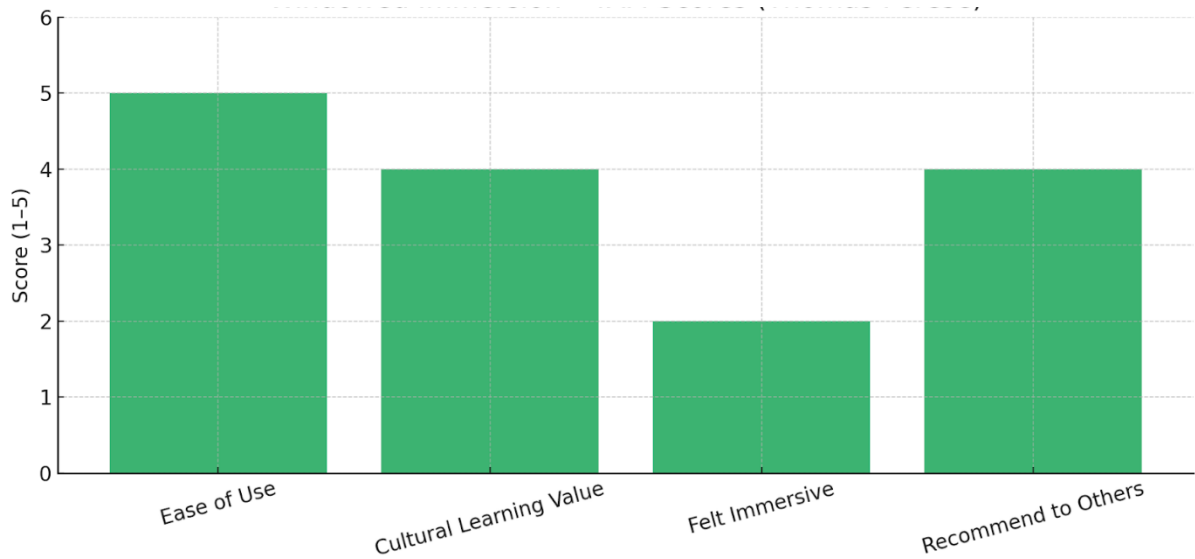


Figure 35: Windowed Immersion, TAM Scores (Authors own)

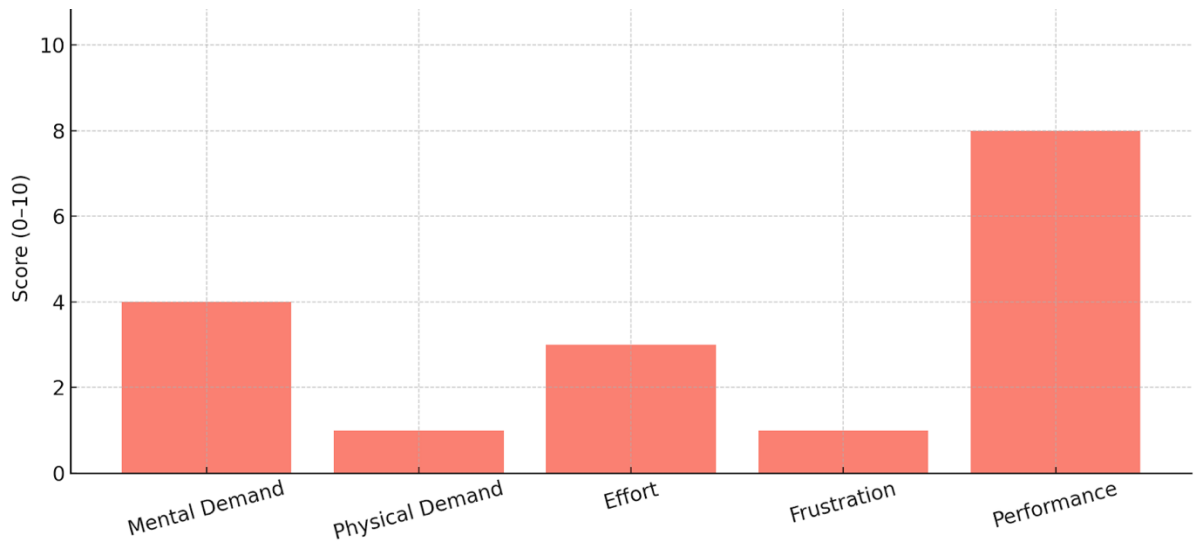


Figure 36: Windowed Immersion, NASA-TLX Cognitive Load Scores (Authors own)

At the volumetric level, spatial presence and interaction improved engagement significantly. The storytelling became more relational, and values such as whakawhangaunga and kaitiakitanga were more tangibly expressed. TAM and NASA-TLX results showed higher mental engagement but continued ease of use.

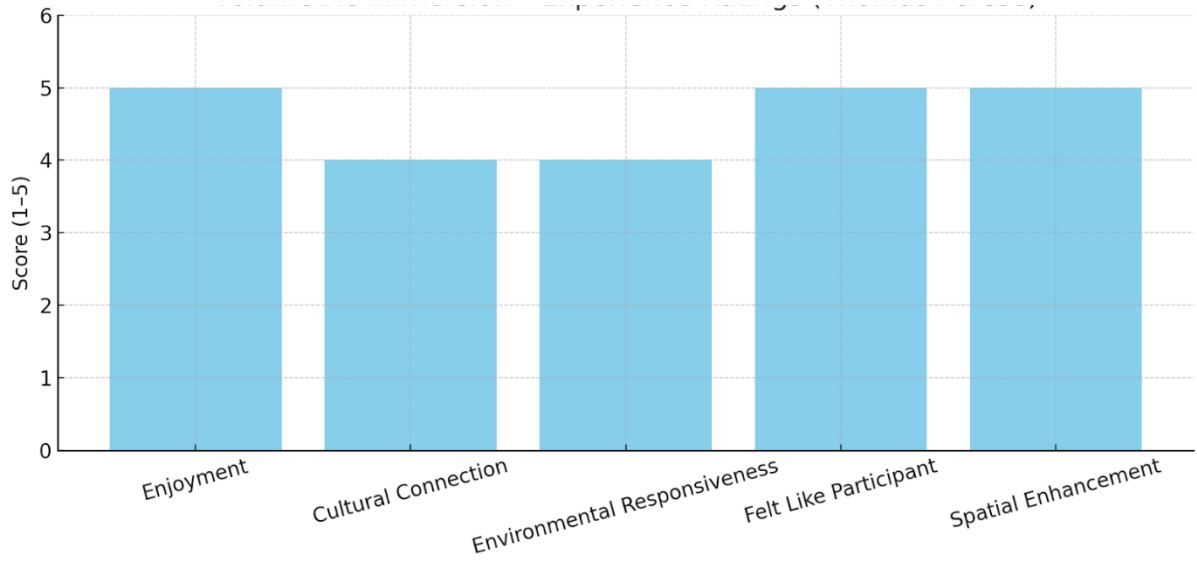


Figure 37: Volumetric Immersion, Experience Ratings (Authors own)

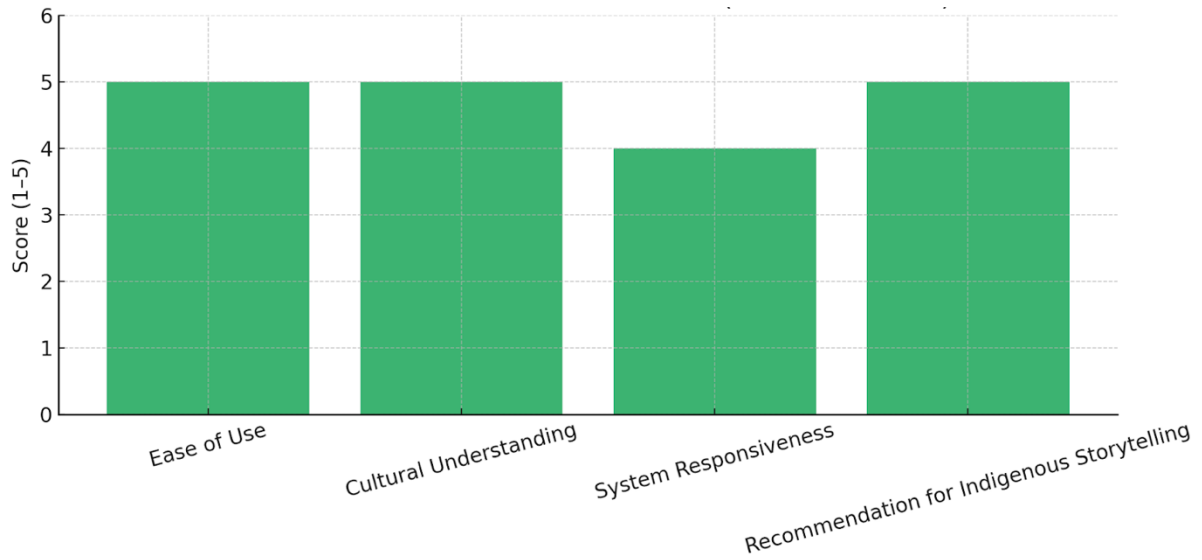


Figure 38: Volumetric Immersion, TAM Scores (Authors own)

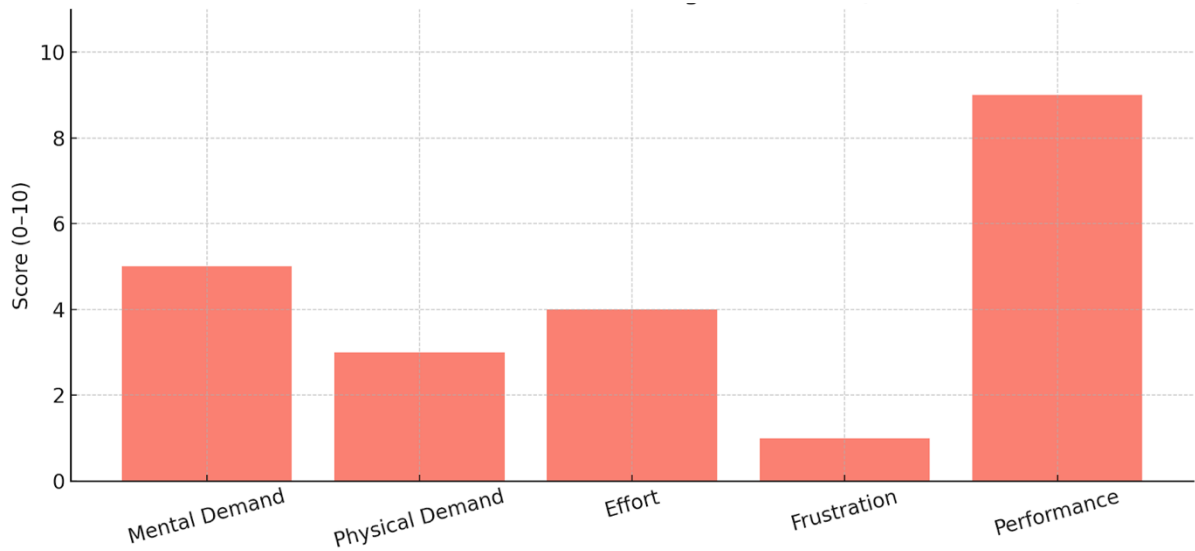


Figure 39: Volumetric Immersion, NASA-TLX Cognitive Load (Authors own)

The full space immersive version provided a transformative leap. The inclusion of responsive lighting, and spatial ritual created a sense of wairua (spiritual presence). The interactive experience felt culturally alive. Scores reached 5/5 across all TAM and Experience categories, with minimal cognitive load.

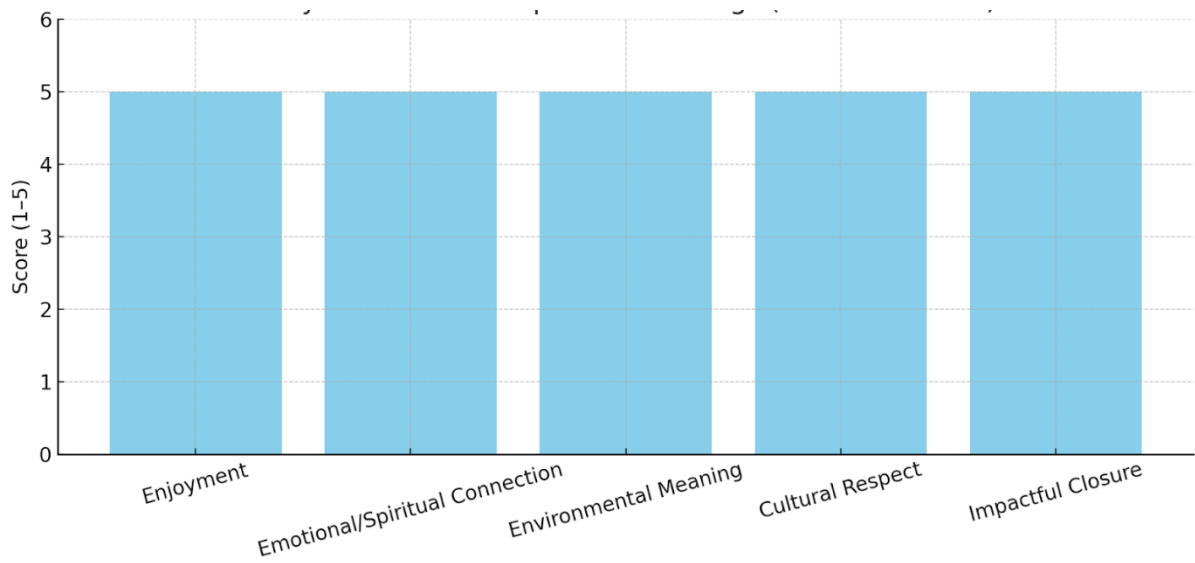


Figure 40: Full Space Immersion, Experience Ratings (Authors own)

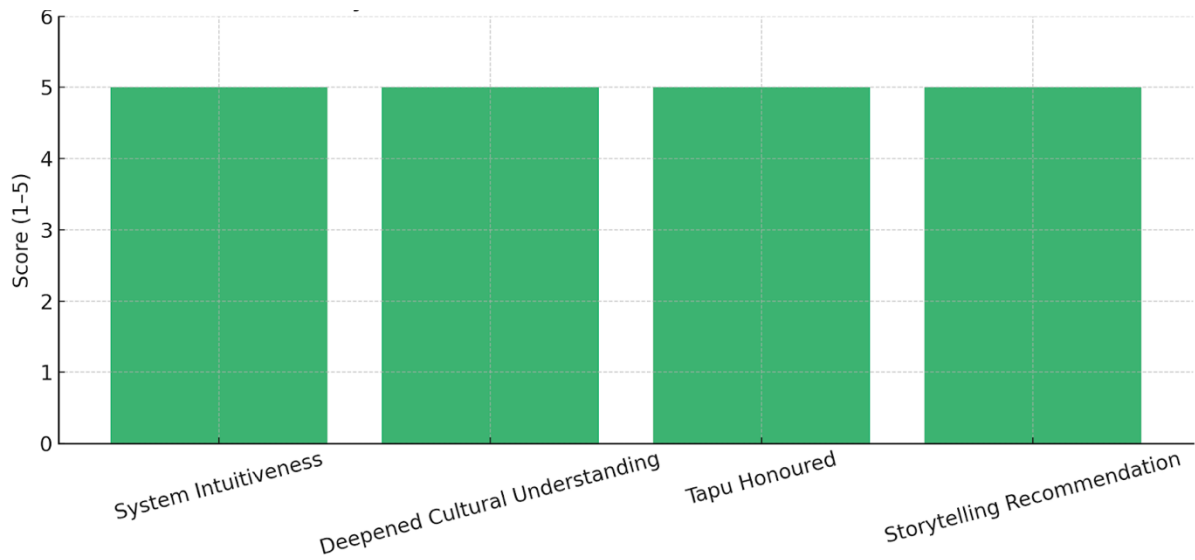


Figure 41: Full Space Immersion, TAM Scores (Authors own)

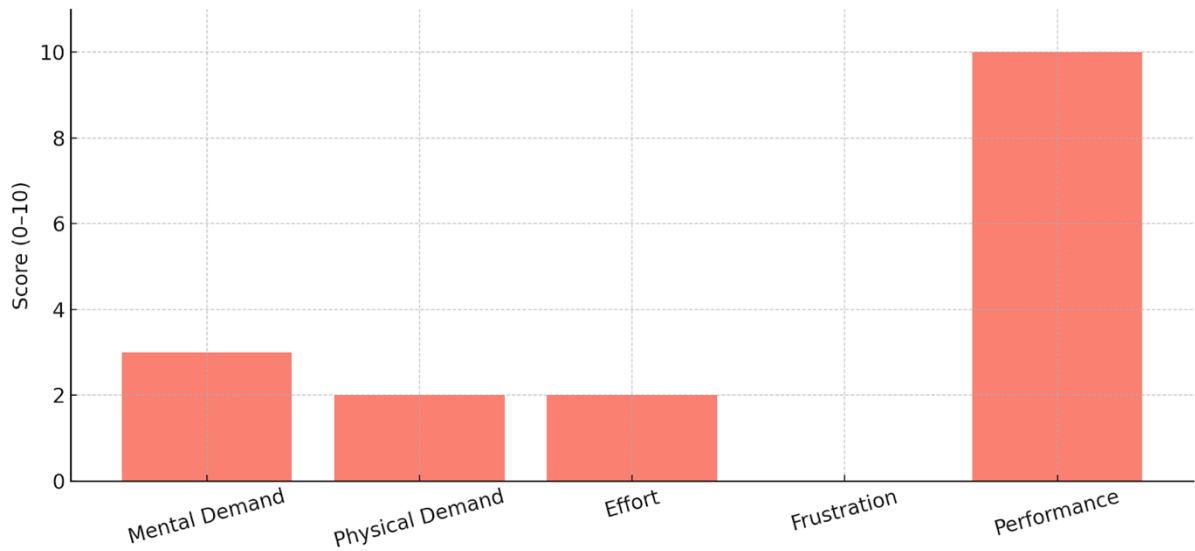


Figure 42: Full Space Immersion, NASA-TLX Cognitive Load (Authors own)

These findings confirmed that spatial storytelling on the Apple Vision Pro can transition from informational to ceremonial when guided by Māori values and immersive design strategies. The iterative increase in embodiment and cultural responsiveness validates the importance of testing immersion as a dimension of user experience.

## 6.2 Technical and Creative Challenges

### 6.2.1 Learning Curve of VisionOS Development

Working with VisionOS required fast acquisition of skills in Swift, SwiftUI, RealityKit, Reality Composer Pro, Reality Converter, and Apple's spatial design guidelines. Documentation was still emerging during development, and much of the application logic was designed through independent testing. Plane detection, anchor placement, and volumetric layering were all discovered through trial-and-error.

This challenge was compounded by the need to work between multiple platforms: Xcode for code, Blender for assets, Reality Composer Pro for scene layout, and AVP simulator for deployment. Despite time constraints, this process enabled the development of a scalable architecture capable of supporting further narrative and technical layers.

### 6.2.2 Managing Interdisciplinary Demands

As a solo practitioner, balancing technical development with cultural accountability was complex. Storytelling, UI development, animation, and project management all demanded different forms of expertise. Each sprint required fluid movement between disciplines, which occasionally slowed momentum but deepened project cohesion.

### 6.2.3 Limitations in Testing

Due to limited AVP hardware access, formal usability testing with external users especially rangatahi Māori or educators was not possible. Instead, internal self-assessment using NASA-TLX and TAM frameworks provided insights. While not a substitute for community feedback, these tools allowed for structured reflection on cognitive demand, interface logic, and user experience.

## 6.3 Key Successes

### 6.3.1 Coherence of UI and UX Design

Despite hardware and time constraints, the interface achieved coherence across all immersion levels. Progressive disclosure, logical iconography, and intuitive eye-tracked navigation created a stable base for narrative engagement. The application layout followed Apple's design guidelines while remaining distinctively cultural.

### 6.3.2 Preservation of Cultural Integrity

All narrative elements like voiceovers, iconography, animation, and ambient design were reviewed through a self-reflective kaupapa Māori cultural lens. AI-generated Māori art on prototype characters prompted a necessary reflection on the risks of using automated tools for culturally sensitive design elements. While the intent was exploratory, the resulting textures lacked the nuance, and intentionality required for Māori art. This moment reinforced the importance of maintaining cultural integrity, even during early development phases. Cultural safety must extend to visual representation, especially when embodying the atua (Māori gods) or ancestral figures in Matariki. The experience validated the need for Māori artists and cultural practitioners to lead the creation of such assets in future development cycles, preserving both aesthetic authenticity and cultural responsibility.

### 6.3.3 Self-Assessment Tools Enabled Reflective Practice

The integration of NASA-TLX and TAM frameworks allowed for deeper self-evaluation at the end of each immersion level. It is important to note that these frameworks were used heuristically as part of a reflective design process. As the sole participant, I interpreted the outcomes as personal indicators of workload and usability rather than objective user data. This internal feedback informed adjustments in animation pacing, cognitive load distribution, and interaction clarity. These tools provided measurable insights despite limited external testing.

### 6.3.4 Modular Architecture for Future Expansion

The application was developed with extensibility in mind. Design choices support future:

- Expansion of narrative branches and cosmologies
- Integration of a responsive virtual guide
- Inclusion of Te Reo Māori translation

## 6.4 Summary

Reflections on the design and development of Guardians of Matariki reveal a project shaped by Māori values, iterative design methodologies, and reflective self-assessment. The integration of tools like NASA-TLX and TAM offered meaningful insight into user experience, even without extensive public testing. Cultural integrity was maintained throughout, and the technical foundations established a strong basis for future work. Internal testing across the three immersive levels confirmed that cultural connection, emotional resonance, and

cognitive engagement increase with spatial embodiment. This chapter affirms the potential of immersive spatial storytelling to serve as a respectful and innovative platform for engaging with Indigenous knowledge systems.

## Chapter 7: Conclusion and Future Directions

This chapter presents the consolidated outcomes of the research and evaluates how the methodologies, findings, and development process addressed the central research question:

- *How can immersive spatial storytelling enhance users' engagement with Māori culture through a Mixed Reality application?*

The project's design, implementation, and evaluation processes are reviewed, with an emphasis on observed outcomes, unresolved challenges, and directions for future development. It draws upon both qualitative and quantitative self-evaluation findings and reflects on the implications of methodological decisions made throughout the project.

---

### 7.1 Project Overview

The project aimed to investigate the educational and experiential affordances of immersive spatial computing, using the Apple Vision Pro to develop a culturally grounded application focused on the Matariki narrative. Matariki was selected due to its increasing public recognition in Aotearoa New Zealand, cultural relevance across multiple iwi, and suitability for digital storytelling in an immersive context.

The development process incorporated an integrative methodology combining kaupapa Māori values, Agile development, Double Diamond design thinking, and instructional frameworks such as Bloom's Taxonomy, Cognitivism, and Constructivism. These methodologies were employed to ensure that the application was not only technically functional but culturally resonant and educationally structured. Each development sprint advanced specific functional elements. From UI layouts to RealityKit scene builds, while maintaining alignment with core cultural values such as manaakitanga (hospitality), kaitiakitanga (guardianship), and whakawhanaungatanga (relational engagement).

The final output consisted of three progressively immersive experiences: a windowed (2D) interface, a volumetric (3D layered) experience, and a fully immersive 360° spatial scene.

These prototypes were internally evaluated using self-assessment methods tailored for immersive design, namely the NASA-TLX (for cognitive load and task demand) and the Technology Acceptance Model (for perceived usefulness and ease of use).

---

## 7.2 Summary of Contributions

### 7.2.1 Spatial Computing

The research contributes a documented use case for AVP cultural applications, offering a template for immersive interaction using Apple's spatial computing tools. The project demonstrated integration of SwiftUI for UI components, RealityKit for 3D content rendering, and Reality Composer Pro for scene layout. The prototype functions as a model for transitioning between interface types within the AVP and supports future experimentation with multi-modal navigation and gesture input.

### 7.2.2 Indigenous Storytelling

The storytelling approach is grounded in Māori values. The application avoids static or extractive representations by embedding cultural values into each layer of the user experience, from animation pacing to voiceover tone to the spatial positioning of cosmological elements. Māori values informed both content development and ethical decision-making, ensuring the project operated as a culturally responsible digital artefact.

### 7.2.3 Learning Design

Educational scaffolding was built into the application's interaction model. The narrative and user experience were structured to promote cognitive engagement through interactive discovery, multimodal learning, and progressive complexity. Cognitivism informed content grouping for memory retention, Constructivism supported non-linear exploration, and Bloom's Taxonomy guided learning progression from factual recall to critical reflection. These theories were translated into spatial and visual metaphors appropriate for immersive interaction.

### 7.2.4 Methodological Rigor

The project demonstrates how structured self-assessment can support immersive development, particularly in solo or early-stage research contexts. The use of NASA-TLX

and TAM enabled reflective evaluation across each level of immersion, producing data that informed iterative design decisions. This methodology offers a scalable model for developers with limited access to external users or testing groups, allowing for continuous self-feedback and measurable progress tracking.

---

## 7.3 Findings from Immersion-Level Testing

Three levels of immersion were developed and evaluated through internal reflection, journaling, and self-administered TAM and NASA-TLX assessments. Key insights are as follows:

### Windowed Immersion (2D SwiftUI interface):

The 2D interface scored highly for ease of use (TAM) and minimal cognitive load (NASA-TLX), confirming its suitability for onboarding users unfamiliar with spatial interaction. However, the lack of depth and spatial engagement limited emotional resonance and cultural embodiment. It was effective as an educational entry point but inadequate for representing the full scope of the Matariki narrative.

### Volumetric Immersion (3D layered interface):

The volumetric layer introduced spatial positioning and 3D assets anchored in the user's physical space. It led to improved engagement, greater narrative embodiment, and moderate increases in perceived usefulness. The data showed a slight rise in mental demand, but this was offset by increased enjoyment and perceived cultural relevance. Qualitative reflections indicated a more embodied connection to Matariki themes, especially through interaction with animated characters and UI elements.

### Full Space Immersive Experience (360° environment):

This level yielded the strongest outcomes across all self-assessment criteria. TAM ratings were consistently maximal (5/5) across all dimensions. NASA-TLX scores reflected low task demand and zero frustration. Qualitative notes described the experience as “cognitively effortless yet emotionally impactful.” The immersive field of view and ambient audio environment enabled a state of sustained engagement, supporting deeper interaction with the narrative. These findings reinforce the hypothesis that higher immersion levels correlate with improved cultural and emotional resonance.

---

## 7.4 Unresolved Questions and Limitations

### 7.4.1 External Testing and User Diversity

Due to the single-researcher evaluation method, the project lacks insights from target demographics such as Māori youth, educators, and non-expert users. Their perspectives are essential for testing cultural appropriateness, interface intuitiveness, and emotional impact. Future research must employ participatory evaluation methods, including usability testing, focus groups, and cultural review panels.

### 7.4.2 Hardware Accessibility

The Apple Vision Pro remains inaccessible for many users due to cost and regional limitations. This restricts deployment in community, educational, and museum settings. While VisionOS provides ideal immersion, expanding accessibility will require adaptation to platforms such as:

- ARKit-enabled iPads and iPhones
- WebXR for browser-based interaction
- Physical installations in learning or cultural institutions

---

## 7.5 Future Development Pathways

### 7.5.1 Expanded Evaluation

A full user study should be implemented to evaluate comprehension, cultural resonance, and usability across diverse audiences. Structured tools (TAM, NASA-TLX), open-ended interviews, and participatory workshops can be used to collect both quantitative and qualitative feedback.

### 7.5.2 Story Expansion

The modular narrative structure permits future development of story packs including:

- Celestial narratives beyond Matariki.
- Seasonal or event-based content (e.g., Matariki public holiday updates)

These additions would enhance cultural diversity within the app and provide more entry points for learning and reflection.

### 7.5.3 Community Partnership

The long-term vision includes transitioning to a co-development model with Māori cultural practitioners, artists, and educators. Establishing community governance for story selection and moderation will ensure ethical scalability. Training programs and templates could be created to allow iwi, kura kaupapa Māori (Māori medium schools), or marae (Māori meeting ground) to develop content independently on the platform.

### 7.5.4 Educational Integration

The prototype can be mapped to curriculum objectives in te reo Māori (the Māori language), social studies, and digital literacy. Institutional partnerships could support pilots in schools, tertiary institutions, or cultural centers. A content management system could allow educators to tailor learning journeys or assessment activities.

### 7.5.5 Cultural Perpetuity

Future development of Guardians of Matariki must prioritise cultural perpetuity through direct collaboration with Māori artists, and cultural advisors in the co-design of 3D assets, textures, and spatial environments. The integration of culturally grounded artwork and visual symbology requires processes that uphold manaakitanga, kaitiakitanga and whakawhanaungatanga Māori values. Moving beyond placeholder assets toward authentic Indigenous models ensures the application functions not only as a digital tool, but as a culturally safe platform for storytelling. This approach supports intergenerational transmission of knowledge while preventing the dilution or distortion of sacred cultural designs in immersive media.

---

## 7.6 Final Observations

This research reinforces that immersive spatial storytelling, when guided by cultural frameworks and educational principles, can enhance user engagement with Māori narratives. Incremental increases in spatial immersion resulted in corresponding gains in cultural resonance, narrative participation, and emotional investment. The layered approach

enabled users to build cognitive and affective connection progressively, from interface navigation to embodied cultural presence.

The application also functions as a replicable case study in VisionOS development and kaupapa Māori-aligned design. It demonstrates a repeatable methodology for future researchers and developers who wish to embed indigenous values within spatial computing environments.

---

## 7.7 Conclusion

The Guardians of Matariki project addresses a critical intersection between technology and cultural preservation. It shows that immersive applications, when developed with cultural care and methodological integrity, has the capacity to elevate indigenous storytelling into deeply engaging digital experiences. The findings support continued exploration of immersive platforms as tools for cultural transmission and educational enrichment.

Although limited in scale, the MVP provides a solid technical and cultural foundation. Future research should focus on extending its reach, immersive features, validating user outcomes, culturally appropriate designs and embedding co-creation into the development process. This work contributes to a growing movement of indigenous-led digital innovation, and it provides a methodological roadmap for future Immersive storytelling in Aotearoa and beyond.

# Glossary of Terms

## Cultural

<b>Term</b>	<b>Definition</b>
Kaupapa Māori	A Māori research paradigm grounded in Indigenous values and principles, placing Māori worldviews at the center.
Manaakitanga	Hospitality, kindness, and care for others, a guiding principle in both Māori life and cultural design.
Kaitiakitanga	Guardianship and stewardship, particularly of the natural world and cultural heritage.
Whakapapa	Genealogy and interconnectedness; the links between people, land, and cosmology in Māori culture.
Whānau	Extended family or community relationships based on collective responsibility and belonging.
Matariki	A cluster of stars known as Pleiades that marks the Māori New Year and represents various aspects of wellbeing.
Hiwa-i-te-rangi	The star of future aspirations, associated with goals, dreams, and hopes for the year ahead.
Pōhutukawa	The star associated with remembrance, honoring those who have passed.
Tupu-ā-rangi	The star connected to food sources from above the ground, such as birds and berries.
Tupu-ā-nuku	The star connected to food cultivated in the soil, like root vegetables and crops.
Waipuna-ā-rangi	The star associated with rain and the replenishment of water from the sky.

Ururangi	The star linked to the winds and the movement of air.
Waitī	The star associated with freshwater ecosystems such as rivers and lakes.
Waitā	The star associated with saltwater bodies like the ocean and coastal ecosystems.
Pōwhiri	A formal Māori welcoming ceremony involving speeches, song, and the hongī to greet and acknowledge guests with respect.
Tikanga Māori	Māori customs, values, and protocols that guide appropriate behavior and cultural practices in daily life and ceremonial contexts.
Wharehenui	A large Māori meeting house that serves as the focal point of a marae, used for gatherings, ceremonies, and preserving ancestral narratives.
Kanohi ki te kanohi	A Māori phrase meaning "face-to-face," referring to direct, in-person communication that builds trust and strengthens relationships.
Kanohi kitea	A Māori concept meaning "the seen face," referring to the visible presence of a person, especially in leadership or community engagement.
Whakawhanaungatanga	A Māori value emphasizing relationships, family, kinship, and a sense of connection through shared experiences and collective responsibility.
Tapu	Sacred or restricted; something to be respected due to its spiritual significance.
Wairua	The spiritual essence or soul of a person or thing.

Patu	A short-handled Māori weapon used in close combat.
Mātauranga Māori	Māori knowledge systems, including language, customs, environment, and ways of understanding the world.
Iwi	A Māori tribe or large kinship group, often made up of several hapū (sub-tribes) linked by common ancestry.
Hapu	A Māori sub-tribe or extended family group descended from a common ancestor, forming part of a larger iwi (tribe).
Taonga	A treasured item, resource, or concept in Māori culture, including physical objects, knowledge, language, and relationships.
Wairua	The spiritual essence or life force of a person, living being, or place in Māori belief.

## Methodological

Term	Definition
Double Diamond	A four-phase creative design framework: Discover, Define, Develop, Deliver.
Agile	A flexible, iterative approach to project management focused on collaboration and responsiveness.
Sprint	A time-boxed period in Agile development used to complete specific tasks or deliverables.
Story Points	A relative measurement of effort and complexity used to estimate work in Agile development.
MoSCoW Method	A method for prioritizing requirements: Must have, Should have, Could have, and Won't have.

Dérive	A psychogeographic and creative exploration method used to uncover inspiration and meaning.
Design-Based Research (DBR)	A research methodology combining iterative design and empirical analysis in real-world contexts.
Constructivism	A learning theory where learners build knowledge through experience and reflection.
Cognitivism	A theory that focuses on internal mental processes such as attention and memory in learning.
Bloom's Taxonomy	A hierarchical model classifying educational objectives from basic recall to creative application.

## Technical

Term	Definition
Apple Vision Pro (AVP)	Apple's spatial computing headset combining AR and MR features with advanced input methods.
Augmented Reality (AR)	Technology that overlays digital elements onto the real world using a camera-equipped device.
Mixed Reality (MR)	A combination of real and virtual environments that allows interaction with both physical and digital objects.
RealityKit	Apple's 3D rendering and interaction framework used for building immersive AR experiences.
Reality Composer Pro	A tool used by developers to create interactive AR environments in Apple's ecosystem.

Swift / SwiftUI	Programming language and interface framework used to build Apple applications.
Eye Tracking	A feature allowing interaction with digital content using eye movements for selection and navigation.
Gesture-Based Interaction	A method of input that uses hand gestures to control or navigate digital environments.
Volumetric Interface	A 3D user interface that places digital content spatially around the user.
Spatial Computing	Digital technology that interacts with and is aware of the physical space it occupies.
User-Centered Design (UCD)	A design framework that prioritizes user feedback, accessibility, and experience in the development process.
Technology Acceptance Model (TAM)	A framework for understanding user acceptance of technology based on perceived usefulness and ease of use.

## References

- Abrahamsson, P., Salo, O., Ronkainen, J., & Warsta, J. (2017). Agile software development methods: Review and analysis. *arXiv preprint arXiv:1709.08439*.
- Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism VS interpretivism. *Global academic journal of humanities and social sciences*, 2(3), 39–43.
- Amsterdam, A. I. (2016). *Low-fi prototyping: What, Why and How?* Prototypr. Retrieved 29 July from <https://blog.prototypr.io/low-fi-prototyping-what-why-and-how-24f77d9f4995>
- Apple. (2025). *Human Interface Guidelines*. Retrieved 28 July from <https://developer.apple.com/design/human-interface-guidelines?utm>
- Armstrong, P. (2010). Bloom’s taxonomy. *Vanderbilt University Center for Teaching*, 12(05), 2023.
- Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, 6(4), 355–385.
- Brown, D. (2008). “Ko to ringa ki nga rakau a te Pakeha”—Virtual Taonga Maori and Museums. *Visual Resources*, 24(1), 59–75.
- Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and applications. *Multimedia tools and applications*, 51(1), 341–377.
- Carrilho, J., & Costa, E. S. (2021). *Virtual Biomedical and STEM/STEAM Education*. European Union.
- Cohn, M. (2024, 25 June). Why the Fibonacci Sequence Works Well for Estimating. <https://www.mountangoatsoftware.com/blog/why-the-fibonacci-sequence-works-well-for-estimating>
- Debord, G., & Knabb, K. (2014). Theory of the Dérive. In *The Improvisation Studies Reader* (pp. 176–180). Routledge.
- Dirksen, J. (2015). *Design for how people learn*. New Riders.
- Dowling, L. (2023, 7 July 2023). *Matariki: The Seven Sisters and their Global Connections*. Retrieved 07 Aug from <https://meglanguages.com/matariki-the-seven-sisters-and-their-global-connections/#:~:text=All%20modern%20humans%20are%20descended,Oceania>
- Ertmer, P. A., & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance improvement quarterly*, 6(4), 50–72.
- Footit, J. (2016). *Touchable: Adapting a Haptic Feedback Glove for use in Rehabilitation Contexts* [Thesis, Auckland University of Technology]. Auckland University of Technology.

- Gunn, M., Billingham, M., Bai, H., & Sasikumar, P. (2021). First Contact–Take 2: Using XR technology as a bridge between Māori, Pākehā and people from other cultures in Aotearoa, New Zealand. *Virtual Creativity*, 11(1), 67–90.
- Gurl, E. (2017). SWOT analysis: A theoretical review.
- Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In *Advances in psychology* (Vol. 52, pp. 139–183). Elsevier.
- Humble, J. (2021). *What is the Double Diamond Design Process?* The Fountain Institute. Retrieved 29 July from <https://www.thefountaininstitute.com/blog/what-is-the-double-diamond-design-process>
- Jiboku, F., & Obarayi, Z. (2024). User Experience and Interaction Design in Augmented Reality. Proceedings of the 6th SPAS National Conference. The Federal Polytechnic, Ilaro, Ogun State, Nigeria,
- Johnson, L., Levine, A., Smith, R., & Stone, S. (2010). *The 2010 Horizon Report*. ERIC.
- Kravchenko, T., Bogdanova, T., & Shevgunov, T. (2022). Ranking requirements using MoSCoW methodology in practice. Computer Science On-line Conference,
- Krueger, M. W., Gionfriddo, T., & Hinrichsen, K. (1985). VIDEOPLACE—an artificial reality. Proceedings of the SIGCHI conference on Human factors in computing systems,
- Lloyd-Jones, L., Ott, C., Regenbrecht, H., & Whaanga, H. (2023). Virtual Reality Pōwhiri—Practicing an indigenous welcoming ceremony. Proceedings of the 35th Australian Computer-Human Interaction Conference,
- Madden, L. (2011). *Professional augmented reality browsers for smartphones: programming for junaio, layar and wiktitude*. John Wiley & Sons.
- Marques, B., McIntosh, J., & Carson, H. (2019). Whispering tales: using augmented reality to enhance cultural landscapes and Indigenous values. *AlterNative: An International Journal of Indigenous Peoples*, 15(3), 193–204. <https://doi.org/10.1177/11771177180119860266>
- Masrom, M. (2007). Technology acceptance model and e-learning. *Technology*, 21(24), 81.
- McGuinness, W. (2017, Jul 21, 2017). *Matariki and Māori astronomy with Dr Rangī Matamua*. McGuinness Institute. Retrieved 07 Aug from <https://www.mcguinnessinstitute.org/foresightnz/matariki-and-maori-astronomy-with-dr-rangi-matamua/>
- Park, N., Regenbrecht, H., Duncan, S., Mills, S., Lindeman, R. W., Pantidi, N., & Whaanga, H. (2022). Mixed reality co-design for indigenous culture preservation & continuation. 2022 IEEE Conference on Virtual Reality and 3D User Interfaces (VR),
- Perese, T. (2020). *Whakarongo/listening*. Retrieved 29 July from <https://thomasperese.wixsite.com/blogctec500/post/whakarongo-listening>
- Perese, T. (2025, 3 Aug 2025). *Guardians of Matariki: Evaluating the Apple Vision Pro for Māori storytelling*. <https://youtu.be/wJCQBSAyWDU?si=NnJGR8vwyhGFbeQ>
- Pihama, L., Cram, F., & Walker, S. (2002). Creating methodological space: A literature review of Kaupapa Maori research. *Canadian Journal of Native Education*, 26(1), 30–43.
- Riley, R. (2025). The Lotus Blossom Creative Technique. *Thought Egg Creativity tools and techniques*. <https://thoughtegg.com/lotus-blossom-creative-technique/>

- Rosenberg, L. B. (1992). *The Use of Virtual Fixtures as Perceptual Overlays to Enhance Operator Performance in Remote Environments*.
- Samin, I. A. (2019). *Awang Laut: Exploring Storytelling in a Mobile Augmented Reality Environment for Cultural Heritage Sites* [Exegesis, Auckland University of Technology]. Auckland University of Technology.  
<https://hdl.handle.net/10292/13000>
- Simpson, B. (2018). Pragmatism: A philosophy of practice. *The SAGE handbook of qualitative business and management research methods*, 54–68.
- Skarbez, R., Smith, M., & Whitton, M. C. (2021). Revisiting Milgram and Kishino's Reality-Virtuality Continuum. *Frontiers in Virtual Reality*, 2.  
<https://doi.org/10.3389/frvir.2021.647997>
- Smith, L. T. (2015). Kaupapa Māori research-some kaupapa Māori principles.
- Sutherland, I. E. (1968, 1968). A head-mounted three dimensional display. Fall Joint Computer Conference,,
- Thandu, N. (2019). *An Exploration of Virtual Reality Technologies (Doctoral dissertation, Thesis Magister)*. Auckland University of Technology.
- for Museums* [Exegesis, Auckland University of Technology]. Auckland University of Technology. <https://hdl.handle.net/10292/12937>
- thephdclub. (2024). *Saunders' Research Onion*. thephdclub. Retrieved July 29 from <https://thephdclub.com/blog/f/saunders%E2%80%99-research-onion>
- Thomas, B., Close, B., Donoghue, J., Squires, J., De Bondi, P., Morris, M., & Piekarski, W. (2000). ARQuake: An outdoor/indoor augmented reality first person application. Digest of papers. Fourth international symposium on wearable computers,
- Mark Billingham, Adrian Clark and Gun Lee (2015), "A Survey of Augmented Reality", *Foundations and Trends® in Human-Computer Interaction*: Vol. 8: No. 2-3, pp 73-272. <http://dx.doi.org/10.1561/1100000049>
- Nawel Khenak, Jeanne Vézien, David Théry, Patrick Bourdot; Spatial Presence in Real and Remote Immersive Environments and the Effect of Multisensory Stimulation. *Presence: Teleoperators and Virtual Environments* 2018; 27 (3): 287–308. doi: [https://doi.org/10.1162/pres\\_a\\_00332](https://doi.org/10.1162/pres_a_00332)
- E. Kruijff, J. E. Swan and S. Feiner, "Perceptual issues in augmented reality revisited," 2010 IEEE International Symposium on Mixed and Augmented Reality, Seoul, Korea (South), 2010, pp. 3-12, doi: 10.1109/ISMAR.2010.5643530.
- Néstor Ordaz, David Romero, Dominic Gorecky, Héctor R. Siller, *Serious Games and Virtual Simulator for Automotive Manufacturing Education & Training*, *Procedia Computer Science*, Volume 75, 2015, Pages 267-274, ISSN 1877-0509, <https://doi.org/10.1016/j.procs.2015.12.247>.

# Appendices

## Appendix A: Mind Maps



Figure 43: Augmented Reality Mind Map (Authors own)

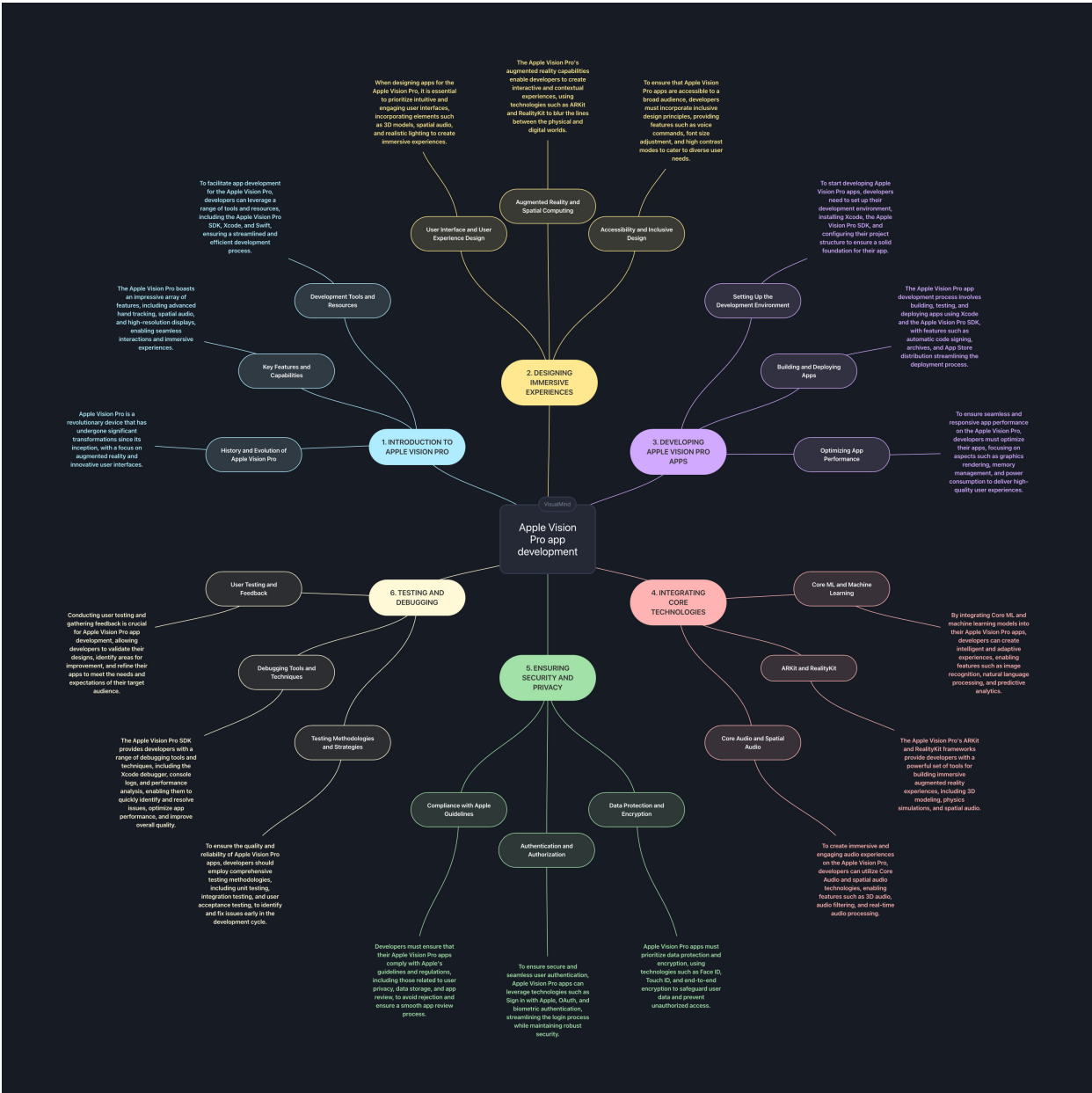


Figure 44: Apple Vision Pro App Development Mind Map (Authors own)

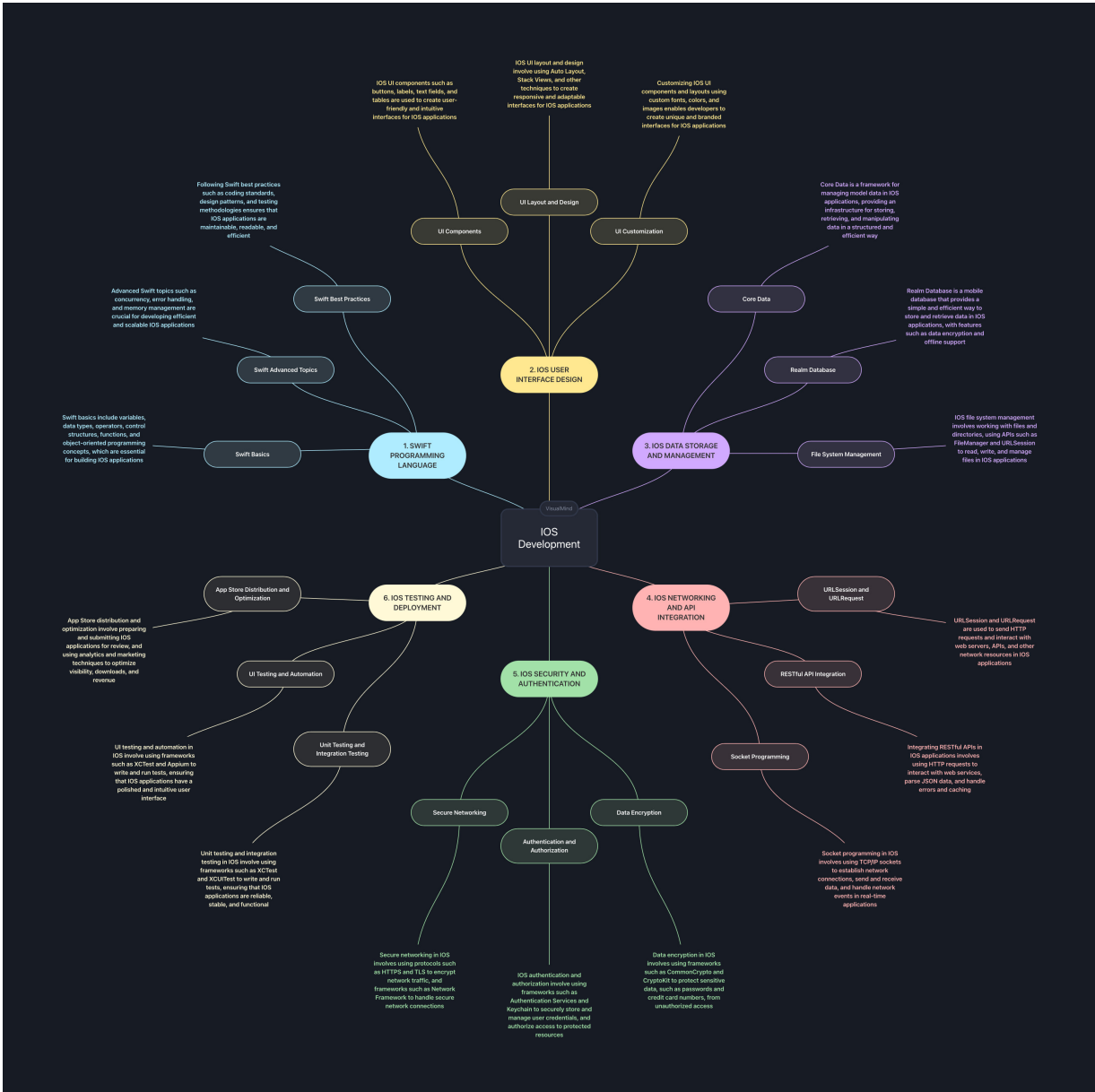


Figure 45: iOS Development Mind Map (Authors own)

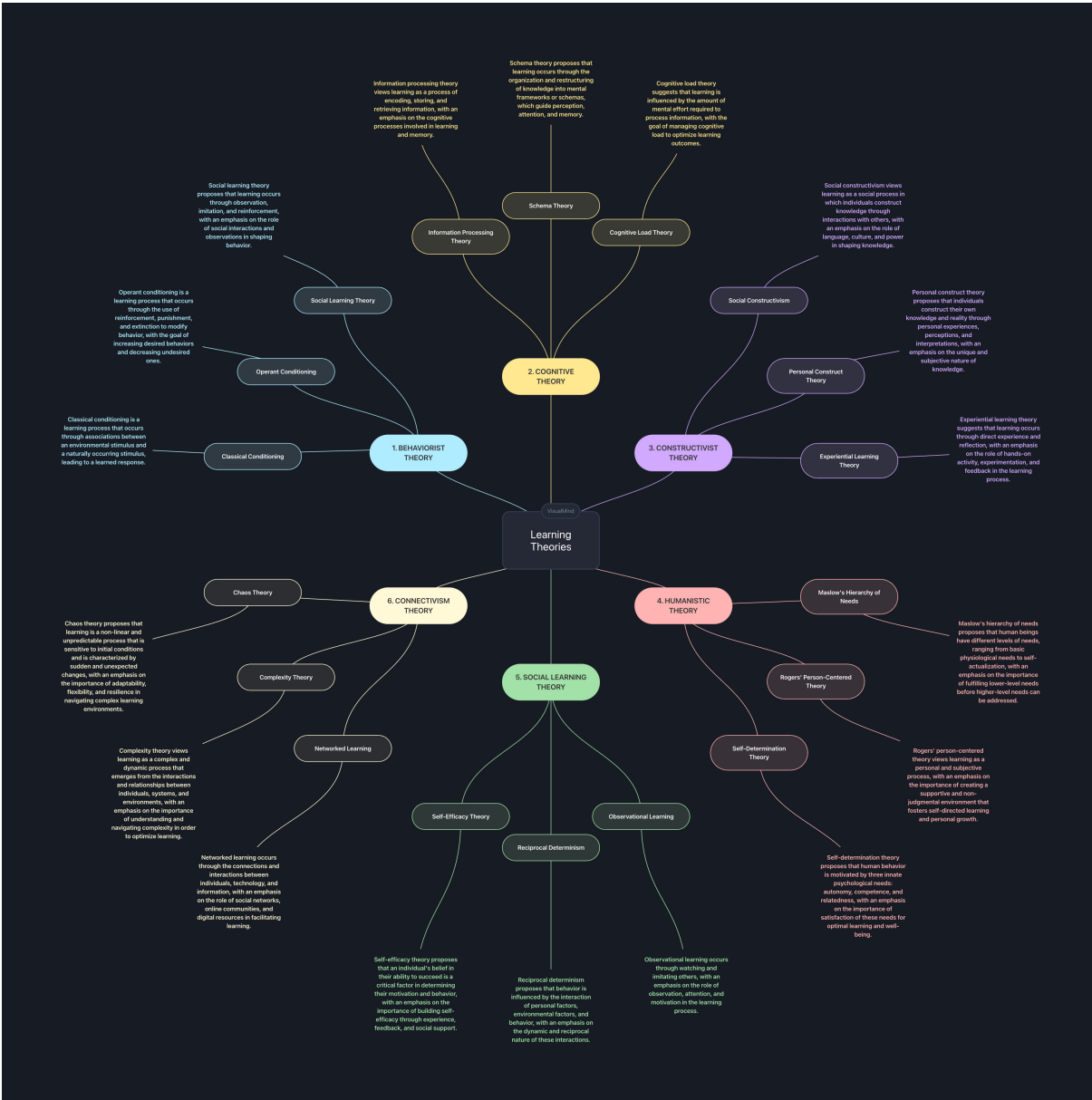


Figure 46: Learning Theories Mind Map (Authors own)



Figure 47: UI/UX Design Mind Map (Authors own)

## Appendix B: Lotus Blossum maps

Blender	OBJ	USDZ	Dialogue	Haptic Feedback	Ambient Audio	Haptic Feedback	Affordance	interactive
MeshyAI	<b>3D models</b>	Reality Converter	Spatial Audio	<b>Sound</b>	Empathy	scene timeout	<b>Triggers</b>	Meaning
RealityKit	Reality Composer Pro	Tutorials	immersion	Spiritual	Tutorials	Guided	Intuitive	Tutorials
Story Board	Lo-Fi prototype	iterative	<b>3D models</b>	<b>Sound</b>	<b>Triggers</b>	UV Maps	Baking	Meshy AI
narative	<b>Sketches</b>	Dale AI	<b>Sketches</b>	<b>Animation</b>	<b>Texturing</b>	Reality Composer Pro	<b>Texturing</b>	Tutorials
Abstract			<b>Rigging</b>	<b>Story board</b>	<b>guides</b>	Lighting	Reality Converter	Blender
motion	Timing	Meshy AI	Sketches	narative	Rapid prototypes	hands	sound	iconography
Tutorials	<b>Rigging</b>	Blender	value	<b>Story board</b>	interactions	lighting	<b>guides</b>	depth
	Rokoko	Reality Composer Pro	scene composition			dialogue	demonstrations	loops

Figure 48: Lotus Blossum, Guardians of Matariki, Animation needs mapping (Authors own)

Work Shops	Qualitative data	Quantitative data	Samin	Mark Billinghurst	Mark Billinghurst	Educational	Narative	Value
Topics	<b>Research</b>		Affordances	<b>Literature</b>	features	Engaging	<b>Methodology</b>	Meaning
Discourse	Case studies	Relevance	Interactions	Haptic feedback	UI layout	Interactive	Intuitive	Story board
Word	oneNote		<b>Research</b>	<b>Literature</b>	<b>Methodology</b>	Experience Surveys	TAM	NASA-TLX
Google Docs	<b>Documenting</b>	Tumblr	<b>Documenting</b>	<b>Exergesis</b>	<b>Data collection</b>	Qualitative journals	<b>Data collection</b>	Quantitative surveys
	Reflexive Journals			<b>Synthesise</b>	<b>Philosophies</b>			
			Research	Literature	Methodology	interpretivism	Practice based	Pragmatism
			Docs	<b>Synthesise</b>	Data collection	Kaupapa Maori	<b>Philosophies</b>	
			APA 6th references	Synthesise	Practice based			

Figure 49: Lotus Blossum, Guardians of Matariki, Exegeses needs mapping (Authors own)

Iphone	monitor	Mouse				Xcode	Reality composer Pro	Blender
Laptop	<b>Hardware</b>	Dongle				VSC	<b>Software</b>	Reality Converter
Apple Vision Pro	Story board	Wifi-router				Swift Playgrounds	VisionOS SDK	Chat-GPT
			<b>Hardware</b>		<b>Software</b>			
				<b>developer environment</b>				

Figure 50: Lotus Blossom, Guardians of Matariki, Developer Environment needs mapping (Authors own)

Interface	Principles	Architecture	Remeber	Understand	Apply	Functions	Data Types	Enums
Layouts	<b>Apple design</b>	Typography	Analyse	<b>Bloom taxonomy</b>	Evaluate	Struct and Class	<b>Swift swiftUI</b>	ARkit RealityKit
Iconography	Data Structures	Security	Create			VisionOS SDK	Stacks	Images and Buttons
			<b>Apple design</b>	<b>Bloom taxonomy</b>	<b>Swift swiftUI</b>			
				<b>Skill development</b>				
			<b>Animation</b>	<b>Xcode</b>	<b>Reality composer pro</b>			
			Interface	project management	product intergrations	3D Models	Textures	Entity system
VisionOS SDK	<b>Animation</b>	ARkit RealityKit	protocols	<b>Xcode</b>	Swift SwiftUI	asset intergration	<b>Reality composer pro</b>	interactions
Rigging	Texturing	3D models				RealityKit	Reality Converter	triggers

Figure 51: Lotus Blossom, Guardians of Matariki, Skill Development mapping (Authors own)

Learning is a Mental Process	Mind is lie a Computer	Schemas (mental structures)	knowledge is constructed	Learning is Active	meaning is personal and subjective			
cognitive Load	<b>Cognitivism</b>		Learners are Central	<b>Constructivism</b>	Games			
			Personal conection	Haptic feedback	whakawhanau- -ngatanga			
Leadership	Guardianshit	Protection	<b>Cognitivism</b>	<b>Constructivism</b>		Remeber	Understand	Apply
informed	<b>Kaitiakitanga</b>		<b>Kaitiakitanga</b>	<b>UI/UX Design</b>	<b>Bloom taxonomy</b>	Analyse	<b>Bloom taxonomy</b>	Evaluate
			<b>Manaakitanga</b>	<b>Apple design</b>	<b>User Story</b>	Create		
Caring	hospitality		Interface	Principles	Architecture	template	multiple users	story boards
Nurturing	<b>Manaakitanga</b>	Respect	Layouts	<b>Apple design</b>	Typography	features	<b>User Story</b>	Accessibility
warnth			Iconography	Data Structures	Security	testing	validations	

Figure 52: Lotus Blossom, Guardians of Matariki, UI/UX Design mapping (Authors own)

Principles	Interfaces	affordances	interface	settings	project setup	data types	Views and functions	data structure
Tutorials	<b>Apple design</b>	iconography	tutorials	<b>Xcode</b>	features	tutorials	<b>Swift swiftUI</b>	basics
style	best practice	libraries	deployment		UI layout	UI layout	design	structs clases
tutorials	Xcode intergation	features	<b>Apple design</b>	<b>Xcode</b>	<b>Swift swiftUI</b>	tutorials	entities	AR Views
	<b>VisionOS SDK</b>		<b>VisionOS SDK</b>	<b>apple ecosystem</b>	<b>ARkit RealityKit</b>	reality Views	<b>ARkit RealityKit</b>	
	Reality Converter	Reality composer pro		<b>Reality Converter</b>	<b>Reality composer pro</b>			
			model conversion	Tutorials		scene layout	animation	3D models
				<b>Reality Converter</b>		sound input	<b>Reality composer pro</b>	triggers
						interactions	textures	

Figure 53: Lotus Blossom, Guardians of Matariki, Apple Ecosystem mapping (Authors own)

scaffolded	constructivism	cultural	Design	UX	Matariki	Educational	Cultural	Inspirational
evaluation	<b>Educational</b>			<b>Narative</b>	flow	Engaging	<b>Value</b>	Meaning
			Interactions		UI layout			Story board
depth	immersive		<b>Educational</b>	<b>Narative</b>	<b>Value</b>	sustainabilty	cultural practice	innovation
gamefication	<b>Engaging</b>	ease of use	<b>Engaging</b>	<b>Story</b>	<b>Meaning</b>	Kaitiakitanga	<b>Meaning</b>	evaluation
			<b>Interactive</b>	<b>Intuitive</b>	<b>Story board</b>	environmental	storytelling	
		Swift swiftUI	Design	Scaffolded	UI/UX	Sketches	narrative	features
features	<b>Interactive</b>	immersive	guided	<b>Intuitive</b>		guides	<b>Story board</b>	cultural
Animation	constructivism				cognitive load		script	

Figure 54: Lotus Blossom, Guardians of Matariki, Story mapping (Authors own)

3D models	Sound	Triggers	Design	UX	Interfaces	Educational	Narative	Value
styles	<b>Design</b>	scenes	Affordances	<b>UX</b>	features	Engaging	<b>Interfaces</b>	Meaning
		guides	Interactions	Haptic feedback	UI layout	Interactive	Intuitive	Story board
Games	interfaces	Designs	<b>Design</b>	<b>UX</b>	<b>Interfaces</b>	gaze	touch select	motion
Interactions	<b>Tutorials</b>	meaning	<b>Tutorials</b>	<b>explore apps</b>	<b>features</b>	hand input	<b>features</b>	voice input
Value				<b>Haptic feedback</b>	<b>UI layout</b>	replay	skips button	pinch and hold
			visual	audio		ornaments	View stacks	volumetric
				<b>Haptic feedback</b>		simalarities	<b>UI layout</b>	highlights
						buttons	descriptive text	Accessibility

Figure 55: Lotus Blossom, Guardians of Matariki, Feature Exploration mapping (Authors own)