Exploring 4E+ Cognition and Spiritual Wisdom in eXtended Reality Interaction and Experience Design

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Dedication

I dedicate this thesis to my parents, whose endless sacrifices and steadfast belief in my abilities have been my guiding light. Your love has been the bedrock upon which I have built my dreams.

To my incredible wife, thank you for your unwavering support, patience, and encouragement. Your love and understanding have been my anchor throughout this journey.

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Abstract

The eXtended Reality (XR) medium, as one of the pivotal components of the Fourth Industrial Revolution (4IR), demonstrates the 4IR's capability to blur the lines between the physical, digital, and biological realms. In the rapidly evolving domain of XR, the medium itself is poised to become a transformative influence on user cognition and emotional engagement. As the adoption of interactive and immersive media continues expanding, the design of interaction and the crafting of immersive experiences play a critical role in shaping the user experience of this emerging medium. This, in turn, significantly influences technology, academic research, culture, and society. However, current design paradigms within this technological landscape remain predominantly reductionist and mechanistic, prioritising efficiency and control at the expense of holistic human and cultural considerations. To fully harness the transformative potential of XR as an emerging medium, there is a need to move beyond these established approaches. Here, embracing design methodologies that are more attuned to the complexities of human experience and cognition is crucial.

This research explores the connection between ancient philosophical traditions and modern technological practices, applying these insights to XR interaction and experience design. By integrating principles of 4E+ cognition (embedded, extended, embodied, and enacted cognition, along with the affective dimension), Neoplatonism, Perennial wisdom, and Ishraq (Illuminationism), the study aims to create experiences that engage users on cognitive, affective, and spiritual levels. The aim of this research is to develop a design approach that leverages recent XR technologies while incorporating cultural and philosophical considerations. Furthermore, it examines the practical applications and potential contributions of the integrated 4E+ cognition approach in designing experiences and human-computer interactions (HCI) for XR. This is achieved by incorporating artistic inquiry and practice-oriented research, proposing a set of design principles extracted from best practices tailored for this emerging field of HCI.

The research methodology in this study is holistic, integrating heuristic and Illuminationist (Ishraqi) approaches to develop an understanding of the potentials of

XR as an experienced-based interactive immersive medium. This illuminationist heuristic methodology, coupled with the *art of steering* (cybernetics), guides this exploration, allowing for adjustments and refinements as insights emerge. The study adopts a practice-oriented methodology, embedded in real-world projects developed at Auckland University of Technology's AppLab. These projects serve as a testing ground where theoretical insights are transformed into practical artefacts, which in turn push the theoretical envelope further.

The significance of this research extends beyond the technicalities of XR design to encompass a rethinking of how we approach technology, culture, and user experience and cognition in the digital age. Integrating philosophical and spiritual elements ensures that the XR environments developed are not only technologically advanced but also intellectually and spiritually enriching. One outcome of this study was the promotion of a deeper connection between the inner self and the physical environment in HCI design. It challenges the prevailing trend in contemporary HCI that often leads to detachment from the body, reality, and the essence of human existence.

The study resulted in a significant shift in the author's ontological perspective, transitioning from a conventional epistemological paradigm and the Cartesian dualistic approach towards adopting a 4E+ cognitive framework. This innovative framework holds the potential for synthesising oriental and occidental philosophical viewpoints, providing a more comprehensive understanding of cognitive processes in XR. Findings indicate that the integration of 4E+ cognition and ancient wisdom into HCI and experience design fosters deeper cognitive and spiritual connections. This paradigm shift in embracing a 4E+ cognitive framework offers a culturally informed structure for XR design. It has significant implications for the design and application of emerging technologies, art, education, and the preservation of cultural heritage.

In the broader context of creative technology, this research contributes to understanding how emerging immersive technologies can be harnessed to enrich human experience. It highlights the importance of integrating philosophical and cultural perspectives into technological development, ensuring that innovation is guided by a deep respect for human cognition and the insights of spiritual wisdom.

Designers can adopt this perspective in their problem-solving and decision-making processes during the creation of complex projects.

The thesis contributes to the field of creative technology by providing a set of principles to enhance the approach to problem-solving and improve the design of emerging interactive media. The philosophical and theoretical knowledge derived from this research also holds the potential to impact the practices of art and art research, as well as real-world projects in the creative industry. Moreover, an essential practical outcome of the research is the utilisation of interactive media platforms in the gamification of cultural and natural heritage. The objective was to create an interactive experience that fosters engagement among younger generations with the ideas and viewpoints inherent in a particular cultural or philosophical perspective.

These findings, coupled with a change in the epistemological perspective on human experience, from the Cartesian duality to a 4E+ and transcendent naturalism view, hold significant transformative potential. This shift could drive positive change across creative fields.

Acknowledgements

As I go through my last days of this seven-year journey, I look back and see the road that I took. At the young age of my early thirties, something called to me, which I mistook for many desires along my road, each of which was part of the goal, and the treasure itself was the journey. I read and wrote about many subjects and objects in my exegesis, learned a lot, and tried to pass it on to as many people as I could.

This wasn't an easy road to pass, but I am happy that I decided to do it, and I would go through it again and again if I could go back. However, this would not have been possible if it weren't for the souls that held my spirit up through these hard days, the days that made me who I am now and are writing these words. First and foremost are the two strangers who became my closest people in academia, who supported me as my mentors and decided to trust me and stayed by my side, my first and second supervisors, Dr Claudio Aguayo and Dr Stanley Frielick. Both individuals have had an impact on my worldview that is visible in my research, without prevarication or indirectly.

I am all thankful to Te Ara Poutama, the Faculty of Māori and Indigenous Development at Auckland University of Technology, for their financial support in the form of a PhD scholarship. The Te Ara Poutama Faculty hosted me as a member of Whānau and was there for me. Now that I am looking back, I realise that my research could not have been done anywhere but Te Ara Poutama, where I met amazing people as part of my research and personal journey. I had a chance to go deeper into Māori culture and get to know the beautiful people who hold this culture in their heart, who had a great role in my projects, practice, and philosophy. I would also like to thank Emily Wu (the Faculty Registrar), Teena Brown Pulu (the Postgraduate Coordinator), and Elwyn Sheehan (the pathway 3 Research Librarian), for the manner in which they supported the infrastructure and resources underpinning the inquiry.

Additionally, I want to thank all AppLab members over the years: Hohepa Spooner, Claudio Aguayo, Joshua Wagstaff, James Harvey Smith, Zohreh Shirazi, Parisa Moradi, Sophia Spivak, Taylor Pringle, Rodrigo Ferrari, and Andrew Denton. As well as anybody who supported AppLab through the years: Professor Pare Keiha, Dr Stanley Frielick, Taituwha King, Dr Valance Smith, Sonia Mehana, Jana Nee, Associate Professor Thom Cochrane, and Professor Hinematau McNeill.

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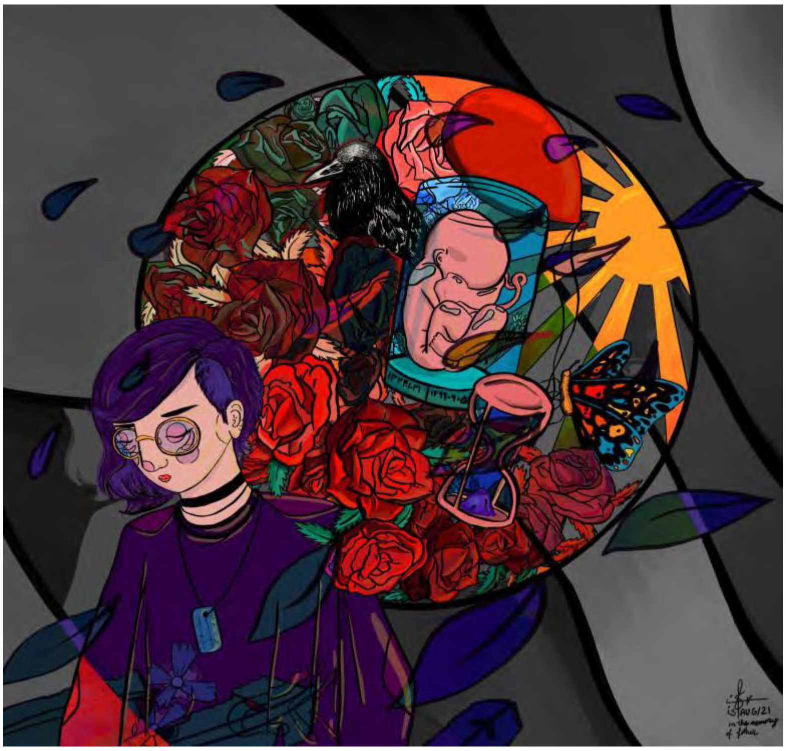
I would like to thank my parents, who were always there for me and my future. I have been the person I was, who wanted to be better, know more, and had the desire to work hard for a PhD for them, for who they are, and for the light they lit for me. As far as I remember, my academic journey was the priority, and I was always supported with all my needs and more by my parents. There is no greater love than that of parents, and there is no greater blessing than having good parents; mine, however, are the best.

Before I thank the last person, I must express my profound gratitude to my wife, the one I chose to be my life partner. In Iran, we have the term “hamsar,” which translates to “spouse” in English, but like many Farsi words, “hamsar” carries a deeper meaning. “Ham,” the first part of the word, means “co-” or “com-,” signifying cooperation or companionship in English, while “sar” signifies “head.” Together, they denote a partnership of equals, a coequal mind. I have always envisioned my wife and me as two galaxies, distinct or even opposite, moving toward each other,

heating and transforming into something else—something unified, greater, brighter, and more beautiful than either could be alone. She introduced me to the creative realm of words, and I shared with her the logical worldview.

I want to thank her for the seven years of companionship during my student life, out of the eight years we have been together. Our early days were filled with challenges and confusion. Yet, as someone who embraces challenges and grows stronger after each storm, I wanted her by my side through it all. Together, we grew, learning and maturing side by side through every obstacle.



Zohreh Shirazi illustration by Zohreh Shirazi.

If it weren't for her concord, I would still thank her for her art, which beautifully illustrated various parts of my PhD journey and how I felt during each chapter. She was always there for me, as I was for her; she cared deeply, as I always looked after her; she was my dearest, as I always strove to make her smile. I know it was not an easy road for her, and I am grateful that she was there with me, allowing me to witness her growth, maturity, and rise, just as she witnessed my ascension. This is not the end for us, but merely the beginning, as I promise to make the rest of our journey together easier.

Third-Party Copyright Material and Embargo Statement

This thesis includes third-party copyright material, for which permission has been secured for two of the artefacts —the NIWA AirBox and Rapua te Mārama projects. However, permission has not been granted for one of the artefacts discussed (AUT Marae project). Consequently, upon completion of the thesis examination, any sections containing analysis or discussion of the artefact without third-party copyright permission (Only P284 to P294) will be permanently embargoed. This measure ensures compliance with copyright regulations while preserving the integrity of the research.

It is important to note that while the embargoed sections will not be publicly accessible, the remainder of the thesis will be available in accordance with the university's guidelines.

The State of Exhibition and the PhD Website

Originally, our supervisory team and I anticipated that the exhibition would be held in person, as is customary in practice-oriented research. This format is particularly important given the experiential and interactive nature of my work, especially in the context of virtual and augmented reality—media that are inherently grounded in first-person experience and embodied interaction. Unfortunately, due to circumstances beyond our control, the supervisory team, in consultation with the Graduate Research School (GRS), made the decision to transition the exhibition to an entirely online format, hosted via a dedicated website. This decision was made after the initial submission of my thesis.

As a result, there may be some inconsistencies in the thesis text, which was written under the assumption of an in-person exhibition. Nevertheless, I have done my best to acknowledge this shift through footnotes and clarifications wherever appropriate.

Initially, the website was intended to serve as a supplementary component to the thesis—a digital space for hosting animated GIFs, images, videos, links to code, and a dynamic mind map of the project. In hindsight, I was fortunate to have developed this platform in advance. Following the decision to move the exhibition fully online, I expanded the site by adding further video content and enhancements, aiming to make it as comprehensive and engaging as possible in its new role as the primary exhibition venue.

The link to the PhD Website (Scroll down for the exhibition):
https://www.fablesofnaranj.com/

The link to the 'PhD Journey' webpage hosting the MindMap of the thesis:
https://www.fablesofnaranj.com/knowledge-base/postgraduate-study/

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Attestation of Authorship

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 acknowledged), 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.

Intellectual Property Declaration

I retain copyright in all original images, designs, and creative works produced and presented as part of this thesis, except for the following images and materials that are the intellectual property of others, listed below in the order they appear in this document. Where such materials are included, if needed, I have obtained the necessary copyright clearance and permissions for their use in this thesis.

Definition of Keywords

In this exegesis, specific terms are used in particular ways that reflect the transdisciplinary nature of my research, drawing on pre-Islamic and Islamic philosophical heritage of Iran and the region, contemporary technological frameworks, and cognitive theories. As terminology can be interpreted differently across varying contexts, it is important to clarify how these terms are employed in this research. Due to the complex and transdisciplinary nature of the research, the definitions of key terms require more extensive elaboration than usual. Instead of providing these definitions in the introductory chapter, they are given their own dedicated section to ensure clarity and depth. The definitions are systematically arranged based on their conceptual relationships, progressing from broad, all-encompassing keywords to more detailed and specific terms.

Philosophy/Philosophia:

Philosophia, meaning 'love of wisdom,' is an expansive pursuit of understanding existence, reality, and ethics beyond formal academia. Inspired by Hadot (1995), in this exegesis philosophy is seen as a transformative way of life focused on cultivating wisdom, virtue, and inner harmony through practices like meditation and contemplation.

Wisdom:

In this exegesis, Wisdom transcends intellectual understanding or mere knowledge accumulation. It refers to the ability to apply knowledge and experience with insight, judgement, and compassion in complex or uncertain situations (Paul & Baltes, 2003). Wisdom entails a harmonious and empathetic understanding of human nature and the world, promoting a balanced life (Versluis, 2017). In highly complex scenarios, it involves focusing on relevant information and shaping oneself to align with situational demands, enabling more effective interventions (Vervaeke & Ferraro, 2013).

Hikmah/Hikmat (Arabic/Persian: حکمة, حکمت):

In Islamic intellectual tradition, Hikmah refers to wisdom that combines knowledge and virtue, often implying spiritual or divinely inspired insight. It integrates philosophical inquiry with ethical and spiritual dimensions. Influenced by Neoplatonism and Aristotelianism, Islamic philosophers like Al-Farabi, Avicenna, Suhrawardi, and Sadra view Hikmah as the culmination of rational inquiry and spiritual realization. In Sufi thought, Hikmah is the wisdom of the heart, associated with mystical knowledge, embodying virtues such as justice, compassion, and humility (Nasr & Leaman, 2013).

Sufism:

Sufism is Islam's mystical dimension, emphasising introspection and spiritual closeness with God. It is characterised by spirituality, arts, music, and philosophy, focusing on purifying the inner self and cultivating a direct connection with the divine. (Chittick, 1983).

Irfan:

Irfan, linked with Sufism, signifies spiritual wisdom from direct encounters with the divine. Scholars like Henry Corbin (1964) and Seyyed Hossein Nasr (1989) describe it as mystical knowledge that transcends intellectual understanding, encompassing both esoteric and experiential dimensions. Irfan involves inner, intuitive knowledge achieved through practices such as meditation and prayer, aiming for a transformative journey wherein the seeker gradually ascends through spiritual stations to attain gnosis (ma‘rifah)—a form of knowing grounded in presence, love, and illumination.

Perennial Philosophy/Wisdom:

The Perennial Philosophy asserts that all spiritual and religious traditions share fundamental truths about reality, the divine, and the human soul, providing a unifying framework across disciplines (Beringer, 2006; Davar & Salamian, 2021). It suggests that the quest for knowledge through science, philosophy, or spirituality reveals the interconnectedness and unity of existence. Neoplatonism is recognized as a foundational basis for these universal truths, underpinning diverse spiritual traditions (D’Ancona, 1997; Huxley, 1945/1990; Versluis, 2017).

Neoplatonism:

Neoplatonism is a 3rd-century philosophical system building on Plato's ideas, centred on the One as the ultimate reality. It emphasises the unity of existence, the soul's ascent to the One, and dialectic for spiritual enlightenment (Gerson, 1996; Wallis, 1972). Influencing medieval Christian, Islamic, and Jewish thought, it structures reality hierarchically into the One, Nous (Intellect), World Soul, and the material world (Perl, 2015). Neoplatonism also served as the philosophical lingua franca of the Silk Road, enabling dialogue between Eastern and Western civilizations (Plant, 2021).

Spirituality:

Spirituality transcends specific religious systems, characterized by a search for meaning, transcendence, and connection to something greater than oneself, such as a higher power, the universe, or collective human experience (Sheldrake, 2007; King, 2008). In the context of this exegesis, it involves personal experiences of the sacred, distinct from formal religious practices, and emphasises a relationship with the transcendent (Vervaeke, 2021). Practices like meditation, contemplation, and mindfulness help individuals transcend the self, confront existential challenges, and integrate life experiences into a coherent self-understanding (Tisdell, 2003).

Polymath:

A polymath, known as جامع‌الاطراف (Jame-al-Atraf) or بحرالعلوم (Bahr al-Uloom) during the Islamic Golden Age, is an individual with expertise across diverse subjects. They integrate knowledge from various fields to achieve a holistic understanding of the world (Niazi, 2011; Burke, 2010; Gutas, 1998).

Ishraq (Illuminationism):

In Islamic philosophy, Ishraq (اشراق), or "illuminationism," emphasizes acquiring knowledge through intuitive inner means and divine light, surpassing rational or empirical methods (Corbin, 1964). Derived from شرق (Sharq, "east") and اشراق (Ishraq, "illumination"), it symbolises enlightenment and spiritual awakening. Developed by Suhrawardi in the 12th century, Ishraq integrates rational philosophy with mystical insights, focusing on the ontology of light as the substance of existence (Corbin, 1971; Nasr, 1993). Scholars like Henry Corbin and Seyyed Hossein Nasr highlight Ishraq's role in fostering direct, intuitive knowledge (Hudhuri epistemology), bridging mysticism and rationality, and influencing comparative philosophy (Plant, 2021). The Ishraqi framework enriches various disciplines by emphasizing metaphysical principles, ethical aesthetics, and holistic educational philosophies.

Imaginal World (Mundus Imaginalis):

The Imaginal World, or Mundus Imaginalis, is a symbolic realm that bridges the Sensory/Sensible World (Mundus Sensibilis) to the purely Intellectual/Intelligible World (Mundus Intelligibilis). Articulated by Henry Corbin, it is conceived as a “world of image” that is as real and ontologically objective as the physical world. This concept plays a crucial role in Islamic mysticism for facilitating spiritual experiences and creative insights (Corbin, 1969; Nasr, 1993). Unlike mere imagination or fantasy, the imaginal uses imagery as a means of perception and for the sake of putting us in contact with reality (Vervaeke, 2022). Rooted in the works of Suhrawardi and Ibn Arabi, Imaginal emphasising intuitive and direct knowledge (Chittick, 1989).

Transdisciplinary Research (TDR):

Transdisciplinary is an integrative approach that transcends traditional disciplinary boundaries, unifying diverse academic fields to address complex issues by synthesising methodologies and perspectives into a coherent whole. It is increasingly vital for tackling multifaceted global challenges (Nicolescu, 2002).

Holistic:

Derived from the Greek "holos" meaning "whole," a holistic approach recognizes the interconnectedness and interdependence of all aspects within a system, whether biological, ecological, social, or psychological. It emphasizes understanding systems in their entirety rather than focusing on individual components (Capra, 1996; Smuts, 1926). In philosophy, it values the whole and the relationships between parts, viewing knowledge as emerging from these connections. In research, a holistic approach integrates diverse factors and disciplines to thoroughly understand complex subjects (Saleem et al., 2014; Jeder, 2014; Jackson et al., 2020). For example, in Big Data, a holistic approach combines technical, analytical, and business insights to leverage data strategically. Holistic epistemology adopts a top-down perspective, emphasizing context and the interaction of system parts for comprehensive understanding (Smith & De Graaff, 2016; Palmer, 2015).

Cybernetic:

Cybernetics is the study of systems—whether biological, mechanical, or social—and the processes that regulate them, with particular attention to communication and feedback. It explores how systems self-regulate and adapt through circular causality and the interaction of their components (Wiener, 1948/2019). Over time, the field has evolved across successive orders, progressively integrating notions of complexity, the role of the observer, and societal context into models of feedback and control. Within the scope of this exegesis, the concept of the Art of Steering has been invoked most prominently as a lens for understanding these regulatory dynamics.

The School of Santiago:

Originating from Chilean biologists Humberto Maturana and Francisco Varela, the School of Santiago emphasises autopoiesis and enactive cognitive theory. It focuses on the self-creating nature of living systems and the interdependent dynamics between organisms and their environment. This theoretical approach challenges traditional views of cognition by proposing that cognition is a continual act of creation rather than mere representation (Maturana & Varela, 1972).

Autopoiesis:

Autopoiesis, introduced by Chilean biologists Humberto Maturana and Francisco Varela in the early 1970s, describes a system's ability to self-reproduce and maintain its structure (Maturana & Varela, 1972). Initially applied to the self-maintaining chemistry of living cells, the concept has significant philosophical implications, particularly in phenomenology and the philosophy of mind. It influenced philosophers like Maurice Merleau-Ponty and Evan Thompson, contributing to enactive cognitive science, which views cognition as a dynamic, interactive process between embodied agents and their environments, challenging traditional representation-based cognitive models (Thompson, 2007).

Cognitive Science:

Cognitive Science is the interdisciplinary study of the mind and its processes, integrating psychology, neuroscience, linguistics, anthropology, and artificial intelligence. It examines how information is processed and utilised to understand the nature and development of cognitive capacities (Thagard, 2014).

4E+ Cognition:

4E+ Cognition posits that cognition extends beyond the brain, distributed across the body, environment, and social structures (Varela et al., 1991). It integrates several components: Embodied Cognition highlights that cognitive processes are rooted in the body's interactions with the world; Embedded Cognition asserts that cognition is situated within physical, social, and cultural contexts; Enactive Cognition emphasises active participation in creating meaning through embodied actions; and Extended Cognition suggests that tools and environmental elements can extend cognitive capacities. The "+" introduces the Affective dimension of Cognition, recognising that emotions are central to cognitive processes, influencing perception, decision-making, and problem-solving.

Relevance Realisation (RR):

Relevance Realisation is a central concept in cognitive science and 4E+ Cognition (Varela et al., 1991), explaining how humans and intelligent systems determine what information is pertinent in a given context. It is crucial for cognition, decision-making, and problem-solving, enabling the focus on relevant data for specific tasks or goals. This dynamic, adaptive, and context-dependent process underlies functions such as perception, memory, and reasoning. Relevance Realisation has broad implications for understanding human cognition, artificial intelligence, and the design of cognitive systems, emphasising the importance of dynamically identifying and prioritizing information in ever-changing environments.

Predictive Processing (PP):

Predictive Processing is a theoretical framework in cognitive science that conceptualises the brain as a hierarchical prediction machine. It posits that the brain continuously generates models of the world to anticipate incoming sensory input and minimise the discrepancy between predictions and actual experience, known as prediction error. This process allows the cognitive system to efficiently allocate attention, update beliefs, and guide adaptive action in dynamic environments (Clark, 2013; Friston, 2010). In the context of this thesis, PP provides a foundation for understanding how Relevance Realisation operates (Andersen, Miller, & Vervaeke, 2022).

Opponent Processing:

Opponent Processing refers to a cognitive whereby opposing or complementary processes interact to maintain balance, regulate attention, and support adaptive behaviour. Within the framework of Relevance Realisation, opponent processing provides a mechanism by which competing cognitive and emotional signals are balanced, allowing the brain to discern which information is most salient in a given context (Vervaeke, 2017; Solomon & Corbit, 1974). This dynamic interplay of opposites underpins cognitive flexibility, insight, and the ability to adaptively navigate complex environments.

Top-Down Emanation:

Top-Down Emanation refers to the process by which higher-order structures, principles, or forms influence and shape the organisation and behaviour of lower-level components within a system. In cognitive science, it can be seen as the influence of global predictive models, intentions, or conceptual frameworks on perception, attention, and action (Friston, 2010; Vervaeke, 2017). Philosophically, it resonates with metaphysical notions of emanation, where higher levels of reality or abstraction instantiate and guide patterns at lower levels.

Bottom-Up Emergence:

Top-Down Bottom-Up Emergence is the process by which complex properties, patterns, or behaviours arise from the interactions of simpler components without being explicitly imposed by higher-level structures. In cognitive systems, this refers to how sensory inputs, local neural interactions, or micro-level behaviours give rise to perception, cognition, or adaptive responses (Clark, 2013; Vervaeke, 2017). Emergent phenomena are often unpredictable from the properties of individual components alone, highlighting the self-organising and context-sensitive nature of complex systems.

The Taxonomy and Terminology of XR in 2024

eXtended Reality (XR) represents a comprehensive term, encompassing the collective suite of immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and other allied forms (Azuma, 1997; Milgram & Kishino, 1994). The taxonomy and terminology of XR not only function to categorise but also elucidate the myriad types of immersive experiences, along with the pertinent technologies deployed for their creation (Bailenson et al., 2018; Bowman et al., 2008). Presented here is a compilation of key concepts that provide the framework of XR's taxonomy and vocabulary. The following definitions aim to shed light on the complex and dynamic realm of XR, which exists at the convergence of technology, human interaction, and experience design.

HCI (Human-Computer Interaction):

Human-Computer Interaction (HCI) studies the design, evaluation, and implementation of interactive computing systems for human use, focusing on optimizing interactions between people and computers (Dix et al., 2004). In this thesis, HCI explores the intersection of eXtended Reality (XR) and holistic cognitive approaches by integrating cognitive principles and immersive technologies. It aims to create interfaces that are not only functional but also aligned with human cognitive processes, including embodied cognition, affective interaction, and spiritual knowledge. This approach enhances user experiences by designing intuitive, engaging, and cognitively resonant interactions within XR environments, consistent with 4E+ Cognition principles.

4th Industrial Revolution:

The Fourth Industrial Revolution (4IR or Industry 4.0) signifies a transformative era where digital technologies like Artificial Intelligence, the Internet of Things, Big Data, Blockchain, and Extended Reality converge, blurring physical, digital, and biological boundaries. It revolutionises how we live, work, and socialise, impacting economies and reshaping human cognition and knowledge systems.

Artificial Intelligence (AI):

AI involves simulating human intelligence in machines programmed to mimic cognitive functions like learning and problem-solving. AI research encompasses areas such as robotics, natural language processing, and machine perception (Russell & Norvig, 2016). A key subset, Machine Learning (ML), is widely applied in fields including image recognition, medical diagnosis, stock market trading, and more, enhancing the capabilities and applications of intelligent systems across various domains.

Deep Learning:

Deep Learning (DL), a subset of Machine Learning, uses artificial neural networks inspired by the brain's structure. Excelling in pattern identification and prediction, DL models complex, non-linear data relationships through multi-layered networks. It advances fields like voice recognition, language translation, and image classification (Goodfellow et al., 2016).

Machine Learning (ML):

Machine Learning, a branch of AI, develops systems that learn from data to make decisions without explicit programming (Alpaydin, 2020). It includes supervised learning with labelled data, unsupervised learning for pattern discovery, and reinforcement learning through trial and error with rewards or penalties.

Immersive Technologies:

Immersive technologies include devices and methods that create a profound sense of immersion and presence in virtual or augmented environments (Slater & Wilbur, 1997; Steuer, 1992). This category encompasses Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), as well as innovations like haptic feedback for tactile sensations (Jones & Sarter, 2008), spatial audio for enhanced spatial presence (Begault & Wenzel, 1993), and eye-tracking for intuitive interactions (Jacob & Karn, 2003). These technologies bridge the virtual and tangible worlds, enabling sensory and cognitive engagement and advancing human-computer interaction (Bowman et al., 2008; McMahan, 2003; Azuma et al., 2001).

eXtended Reality (XR):

eXtended Reality (XR) encompasses immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (Milgram & Kishino, 1994; Schwab, 2016). The XR ecosystem involves diverse stakeholders collaborating to develop, distribute, and consume XR experiences, integrating technology, creativity, commerce, and user engagement. This multifaceted and interdependent framework supports the creation and delivery of immersive environments. Additionally, the XR ecosystem is influenced by broader societal, ethical, and regulatory considerations, including privacy and data security issues (Mann et al., 2018).

Real Environment:

In XR, the real environment refers to the user's actual physical surroundings, providing the spatial and contextual framework for interaction with digitally overlaid elements in AR, VR, and MR. Distinguished by its tangible, sensory-rich characteristics, it serves as an anchor for presence and user engagement, enhancing the believability and efficacy of the XR experience (Azuma, 1997; Milgram & Kishino, 1994).

Virtual Reality (VR):

Virtual Reality is a distinct XR paradigm that creates a fully immersive, computer-generated environment separate from the physical world (Sherman & Craig, 2003; Steuer, 1992). Accessed through specialised hardware like VR headsets and motion controllers, VR replaces real-world surroundings with a digital realm, stimulating the senses to create a convincing alternate reality (Bowman et al., 2002).

Augmented Virtuality (AV):

Augmented Virtuality integrates real-world objects, images, or data into primarily virtual environments, blending reality with the digital (Jerald, 2015). Utilising sensing and imaging technologies like video cameras and object recognition software, AV enhances virtual experiences by incorporating elements from the physical world seamlessly.

Augmented Reality (AR):

Augmented Reality superimposes digital artefacts, such as 3D objects or multimedia elements, onto the user's physical environment in real-time (Azuma, 1997; Carmigniani & Furht, 2011). Unlike VR, AR enhances the real world by overlaying interactive virtual components, accessible through devices like smartphones, smart glasses, and specialised headsets (Schmalstieg & Höllerer, 2016).

Mixed Reality (MR):

Mixed Reality blends virtual and physical elements, allowing real and digital objects to interact in real-time (Azuma, 1997; Billinghurst et al., 2001). MR offers higher immersion and interactivity than AR by enabling two-way interactions between virtual entities and physical items, often referred to as "Digital Twins" (Kritzinger et al., 2018).

Digital Twins:

Digital Twins are virtual replicas of physical systems or entities that simulate, analyse, and optimise their real-world counterparts in real-time using data from IoT sensors and other sources. Integrating with XR, Digital Twins provide immersive visualizations and simulations, enhancing decision-making and operational efficiency across various sectors (Mann et al., 2018).

Internet of things (IoT):

The IoT is a network of interconnected devices that communicate and exchange data over the internet, enhancing functionality and connectivity. Integrating enchanted objects within IoT ecosystems further amplifies their capabilities, enabling more sophisticated and interactive user experiences.

Smart Objects:

Smart objects are physical items equipped with computational power, data storage, and communication capabilities. They perceive their environment, process information, and interact with other devices and systems. Enchanted objects are a subset of smart objects, distinguished by their focus on user experience and their magical, anthropomorphic qualities (McCullough, 2013).

Enchanted Objects:

Enchanted Objects emerge from the intersection of design, technology, and human-computer interaction, describing everyday items enhanced with interactive, intelligent features (Rose, 2014). Within the Internet of Things (IoT) and smart objects, they gain digital capabilities to provide new functions, communicate with users, and integrate into digital ecosystems. These objects transcend their original purpose by offering additional utility and engagement through sensors, connectivity, and AI. Rose emphasises design principles of simplicity, familiarity, and delight, ensuring enchanted objects are easy to use, intuitively understood, and evoke a sense of wonder. An example is a smart thermostat that adjusts temperature based on room occupancy, enhancing comfort and energy efficiency.

XR as a medium of experience:

Extended Reality (XR) technologies create distinctive, immersive experiences by integrating virtual and real components into shared environments, enabling simultaneous and collaborative interactions (Billinghurst & Kato, 2002). This seamless interplay between digital and tangible elements fosters a harmonious blend of interactions among users and their surroundings (Schwartz et al., 2019). Key characteristics of XR as a medium of experience include spatial computing, which allows real-time manipulation of virtual objects within physical spaces (Milgram & Kishino, 1994); real-time interactions through gestures and voice commands, enhancing user agency and control (Azuma, 1997); contextual integration, where virtual elements are anchored to specific physical locations for spatial coherence (Billinghurst & Kato, 2002); and shared experiences that facilitate communal interactions in mixed reality environments (Schroeder, 2006). These attributes distinguish XR from other reality technologies, establishing it as a significant medium for experiential engagement and reshaping interaction paradigms both personally and societally (Carmigniani & Furht, 2011).

The Journey

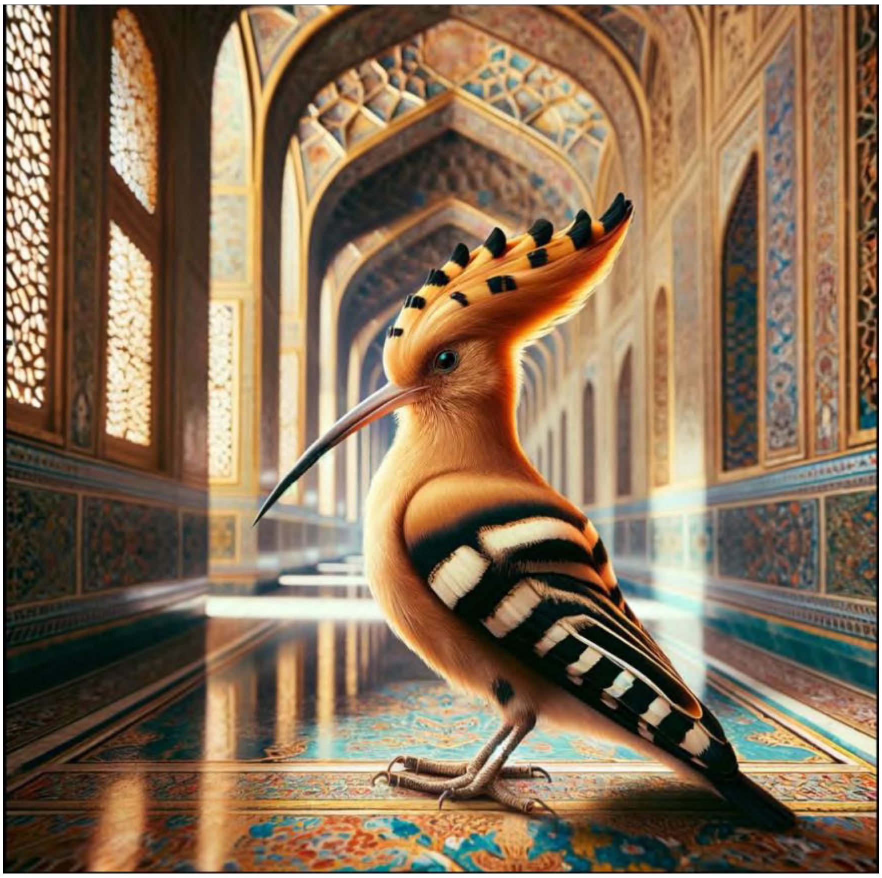
Before going into the main body of this thesis, I invite you to read the esoteric story located in Appendix 1. Rooted in rich cultural traditions, this narrative sets the mood and encapsulates the themes of departure, discovery, and transformation that are central to my journey. Reading it first will provide valuable context and enhance the understanding of the perspectives presented herein.

This tale of esoteric exploration and transformation began a decade ago with the seeds of a PhD journey. My worldview—once firmly grounded in modern science and technology—began to shift as life in Aotearoa, and the quiet solitude of the COVID lockdown, took hold. Like the Hoopoe bird in Attar's mystical parable, symbol of wisdom and spiritual guidance, I flew far from home to the mystical land of the long white cloud. Through trials and introspection, I experienced a profound metamorphosis—an inner turning that reshaped my understanding and reoriented my sense of self. This narrative reflects my journey: a departure from the familiar, a discovery of the hidden, and a transformation wherein ancient wisdom and lived experience converge.

The author strongly encourages readers to engage with the story in the following pages before proceeding to the main body of the exegesis, as it serves to orient and attune the reader's mind, preparing them for the journey ahead.

In the Name of Eternal Wisdom

This tale of esoteric exploration and transformation began a decade ago with the seeds of a PhD journey. My worldview, once rooted in Western science and technology, began to shift as life in Aotearoa and the solitude of the COVID lockdown took hold. Like a Hoopoe bird on a quest, symbolic of wisdom, I flew far from home to the mystical land of the long white cloud. Through trials and introspection, I underwent a profound metamorphosis, shedding my former self and embracing a new, enlightened perspective. This story reflects my journey—of departure, discovery, and a transformed understanding where ancient wisdom and lived experience converge.



Guided by the universal spirit of truth, I present “Living Poetically”—a reflection on my transformative journey through travel, academia, and research. Woven from inner struggles and external encounters, this tale honours the wisdom of Suhrawardi, Avicenna, Ibn Tofail, Rumi, and Attar, offering enlightenment I hope will illuminate the reader's path in this inquiry.

The Story of the Bird

Ali Taheri & Zohreh Shirazi

Chapter One

The Call of Gabriel's Feather

Seeking

It's the *path* that matters,
The destination is always Knowledge.

When I gathered everything I needed and headed towards the exit of the cave,I felt the pressure of being surrendered by others, and their opinions:

- Don’t go, stay;

- There is nothing out there;
- You will be blinded by too much light;
- Everything is right here; look at these shadows, these designs;
- You will find the truth right here;
- There is no news of the fate of those who have gone;
- There is nothing outside at all. You are heading towards nothing.

With all haste, I moved through the crowd, occasionally bumping shoulders with others. The number of birds around me was increasing, each providing arguments why this journey should not take place. Softly, I said, “Today is Yom Yalqun[I] (the Day of Meeting). Someone amid the noise, a little further away, asked, “What did you say?” Louder, I replied: “The kingdom of Solomon, in all its grandeur, cannot fit within our cave; I must leave the nest and approach the King.” Someone nearby, with a calm voice that quieted the crowd, said: “Everyone and everything returns to its origin; now he must go to return to the light. If his origin is here, he will eventually return here, but the journey is necessary.” I stepped out of the cave, and for a moment the sunlight blinded my eyes. I spread my wings with all the strength I had and flew into the open air. I did not know where I was going or what awaited me, but something was calling me.

Soaring through the skies, absorbing the sun's warmth, I embraced the boundless possibilities of my path. From afar, amidst the wind and mist, I glimpse my first destination. A colossal mountain range unfolds before me, stretching from the easternmost edge of the sky to the westernmost—they call this range Plato. If I have walked the right path, the greatest mountain stands before me. Yes… the first mountain lies ahead. A pleasant anxiety slips beneath my skin. As far as my eyes can see, there are mountains—vast and majestic. The entrance to the mountain still looms fifty meters above me. I begin my ascent, pulling myself upward, and place my foot upon the ancient stones of the gateway.

[I] Referring to stories about Solomon ((/ˈsɒləmən/)[a] also called Jedidiah) - The figure of Solomon, known for his wisdom, wealth, and rulership, occupies a significant place in various religious traditions, academic discourses, and psychological interpretations. In Suhrawardi's mystical short story collection "لغت موران" (Lughat al-Murān, often translated as The Language of the Ants), the reference to "Yom Yalqune'" (یوم یلقونه) is indeed significant. This term, which can be translated as "The Day of Gathering," refers to a moment of profound spiritual importance, especially within the context of the story where Solomon requests to see all the birds.

Chapter Two

Cave

Love

Stepping softly into the cave, everywhere is silent and serene; torches are lit, casting light upon the stone walls of the cave. As I step inside from the entrance, I become intoxicated by the grandeur of the hall. Mesmerized and unawares, I had taken only a few more steps deeper when a wave of migratory birds swept into the cave. Those for whom this journey was not new, and a few young novices among them, advanced with the strength of the elders' experience. They swiftly passed by, and the mountain officers arrived, forming a line. I stood somewhere at the end of the queue.

'Name?'

Asked the bird behind the falcon checking documents. There were several corridors, each beginning with another falcon standing tall with heads high and chests out.

- 'Where are you going?'
- 'I'm travelling.'
- 'Destination?'
- 'I'm not sure.'

He gazed at me and handed me a brochure from a drawer in front of his desk. It showed a painting of a bird flying in the sky, with 'Travelers of Love' written in big letters. I opened the brochure and looked at its contents. guidance on not flying too high, where I might find water, how to determine my location if I become lost, a map of the journey ahead, and a reminder that I cannot carry too heavy a burden with me.

- ‘You can't carry all that load with you.

I grabbed the suitcase handle and thought about the things I had in it.

- ‘Because I don't have a destination?’

I asked while I knew the answer.

- ‘Yes.’
- ‘But it's ok, I can handle it.’
- ‘You won’t last ten minutes outside the door, it's beyond your capacity to carry, you haven't flown anywhere yet you'll get tired somewhere in the air and leave everything, or worse, fall with your load.’
- ‘I have read about it, I know…’

He interrupted me.

- ‘I can’t let you pass. You need to reduce your load. Take only what you really need. Here, we can provide a window for you to keep some of your belongings, but you have to let go of the rest. Only take what you really need! You can’t take any excess. You have to be light to have permission to leave Mount Plato, otherwise, the curtain won't open for you.’

- ‘Which curtain?’

He looked at me, saw the excitement in my eyes – something that he too has experienced.

Lost in my thoughts, I approached one of the tables that were located all around the entrance hall for passengers to sort their possessions. I started to decide what to keep and what to leave behind.

I was given a small window for storage—just enough for a few mementos. I placed my father's plaque, my mother's brooch, and unopened letters inside that I found in my belongings, resolving to read them upon my return. I know I have to dispose of my remaining belongings when I go outside the mountain, so I tasted the final morsel from my mother.

For the last time I looked at the rest of my items. In that final moment, I snatched from the table the group photo, my brother’s rosary, and the love and affection of my sister. Closing the window and surrendering the key, I proceeded down a corridor named 'Love,' embarking on a solitary journey.

This corridor, unique and solitary, echoed with the sound of my claws against the floor. As I got further and further into the corridor, my initial vulnerability transformed into a profound lightness, culminating in a sense of true self-identity. I was alone for so long with my thoughts, a true experience of loneliness. It took me long hours to realise I was getting closer to nearing the corridor's end; my pace quickened, and, feeling as light and free as a feather, I ran, spreading my wings to embrace the open air.

Chapter Three

Detachment

Knowledge

Upon exiting the cave, a fierce storm immediately assaulted me, its force pressing me against the mountain as snow harshly struck my face. Struggling to free myself before the cold bonded me to the stone, It was as if it had been me all along! As if everything was but a dream, an experience beyond my very existence.

As I fought for elevation, aiming to rise above the storm, its wrath intensified. Despite the struggle, I managed to soar above the clouds, only to be greeted by violent strikes to my face and wing. Caught in a battle with predatory birds above the clouds, I dodged an attack, finding refuge in a brief respite. With a surge of determination, I found my voice and yelled out:

- ‘What do you want? I have nothing.’
- ‘Yes, you do, and because you deem them nothing, you're unworthy of keeping them.’
- ‘What do you want? My wings? My feathers?’
- ‘No, keep your body. We want your memories, a bit of your tongue's flavour, more so, your intellect and senses.’

Before I could fathom what they were saying or what they desired, they had already distanced themselves from me, leaving me with only a fragment of all my possessions. They had stolen my language, seized my senses, and torn me away from myself.

Wounded in both spirit and flesh, I sought refuge above the storm, I flew without balance, soaring so far that, high above the storm-laden clouds and away from the bandits, I found solid ground where I landed, spinning around myself several times. Despite all that had befallen me, I could still be me—a bit different, perhaps even better. Slightly dazed and with less vitality, I asked myself, “Do you wish to return?” I thought deeply, listened to the sound of the wind, opened my eyes, saw the clouds gently gliding across the sky, and felt the sun still shining upon my wings. No, I want to continue onward.

Chapter Four

Wonder

Inhibition

Trapped in a sleep too deep, I lost track of time—be it a week, a century, or a millennium. Awakening beneath a canopy of spring, with autumn's remnants beneath me, and birds heralding the season, I found myself in a timeless land. Here, snow fringed the edge of the valley where flowers, caught in a perpetual frost, neighboured winter's purple blossoms. The encroaching crows, a stark contrast to the solitude, broke my reverie:

- ‘You're finally awake.’

He grasped my wing, brushing leaves off it. I noticed he cared for me and kept me warm under the cover.

- ‘You can slowly start to fly again, you can continue on your path. Where are you going?’
- ‘I am not sure.’

Surprised, he looked at me and then glanced back at the path I had taken.

- ‘I've never seen thieves take the destination and path away from someone before.’
- ‘They didn't, I never had a destination to begin with.’

Smiling, he laid a leaf in front of me, covered in blackberries and other edible fruits.

- ‘Here, after eating these you will feel much stronger. Good luck with your journey. This land is called the “Field of Time”. You'll find many things on your path, don't worry about food, but don't overindulge.’
- ‘Thank you, How long have you been here?’
- ‘I don't know, a hundred years! a day!’

I began eating the blackberries, and I flexed my wings, their pain not hindering my ability to fly. He ask:

- ‘So, you're a traveller of love?’
- ‘I think so.’

The bird stood up, ready to leave, and pulled a cosmetic necklace from around his neck, handing it to me. The necklace had three beads tied around himself.

- ‘Each bead you untie, you can see the answer to your question in this cosmic bowl, provided the Big Dipper faces you and the sun is at its zenith. It's easy to lose your way in the Field of Time, that’s why everyone has a destination. This field could become a vast pit you fall into without realising, and you might wander for a lifetime. Face towards the light, and continue travelling.’
- ‘Is that what happened to you? Don’t you need this stone?’
- ‘Not anymore, it's been a long time since I realised I belong here.’

Chapter Five

Unity

In the Field of Time, I briefly regained my spirit, yet the fear of losing it propelled me across its vast expanses—seven seas and continents. Gliding low, where food was plentiful and peace reigned, I nearly forgot my purpose, saved only by the cosmetic necklace, I had to use one of its beads as guides through this timeless expanse. Departing this serenity, I journeyed over oceans to a small land torn apart by two groups locked in a forgotten conflict, their discord deep yet ignorant of its roots, committed to a dispute without memory of its cause. On the small island, emissaries from every faction visited, exchanging tales of the wider world and they shared their sustenance with me, along with a reason why they were on the righteous side of the fight on this land. To an outsider's eye, their similarities outshone their disputes. Aiming to reflect this back, I gathered pairs from each faction at my home for dialogue.

- ‘Who are you?’
- ‘I am a bird.’

Said the first bird from the east side of the land.

- ‘No, I am a bird.’

With no minute to spare, said the second bird from the west side.

- ‘Can’t you both be birds?’

I asked.

- ‘Yes, but I am the rightful one!’ Said the West.

Therefore, since in his mind he was the right, on a level that meant no question needed to be asked, and that is why he was the bird, the best bird, superior one, the one holding the right of this fight in his heart.

- ‘No, I am the rightful one.’

Like a mirror they were reflecting one another.

- ‘Can’t both of you be right?’

I asked again. They started to fight with each other.

- ‘No, you did this to us.’
- ‘You did that to us.’
- ‘Isn’t it possible that both of you have harmed each other?’
- ‘Yes, but they started it first.’
- ‘No, you started it first.’
- ‘No, it was before that.’
- ‘No, before that.’

After all the arguments had ended, I asked them:

- ‘Who are you?’
- ‘I am a bird.’
- ‘I am a bird too.’

- ‘Can you fly?’
- ‘Yes.’
- ‘What about you?’
- ‘I can too.’
- ‘Can you hunt? Choose a mate? Improve? Do good? You are not two; you are one. This entire island is one. You are so close to each other that you fail to see one another. You are not the darkness of an old wound, what has been taken from you is light. Restore goodness, see the light, as everything else stems from it. You unite, one by one, forming a whole. Start seeing with the good eye.’

Chapter Six

The One

Astonishment

It was beyond belief. Was it truly me? Did I really have a family? Had I traversed lands, or were they all nothing more than dreams, like these mirages? Who am I, if I am anyone at all? My purpose was to journey without arriving. Arriving where?

Amidst the pain, I was awakened, made aware, kept vigilant—until one day even pain became a mirage to me. Is this wound upon my wing? Is this pain upon my body?

Alone, I questioned the fabric of my reality. Were memories of family and past adventures real, or mere illusions? My quest seemed not for a destination but for the journey itself. Pain, once a tangible proof of life, became just another illusion. Years passed, taking my youth and leaving me in ambiguity—was I emptied or enriched? In the solitude of night, seeking refuge in a cave, a voice pierced the darkness, offering a semblance of connection.

- 'Who are you?'

'Who am I? I don't know.' I thought to myself. The bird asked again:

- 'Who are you?'

I replied:

- 'A traveller.'
- 'Where have you come from?'
- 'I don't remember anymore.'
- 'Where are you going?'
- 'A traveller of love.'

The owner of the voice flapped its wings and sat beside me.

- 'This is my home, but you can rest here. We are a small tribe here. You can stay as long as you like.'

In a realm where bats and sun-gazers lived yet clashed, the bats once captured a sun-gazer. Amidst heated debate, they resolved to exile it to daylight as punishment, unaware that for a sun-gazer, daylight was the harshest sentence imaginable.

After a while, I decided to continue my journey. I said ‘I would leave the next day.’

- ‘In the morning? In daylight? In brightness that blinds the eyes? It's in the night that the path can be found. Nothing can be sought in the day.’

- ‘My eyes are not like yours; I cannot see in the darkness, I see in the daylight.’

Before I knew it, I had gathered many from the tribe around me. They spoke of the path of night and darkness, and I spoke of day and light. A voice rose from within the crowd and said:

‘This bird claims to see in daylight, and as daylight blinds, he is lying. We should end him right here!’

Recognising the futility of convincing those unacquainted with daylight, I saw their inner darkness as a greater loss than any I'd faced. I conceded, claiming blindness like theirs, choosing to remain with them overnight, learning from their perspective. Yet, I resolved to resume my quest under the cover of the next night, departing silently at dawn.

Chapter Seven

Illumination

Poverty and Annihilation

From the Final Cup of the World I Partook, Embarking upon the Path of Light. Light, my ultimate destination, I soared through clouded realms, Each flutter of my wings made me lighter, A transformation stirring within me. This journey had wrought change, I felt unburdened, grown vast, Wounded along the way, grounded, weary, Yet never lost hope in my very existence. Now, within a fresh vessel, A home for my expanded soul, This new being couldn't fit within my former form, I needed a body more wounded yet stronger, To feel greater lightness and peace. From afar, I glimpsed a mountain range. I whispered to myself:

- Plato…?

A strange sensation enveloped me, clutching tightly the Orb of Vision in my head, returning me to my essence. What I sought had stood before me all along, Yet I hadn't freed myself, The veil before my eyes remained unlifted. I stepped into the inn, This self-standing here was not the one who had left the cave. Traveler birds fluttered about, The inn was bustling, I gazed in awe at its architecture, Never had my eyes beheld such artistry and grace. A hawk flew towards me, landing before me. It examined my documents, I felt myself standing above the earthly realm, beyond my physical form, liberated and free. It placed the window key in my hand and soared, Toward a couple stranded at the inn, guiding them. I held the key, approaching my window, In a dreamy haze, still not returned to this world, breathing in a mysterious realm. I opened the window, draped my father's plaque around my neck, Under my brother's rosary, I lifted the letter, Something within me pulled, The inn's sounds grew louder, Unconsciously I opened the letter, Reading my father's script:

In the name of the Light and Being, To whom all existence and non-existence wholly belong. In the name of your very existence, Where every breath and sigh reflects His grace.

My child, my beloved, I know that soon, one day, At dawn's first ray, you'll greet the call, stepping forth on the path of light and brightness. For me, having watched your growth and joy through the years, I can no longer wait to witness your bloom upon the dusty road, To see your ascendant spirit flourish. I write this letter so that when the time of your ascension comes, your eyes may not overlook these few guiding words from the past, For He knows the way and the path, And I fulfil my duty as a father before His luminous gaze, Leaving the rest to the Divine.

In my childhood days, my father recounted this tale from his own youth, of a day when someone asked their father, "Is light in existence flowing?" The answer was, "Yes, it flows." The person asked again, "How do you know this knowledge?" The response came, "One day I was captured, fishermen covered my eyes, and took me into darkness in another realm." In that land, I was so bewildered that I gradually forgot all I knew of my homeland. Yet I always longed for the day guardians would release me. Until one night, seizing a moment, I fled into the heart of a desert. In the desert, I met a red-faced stranger, inquiring about his identity.

"Who are you?"
"I am the first child of creation."
"You're young, how can you be the first creation?"

- *"I too spent years captive, held in a black well. In that darkness, my spirit's light dimmed, like sunlight reddening between night's gloom and day's pale."*

- *I asked: "Where do you come from?"*
- *"From Mount Qaf! Like all of us, even you, we have forgotten."*
- *I inquired about Mount Qaf,*

The first child of creation spoke of existence's origin story, Eleven mountains, seven celestial orbs, two Atlas spheres above, Pointing to the two captives below. In this land, angels guide between moon and sun, An old red-haired man describes the no-where like this:

"no-where, the city of angels, the city of souls and minds, Home of luminous beings." He continues, "Opposite this city of light lies the dark world, The celestial west, called the astral firmament, A heavenly west enriched by light's proximity, Yet a realm not void of matter."

- *"So I only need to return east to my land?"*

- *"No, the east and west I described aren't earthly directions. Above the ninth sphere lies the angelic realm, Your true origin belongs there. Below lies the moon's sphere, called the west, where that very prisoner exists, where you and I were held captive, That darkness where human truth is ensnared."*

- *"How can I find the way back?"*

- *"Trust your senses, for the crimson border of your being, The boundary between body and soul, guides you." My father heard from his own father that the first child of creation, An angelic being named Sayed Ascending, appeared as a red-haired elder, My father spoke of his own experience,*

- *The first intellect is the tenth intellect, Or in other words, the beginning of the Holy Spirit and Gabriel, Indeed the first intellect, where the soul's components, Scattered in eternal darkness, suffer in the black well's captivity. These components are known as the divine aspects of humanity. To find the path, one must seek these scattered parts.*

My son, I too have journeyed through this darkness and redness, And through my experience, I've realized that darkness complements light, To reach the redness, both are equally vital, perhaps *neither surpassing the other. Now, as you read this letter, your journey has begun. You've found a piece of radiant light, You've traversed beyond a stage of shadows, Heading towards Mount Qaf. In the face of darkness, use the Simorgh's light to find your way, And ultimately, at the spring of life, From where you emerged, you shall be baptized, By the wound of Emin's blade. Know that you are the very bird that captors seek to imprison, And you belong to this captivity.*

References:

I drew inspiration from these timeless classical works, which served as subtle yet profound guiding lights for the creation of this story. They stand as my indirect references, weaving their essence into the narrative's fabric.

Attar of Nishapur - The Conference of the Birds (Persian: منطق‌الطیر):

"The Conference of the Birds" (Persian: منطق‌الطیر, Manṭiq-uṭ-Ṭayr), written by the great Persian mystic poet Farid ud-Din Attar of Nishapur, is a seminal work in Sufi literature. This allegorical poem, composed in the 12th century, is one of the most celebrated works of Persian literature and a profound exploration of the spiritual journey towards enlightenment.

Suhrawardi - Language of the Ants (Persian: لغت موران):

"The Language of the Ants" is a fascinating and symbolically rich work within the broader context of Suhrawardi's Illuminationist philosophy. Suhrawardi (1154–1191), known as the "Master of Illumination," was a pivotal figure in Islamic mysticism and philosophy, and his works often explore the interplay between light and darkness, knowledge and ignorance, and the spiritual journey of the soul.

Ibn Arabi - The Meccan Revelations (Arabic: الفتوحات المكية, Al-Futūḥāt al-Makkiyya):

"Futuhat al-Makkiyya" (Arabic: الفتوحات المكية), or "The Meccan Revelations", is one of the most significant works by the renowned Andalusian Sufi mystic, philosopher, and theologian Ibn Arabi (1165–1240). This monumental text is a comprehensive exploration of Islamic mysticism, metaphysics, theology, and spiritual practice, and it remains a cornerstone in the study of Sufism and Islamic philosophy. One of the central doctrines in "Futuhat al-Makkiyya" is the concept of Wahdat al-Wujud, or the

"Unity of Being." Ibn Arabi argues that all existence is a manifestation of the One Reality, God. This concept does not imply pantheism, but rather that everything in existence reflects the divine reality, and all distinctions are ultimately illusory. The goal of the spiritual seeker is to realise this unity and to see God in all things.

Avvecina - Alive Son of Awake (Arabic: حي بن يقظان , Ḥayy ibn Yaqẓān):
Avicenna's "Ḥayy ibn Yaqẓān" is written in early 11th century, focusing on the soul's journey towards intellectual enlightenment. In his narrative, Ḥayy ibn Yaqẓān symbolises the soul's journey towards enlightenment and the realisation of divine truths through intellectual and spiritual refinement. The story illustrates the process of the soul awakening to its true nature and the pursuit of knowledge as the path to ultimate truth.

Ibn Tofail - Alive son of Awake (Arabic: حي بن يقظان , Ḥayy ibn Yaqẓān; Latin: Philosophus Autodidactus 'The Self-Taught Philosopher'; English: The Improvement of Human Reason: Exhibited in the Life of Hai Ebn Yokdhan):
Ibn Tufail, an Andalusian philosopher, also wrote his own version of "Ḥayy ibn Yaqẓān", which became more widely known in the Western world, particularly through its Latin translation as Philosophus Autodidactus ('The Self-Taught Philosopher'). This was composed around 1160 CE (555 AH) in al-Andalus. In Ibn Tufail's version, Ḥayy is a man who grows up alone on a deserted island and, through his observations of nature and reflection, arrives at the understanding of the world and the divine without any external guidance. The story is a profound exploration of the nature of human reason and its capacity to achieve knowledge independently of revealed religion. It reflects Ibn Tufail's belief in the harmony between reason and faith, and the potential for human beings to attain a state of enlightenment through introspection and intellectual inquiry.

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Note. Illustration created by Zohreh Shirazi (2021) based on concepts by Ali Taheri.

Chapter 1: Explanatory Introduction

In an age where technology rapidly evolves, the boundaries between the physical and digital worlds continue to blur. My research delves into this intersection, where human cognition, spiritual wisdom, and technological innovation converge. This introductory chapter is structured to guide readers through the core concepts that underpin the research, providing a clear and contextualised framework for the study. It establishes the research objectives and significance by exploring the unique intersection of spiritual wisdom and perennial philosophy, notably Ishraq (Illuminationism[1]), with modern cognitive and technological paradigms. It lays the foundation for an in-depth examination of the convergence between cognitive theories, spiritual insights, and the evolving field of eXtended Reality[2] (XR). Additionally, the chapter outlines the motivations driving the research, detailing how personal experiences, philosophical reflections, and technological advancements have come together to shape the direction and scope of this study.

1.1. Title of the Research

I submitted my PhD confirmation document in 2019 with the following research title ‘Design Principles for an Emerging Medium: Exploring Embodied Interaction in Mixed Reality’. As my work progressed and evolved, informed by the guidance of my supervisors, I refined the title to better capture the essence and direction of my research. The final title is *‘Exploring 4E+ Cognition and Spiritual Wisdom in eXtended Reality Interaction and Experience Design’*. This title reflects a more comprehensive and nuanced exploration of the intersection between cognitive science, philosophia[3], experience, and interaction design in the innovative field of eXtended Reality. The decision to change the exegesis title was made after thorough and deliberate

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[1] Suhrawardi's Ishraq philosophy (Illuminationism) introduces a metaphysical framework where light serves as the fundamental principle of existence, distinguishing it from the more rationalist approaches of his predecessors.

[2] eXtended Reality (XR) is an umbrella term encompassing augmented reality (AR), virtual reality (VR), and mixed reality (MR). It refers to immersive technologies that blend the real and virtual worlds to varying degrees. (Refer to ‘Definition of Keywords’ section).

[3] Historically denoting the ‘love of wisdom’, Philosophia in this context is understood as an expansive pursuit of knowledge and understanding concerning the fundamental nature of existence, reality, and ethics, transcending the boundaries of formal academic philosophy (Hadot, 1995/2016).

consideration throughout my PhD journey, undergoing multiple revisions. The proposed title change aims to better encapsulate the direction and scope the research has ultimately taken, offering a more precise and effective depiction of the study's findings and its complexity.

The research journey evolved in parallel with the rapidly changing interactive and immersive media industry, causing a shift in focus from Mixed Reality (MR) to the broader concept of eXtended Reality. This adjustment more properly represents the inclusive nature of various interactive and immersive media technologies (for further details, refer to the *Definitions of Keywords* section, seek for '*The Taxonomy and Terminology of XR in 2024'*).

The term *4E+ Cognition*[4] signifies an in-depth comprehension of cognition that extends beyond the brain. This comprehensive approach recognises that cognitive processes are not isolated within the mind but are influenced by our bodily experiences, the contexts in which we live, and the tools and technologies we use.

While the initial focus was solely on *embodied* cognition, the 4E+ framework now incorporates how cognition is embedded in our surroundings, enacted through our actions. Extended via tools, artefacts, and technologies, the framework offers a more nuanced exploration of experience and interaction in XR. The addition of the '+' to 4E, recognises the critical role of emotions and affects in the cognitive experience. Emotional responses (such as a sense of awe in a vast virtual landscape or the impact of culturally sensitive experiences) can significantly influence how users perceive and interact with real or virtual environments, affecting cognitive processes.

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[4] The 4E+ Cognition approach refers to a framework in cognitive science that emphasises how cognition is not just brain-bound but extends across the environment, body, and social interactions. The *4E* stands for Embodied, Embedded, Enacted, and Extended cognition, highlighting that cognitive processes are influenced by the body's interactions with the physical world, are integrated into larger systems and networks, arise from bodily actions, and extend into the environment via tools and technologies. The + in 4E+ includes additional aspects like affective and emotional processes, which recognise the role of feelings and emotions in shaping cognitive experiences. This approach is particularly relevant in understanding human interactions with complex systems such as those encountered in eXtended Reality environments (Clark, 2010; Colombetti, 2014; Newen et al., 2018; Varela et al., 1991).

The exploration of philosophical concepts such as *Autopoiesis*, *Cybernetics*, *4E+ Cognition* and their intersection with *Neoplatonism*[5]—with its focus on the emanation of reality from a singular divine source—and *Illuminationism* presents a rich tapestry for academic inquiry. Viewing these intersections through the lens of perennial philosophy[6] offers a unified framework that transcends disciplinary boundaries, providing a comprehensive understanding of cognition, consciousness, and the essence of interconnectedness that pervades the cosmos. This synthesis proposes a holistic approach to understanding the nature of reality, cognition, and the human experience. In doing so, it encourages a rethinking of the boundaries between the material and immaterial, the empirical and the mystical, ultimately proposing a unified theory of mind and cosmos.

The current study adopts a holistic[7] epistemological approach aligned with perennial wisdom, notably Ishraq Hikmah[8], which emphasises the interconnectedness of knowledge and experience. This holistic approach complements the transdisciplinary aspect of this research by enabling a top-down understanding and macro perspective of complex systems, which allows for integrating various knowledge domains. By weaving these diverse strands of knowledge together, this research aims to develop a comprehensive framework that can help researchers and practitioners address the multifaceted challenges of Human-Computer Interaction within interactive immersive XR technologies.

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[5] Neoplatonism is a philosophical system that posits a hierarchy of reality, beginning with the One, the source of all existence, followed by the Intellect (Nous), and the Soul. These primary levels of reality illustrate the process of emanation, where all things derive from the One and return to it, reflecting a deeply interconnected and ordered cosmos (Perl, 2015).

[6] Perennial philosophy (or perennial wisdom) refers to a perspective in spiritual and philosophical thought that posits an underlying, universal truth at the heart of all major world religions and wisdom traditions. This viewpoint suggests that despite the diverse expressions and practices of different cultures and religions, there exists a shared metaphysical and spiritual foundation.

[7] The holistic approach recognises the interconnectedness and interdependence of all aspects of a reality or system. It implies understanding and addressing any system, be it biological, ecological, social, or psychological, in its entirety rather than focusing on its individual components in isolation.

[8] 'Hikmah' refers to wisdom. Wisdom is considered one of the highest and most sought-after qualities in Islamic thought, and it is closely linked to the concept of truth. In Islamic intellectual tradition, Hikmah refers to wisdom that combines knowledge and virtue, often implying a spiritual or divinely inspired insight. It integrates philosophical inquiry with ethical and spiritual dimensions.

1.2. Research Questions

In this section, I seek to elaborate on the core questions driving this inquiry, examining the complex interplay between philosophical perspectives, cognitive theories, and applied design methodologies. In the pursuit of a more profound understanding of Human-Computer Interactions (HCI) within the realm of eXtended Reality, this research is anchored in exploring the harmonious integration of 4E+ Cognition and spiritual wisdom.

This investigation is framed around questions that are designed to uncover new insights and real-world applications within the field of eXtended Reality. Together, the questions guided the exploration of how 4E+ Cognition and spiritual wisdom–namely perennial philosophy, Neoplatonism, and Illuminationism–converge. Thus, by emphasising an integrated approach that combines philosophical, ethical, and cognitive perspectives with innovative technology, the research aimed to answer the following central question and its three sub-questions:

How can integrating 4E+ Cognition and spiritual wisdom in eXtended Reality inform holistic experience and interaction design for enhanced cognitive, emotional, and spiritual engagement?

a. *What kind of design principles might emerge from a practice-oriented exploration of 4E+ interaction in XR artefacts?*

b. *How can interaction in XR be designed to effectively reflect and incorporate ethical, cultural, and philosophical considerations?*

c. *What are the potential impacts and future implications of these integrated design approaches on the evolution of Human-Computer Interaction in XR technologies?*

The sub questions were selected to provide a comprehensive exploration of the core research themes. Each sub-question delves into specific aspects of XR design, ensuring a thorough understanding:

a. ***Emergence of Design Principles:*** The first sub-question revolves around the discovery of design principles through a practice-based exploration in XR. It probes the potential for new methodologies and guidelines to surface when the theoretical frameworks of Ishraq Hikmah and 4E+ Cognition are applied practically within XR environments.

b. ***Incorporating Ethical, Cultural, and Philosophical Considerations***: The second sub-question addresses the integration of ethical, cultural, and philosophical elements into XR design. This part of the inquiry is crucial for ensuring that the developed XR experiences are not only technologically advanced but also culturally sensitive and ethically sound.

c. ***Impact on Human-Computer Interaction Evolution***: Finally, this subquestion looks at the larger significance of the study. It explores how the confluence of these philosophies and cognitive theories within XR could shape the future of HCI, potentially leading to more immersive, intuitive, and meaningful user experiences.

The exploration of these questions holds the potential for both academic enrichment and tangible contributions to the fields of HCI, XR, and cognitive philosophy. By answering these questions, this research aims to bridge gaps between theoretical knowledge and hands-on application, paving the way for a future where technology is intertwined with human cognition, interaction, and cultural landscapes. This integration of spiritual wisdom and cutting-edge technology has the potential to reshape how we interact with digital virtual environments, making them more intuitive and meaningful. This approach envisions a future where technology is innovative and deeply intertwined with the human experience.

1.3. The Transdisciplinary Nature of this Research

This research is grounded in a transdisciplinary approach that transcends traditional academic boundaries, aligning with the evolving paradigms of the Fourth Industrial Revolution (4IR) and the growing complexity of contemporary knowledge. By integrating diverse disciplines, it advances the research itself and reflects the interconnected nature of modern technological and cognitive developments.

The methodology embraces the 4IR ethos, where the convergence of physical, digital, and biological domains requires a comprehensive understanding. This transdisciplinary approach is essential for addressing complex real-world issues, as it integrates both academic and non-academic knowledge systems. By fostering collaboration across various fields, the research ensures that ethical, cultural, and humanistic perspectives are integral to the innovation process, especially in the context of XR technology.

This research integrates concepts from cybernetics, digital art, and spiritual philosophy. It draws upon holistic epistemology, emphasising a top-down[9] approach in understanding complex systems, mirroring the dynamic, interconnected nature of 4IR technologies. The analogy here is that these technologies, akin to pieces of a dynamic Lego set, are creatively assembled to form systems that can solve larger and more complex problems.

By moving beyond traditional disciplinary confines, this transdisciplinary approach provides a framework for exploring how diverse technologies and cognitive theories can enhance Human-Computer Interaction in XR. The research contributes to academic discourse and also offers actionable solutions for the ethical and innovative application of emerging technologies in an increasingly interconnected world.

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[9] for more information on the Top-Down Emanation concept, refer to Chapter 4, Section 4.2.2, titled ‘Levels of Intelligibility and Cognitive Science’, on page 131 to 137.

1.4. The Nature of the Practice

This research adopts a practice-oriented methodology, combining practice-led research with research-led practice (Smith & Dean, 2009), to create and refine eXtended Reality artefacts. Central to this approach is the active design and development of XR artefacts, which serve as a medium to explore and expand upon foundational concepts. The study navigates between practice-driven experimentation and theory-guided development, ensuring that applied outcomes both inform and are informed by theoretical insights.

Adopting a practice-oriented approach, the study is conducted through practical projects, with the exegesis informed by these real-world applications. Digital artefacts and their production processes, developed through projects at AUT's AppLab and the researcher's personal endeavours, are central to this inquiry. This methodology emphasises the dynamic interaction between theory and practice, where practical experimentation informs the theoretical framework, and vice versa. The research embodies a cyclic process of discovery and learning through hands-on engagement with XR design, allowing for continuous refinement and evolution of both theoretical and practical insights.

As an artist and practitioner, my research unfolds within the creative process, guided by mystical concepts from Iranian-Islamic culture and a transcendental paradigm that values intuition and personal revelation. The study introduces design principles for technological application that emphasise holistic problem-solving, cultural considerations, and embodied interaction, aiming to create XR experiences that are immersive, meaningful, and resonant on cognitive and spiritual levels.

The research introduces new design principles for the application of XR technologies, with a focus on preventing disembodiment and alienation. These principles include holistic problem-solving, recognising XR as an independent medium, and considering affect, cultural nuances, physical and embodied interaction, sensory experience, immersion, contextual awareness, physical affordances, and emotional connection. By emphasising 4E+ Cognition, they offer users an immersive and meaningful experience, showcasing the potential of XR as an independent medium that fosters a symbiotic relationship between the user and the digital world. The XR artefacts developed in this study exemplify the integration of 4E+ Cognition, autopoiesis, endosymbiosis, and aspects of ancient philosophical wisdom into XR design. These artefacts, which range from interactive installations to digital environments, serve as practical manifestations of the theoretical concepts explored.

1.5. Introduction to Core Ideas

This research is anchored in a transdisciplinary approach that aims to fuse technological advancements with cultural, spiritual and philosophical insights. At its core, the study seeks to explore and develop a novel framework for HCI design by integrating the 4E+ Cognition approach with elements of philosophical and spiritual wisdom. The primary focus is on applying these principles within the emerging field of XR medium. The spiritual and philosophical foundation of this research is grounded in the phenomenological interpretations of perennial philosophy, with a particular emphasis on three key concepts. First, the Neoplatonic perspective on psycho-ontology[10]. Second, the epistemology of Ishraq Hikmah (Illuminationism) developed by Suhrawardi (1154–1191). Third, the concept of the Imaginal Realm (Mundus Imaginalis[11]), as elaborated by both Suhrawardi and Ibn Arabi (1165–1240) and further articulated by Henry Corbin (Landolt, 1999). These philosophical and spiritual traditions offer a deep ontological and epistemological framework that has been largely underexplored in contemporary HCI.

By bridging these ancient insights with modern cognitive theories, particularly Neoplatonism, this study aims to deepen our understanding of cognition. Neoplatonism, with its emphasis on the hierarchical structure of reality and the emanation of all existence

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[10] Neoplatonic framework integrate the concepts of psyche and ontology, viewing the psyche as the self and ontology as the study of being. In this framework, these elements are woven together, offering a holistic understanding of the individual's existence and experience. The Neoplatonic perspective envisions the psyche as a reflection of the ontological order, where the self's realisation is integrally tied to its participation in the hierarchy of being, ascending toward the One (Plotinus, *Enneads* VI.9, trans. Perl, 2013).

[11] Corbin developed his philosophical framework by drawing on Islamic philosophy, particularly the works of Suhrawardi (1154–1191) and Ibn Arabi (1165–1240), integrating their metaphysical and mystical insights.

from a singular source, serves as a crucial bridge between the metaphysical aspects of Irfan and the empirical approaches found in 4E+ Cognition. This synthesis highlights the dynamic interplay between mind, body, and broader ontological structures, enriching the application of 4E+ Cognition in XR design. The research posits that by integrating these diverse cognitive dimensions, XR technologies can be developed in a way that resonates on multiple levels—cognitively, emotionally, and contextually. This comprehensive framework not only supports the technical aspects of XR development but also ensures that these technologies are aligned with deeper cultural and spiritual values, thereby fostering more meaningful and immersive user experiences. Further elaboration on these key concepts is provided in Chapters 3 and 4, where the theoretical foundations and practical applications are discussed in greater detail and the full potential of this integrative approach in shaping the future of HCI and XR environments is explored.

1.6. Rationale

In technology design, reductionist and mechanistic paradigms have long dominated, focusing on breaking down complex systems into simpler components and emphasising efficiency, control, and predictability. This approach, while effective in certain contexts, often neglects the broader human and environmental implications, leading to designs that can be rigid, dehumanising, and unsustainable (Baxter & Sommerville, 2011; Stapleton et al., 2020).

Critics argue that this focus on reductionism overlooks the complexity and interconnectedness inherent in real-world systems, which can result in solutions that fail to address the underlying systemic issues (Flood, 2010; Martins, 2010). To counter these limitations, a growing movement advocates for more integrated and human-centred methodologies, such as the "ENRICHER" method, which promotes human-machine symbiosis and evolutionary development processes that value human knowledge alongside technological capabilities (Stapleton et al., 2020).

These limitations of the reductionist approach highlights the need for a paradigm shift towards more holistic, adaptive, and socially responsible design practices. By integrating principles of Neoplatonism and illuminationism into my research, I aim to bridge the gap between the ancient and the modern, exploring how contemporary technologies can be employed to facilitate experiences of illumination and insight.

This research explores the rapidly evolving domain of eXtended Reality and its user experience and interaction design, with a focus on 4E+ Cognition. The increasing integration of ubiquitous computing, wearable devices, and x-realities into daily life underscores the human body's centrality in modern communication technology (Ita & Fuji, 2006; Shi et al., 2023; Want et al., 2002). These technologies are progressively becoming extensions of our body and mind, altering the nature of Human-Computer Interaction.

The core challenge in XR experience and interaction design lies in shifting from traditional third-person narratives to immersive first-person experiences. This paradigm shift necessitates a redefinition of embodiment in HCI, where interaction is no longer a unidirectional experience but a co-authored, bi-directional process. This research aims to explore this transformation, focusing on the design of intuitive interaction systems that foster co-creation between designers and users.

The 4IR has ushered in a technological landscape that is in constant flux, presenting unique challenges and opportunities in education and the workplace. This research seeks to address these challenges by developing navigation and interaction systems that are relevant, effective, and adapted to the evolving dynamics of digital environments.

1.7. Outcomes

Multiple works of literature suggest that an individual's worldview significantly influences their approach to problem-solving, a concept explored in the conversation between Maturana and von Foerster (The Matrix that Embeds - refer to American Society for Cybernetics - ASC, 2012; Pangaro, 2007). The shift from Cartesian reductionism and algorithmic thinking towards systemic, cybernetic, and embodied thinking was crucial to shaping the research design of my study.

My inquiry proposes design principles for application in the 4IR, with a focus on preventing disembodiment and alienation in next-generation HCI design. These principles emphasise holistic problem-solving, XR as an independent medium, and integrating affective, cultural, and embodied interaction. This framework encourages the creation of innovative XR technologies that are deeply in tune with human cognitive and cultural dimensions. This is done by making sure that sensory immersion, contextual awareness, physical affordances, and emotional connection can take place. The result is XR environments that are both immersive and meaningful.

The research makes a significant contribution to theoretical and practical aspects of Human-Computer Interaction. It generates innovative design solutions tailored to user needs, refined through iterative design, testing, and evaluation processes. The study produces design principles and guidelines based on empirical data, which can guide future HCI projects. Furthermore, the research is likely to offer new insights into user behaviour and technology interaction, which can be used to develop novel conceptual frameworks within HCI. It also introduces new evaluation metrics and tools to better assess the usability and impact of HCI technologies. In educational contexts, the outcomes could be used for the development of instructional materials that integrate HCI concepts, advancing pedagogical approaches in the field. These outcomes represent a comprehensive advancement in HCI, bridging the gap between theory and practice, and fostering the development of more effective, user-centred technologies.

1.8. Significance

One of the critical outcomes found during this study was the promotion of a stronger connection between the inner self and the physical environment in HCI design, counter to the prevailing trend in contemporary HCI that often leads to detachment from the body, reality, and the essence of human existence. This research presents innovative design principles derived from practical digital artefact creation, aiming to shape future interaction design within XR. By focusing on embodied interaction and the concept of extended cognition—where technological artefacts act as extensions of our minds and cognitive processes—this research showcases how XR can make digital content more immersive and impactful, enriching user experiences with affective dimensions.

This study resulted in a significant shift in the author's ontological perspective, moving away from a traditional Western epistemology and partial Cartesian duality towards a 4E+ cognitive framework that has the potential to integrate both Eastern and Western philosophical perspectives. Designers can adopt this perspective in their problem-solving and decision-making processes during the creation of complex XR projects. The exegesis presents a novel approach to problem-solving and enhances the experience design and interaction design of interactive immersive technologies, making it a valuable contribution to the field of creative technology. The improved thinking derived from this research also holds the potential to impact the practices of art and art research as well as real-world projects in the creative industry.

Further, this research has produced an essential outcome through the utilisation of game-related and emerging technologies in the gamification of cultural heritage. The goal was to establish an interactive experience that promotes engagement among younger generations, centred around ideas and viewpoints embedded in a specific cultural or philosophical perspective. The results demonstrate the potential for using technology to engage audiences in the preservation and critical promotion of cultural heritage. The virtualisation of cultural heritage into a game-like experience presents a unique opportunity to make the cultural experience more accessible and appealing to younger generations, thereby contributing to the preservation of cultural heritage for future generations.

Last but not least, the outcomes of this research are epistemological; the findings highlight the need to re-evaluate the traditional concept-based teaching methods and shift towards an embodied and experiential-based approach. This, in combination with the shift in the epistemological perspective from Cartesian duality to embodied cognition and autopoiesis philosophy, has the potential to bring about positive change across all educational fields.

1.9. Outline of the Exegesis

To provide a clear roadmap of the research journey and ensure coherence throughout the exploration of complex, interconnected ideas, the following outline will guide the reader through the structure of the exegesis. By offering an overview of the chapters and the thematic flow of the research, the outline helps establish a clear understanding of how each section builds upon the previous one, ensuring a smooth progression from theory to practice. It also assists the reader in navigating the transdisciplinary nature of the study and grasping how the philosophical, technological, and practical aspects are interwoven. The outline of the exegesis is as follows:

Chapter 1: Introduction

The chapter introduces the research questions, the context, and the importance of the study. It frames the investigation and sets the stage for the subsequent chapters. This chapter outlines the rationale and significance of the research, positioning the study as a transdisciplinary exploration that integrates technology, art, and philosophy.

Chapter 2: Positioning of the Research and the Researcher

In this chapter, the focus shifts to the personal and intellectual journey of the practitioner-researcher, detailing the cultural, educational, and philosophical influences that have shaped the research perspective. This chapter explores the researcher's identity, philosophical heritage, and the transition between different cultural and intellectual traditions, establishing the subjective framework through which the research is conducted.

Chapter 3: Contextual Review of Knowledge

This chapter presents a transdisciplinary review of the relevant literature, traversing fields such as technology, cognitive science, tacit knowledge, media studies, and philosophy. This chapter integrates technological advancements in XR with philosophical frameworks like 4E+ Cognition and Illuminationism, offering a multi-layered understanding of how knowledge across these fields informs the research.

Chapter 4: Design of the Study

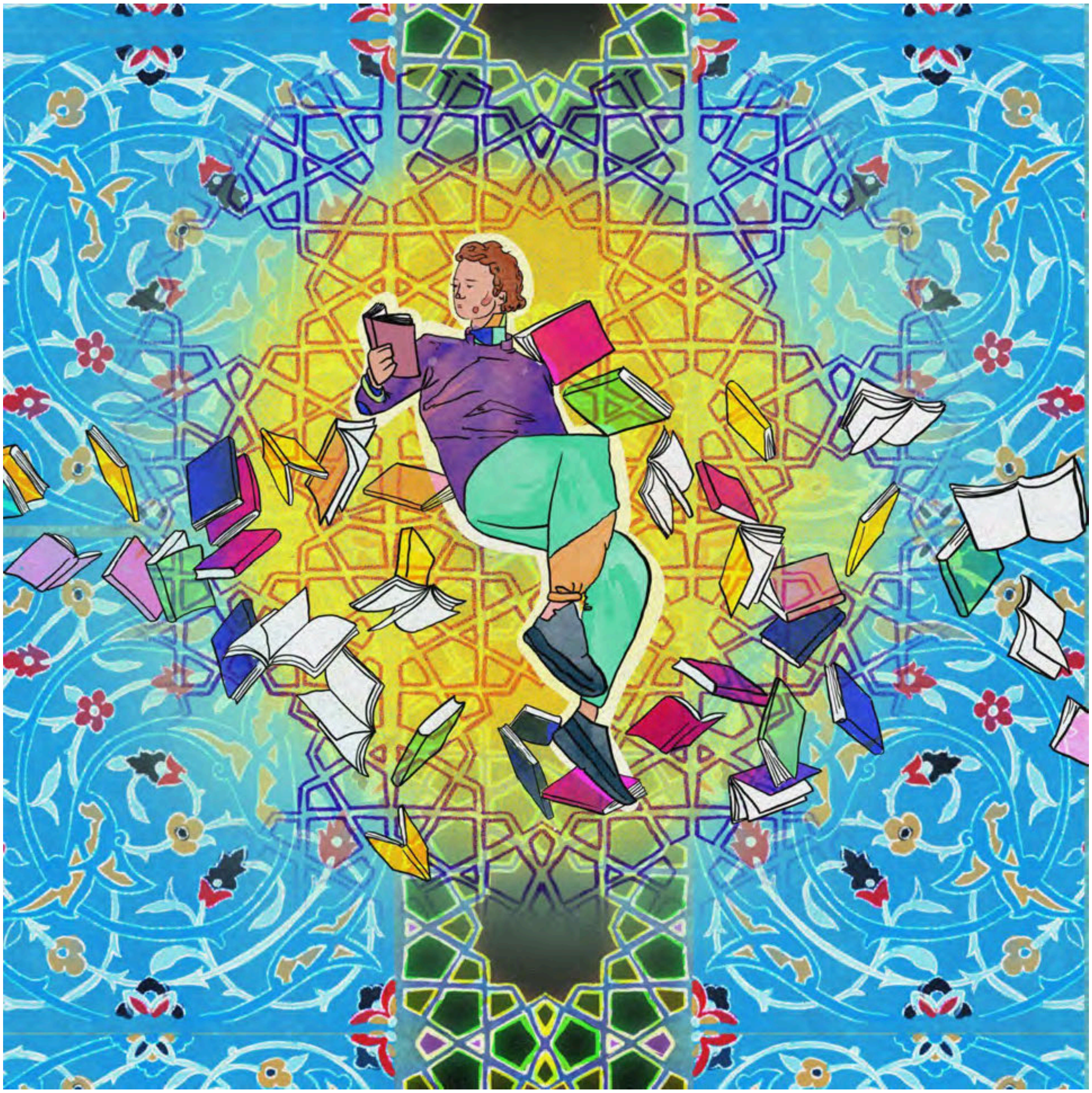
In chapter 4, the study's research design is explained in detail, including the philosophical and epistemological underpinnings that shape the research process. This chapter lays out the methods and approaches used to explore the research questions, combining practice-led and research-led methodologies within a transdisciplinary framework. It highlights the importance of integrating philosophical traditions, heuristic inquiry, and practical experimentation in the design of XR experiences.

Chapter 5: The Practice and Critical Commentary

This chapter explores the practical aspects of the research, critically examining the real-world applications and projects developed as part of the study. This chapter serves as a bridge between theory and practice, reflecting on how theoretical insights into cognition, interaction design, and cultural heritage are applied in XR design. Through practical projects, the research demonstrates how abstract concepts are translated into tangible outcomes, providing a critical analysis of the successes and challenges encountered.

Chapter 6: Conclusion

Finally, the conclusion summarises the key findings of the research, discussing the contributions made to the fields of XR, HCI, and embodied interaction design. This chapter reflects on the broader philosophical and technological implications of the study, acknowledging its limitations and proposing directions for future research. The conclusion also offers a personal reflection on the researcher’s growth, emphasising the significance of the transdisciplinary approach taken throughout the study.



Note. Illustration created by Zohreh Shirazi (2024) based on concepts by Ali Taheri. Copyright 2024 by Zohreh Shirazi and Ali Taheri. Reprinted with permission.

Chapter 2: Positioning of the Researcher and the Research

This chapter highlights the critical role of positionality in research, exploring how the researcher's identity and experiences shape the research process. The chapter begins with an introduction to the significance of positionality, grounding the discussion in relevant theoretical frameworks. It continues by positioning the researcher (myself) through an examination of identity, offering insights into my cultural roots and how Iranian traditions and values have shaped my worldview. It further explores into my philosophical and intellectual heritage, tracing the influence of both ancient wisdom and broader philosophical traditions. My educational background is also discussed, with a focus on the role of lifelong learning in shaping my approach to research. The chapter then transitions to themes of illumination, discussing personal and intellectual enlightenment. Additionally, it introduces the idea of an ontological transition, examining the shifts in my understanding of being and existence. By outlining this, I provide the necessary context for understanding the specific intellectual lens through which my work is approached. Finally, the chapter segues into positioning the research itself within the broader academic context, setting the stage for the exegesis.

2.1. Introduction

Bourke (2014) examined the significance of positionality in research, arguing that researchers must reflect on their own positions within the research process. Positionality refers to how a researcher's identity can influence their approach, methodology, and their interpretations. Hence, engaging in reflective practice is an essential part of research design, as it forces researchers to question their choices and critically examine their inherent subjectivities and preconceptions that influence their decisions (Schön, 1992/2017). This reflective practice fosters a continuous, dynamic dialogue between the researcher's personal perspectives and the subject of inquiry, as highlighted by Merriam and Tisdell (2015). Moreover, integrating personal experience with professional insights enhances the research process. This approach, as noted by Ngunjiri et al. (2010), leads to a more nuanced and meaningful engagement with academic discourse.

Drawing on Chavez's (2008) concept of insider positionality, this chapter presents an examination of the interplay between my personal history and academic endeavours. This analysis clarifies my approach, methodology, ontological-epistemological stance, and the rationale behind my interpretation of the findings. Incorporating cultural heritage, philosophical perspectives, and intellectual interests is vital for a comprehensive understanding of the research context. These elements leverage the author's unique experiences and enrich the investigation (Chavez, 2008).

Positioning the researcher (myself) within the study emphasises how my background influences my approach to research design and execution. Hence, I aim to weave both personal and professional insights into my research narrative. This approach ensures a balanced reflection of the complexities involved in practice-oriented research, integrating both personal and academic perspectives.

2.2. Birth and Identity - Positioning the researcher

In this first section, I discuss the nuances of my background, focusing on how my upbringing and identity have shaped the positioning of myself as a researcher. I explore my cultural roots, Iranian traditions, and values, which are integral to my understanding of identity and shape my Iranian heritage. Additionally, I reflect on how the philosophical and intellectual heritage and my educational background have informed my worldview. These elements collectively illuminate the origins of my research interests, the evolution of my methodological approaches, and the interpretative frameworks that guide my analysis.

The process of self-reflection is vital for several reasons. First, it aligns with Moustakas' (1990) heuristic research methodology, which emphasises the importance of the researcher's personal experience and identity in the creation of knowledge. This approach acknowledges that research is inherently subjective and influenced by the researcher's worldview (Bourke, 2014).

Second, it enhances transparency, allowing readers to understand the perspectives that shape the research, thus making the study more credible (Berger, 2015; Noble & Smith, 2015). Finally, heuristic research serves as a bridge between the personal and the universal, connecting my personal narrative to the broader quest for knowledge within my field. This connection offers a more nuanced understanding of the research topic (Douglass & Moustakas, 1985; Sela-Smith, 2002).

2.2.1. Cultural Roots

Born and raised in Tehran (Capital of Iran), I trace my roots back to *Mughar* (Figure 2.1), a village near Isfahan (Ancient Capital of Iran). Mughar has a rich historical background dating to the Sasanian era (224-651 AD), which has infused me with a deep sense of awe of Iran's cultural heritage. Mughar (Farsi مُغآر - موغار meaning the place of *Zoroastrian* worship) has influenced my cultural understanding and worldview.

Figure 2.1 - The map of the region with 'Mughar' pinned in the middle.
Note. Image © 2024 Google Earth. Data from © 2024 TerraMetrics, Map data © 2024 Google. Retrieved from https://earth.google.com/.

This village, located in the Mahabad District of Ardestan County within the Isfahan province, has long sustained itself through agriculture, reflecting a deep connection to the land. Sheep herding and poultry farming, along with horticultural activities, have played a central role in Mughar's economy. This reflects a traditional agrarian society where life is closely connected to the natural cycles of the land. The bond between the community and its herd is both economic and cultural, as the wool is used for traditional crafts like carpet and rug weaving.

The skill in carpet weaving, passed down through generations, demonstrates how deeply the community's livelihood is connected to its cultural practices. The Weaving history of carpets and their patterns in different regions of modern day Iran and beyond represent the concept of 'unity in multiplicity' where the craft pulls together different communities across a region.

Through this craft, the people could express their creativity and maintain a vital link to their cultural identity, weaving their stories into each thread. My personal connection to this craft is symbolised by the memory of my mother weaving a Persian carpet. This process intertwined daily life with artistic expression and preserved our cultural heritage. The rhythmic motion of her hands, the soft rustling of the wool, and the gradual emergence of a complex design were all reflections of the deep-seated traditions.

Growing up in a different location and regularly visiting Mughar, I observed firsthand how deeply intertwined the villagers' way of life was with their environment, culture, and worldview. These experiences highlighted for me the profound impact of the interaction between the environment and cognition, revealing how deeply culture and worldview are intertwined with the physical and social surroundings that shape daily life. For me, this revealed the intricate and complicated systems of how deeply culture and worldview are intertwined with the physical and social surroundings that shape daily life.

My experiences in Mughar, especially time spent with my grandfather in the village's lush gardens, further deepened my understanding of patience, harmony with nature, and the concepts of Hikmah (wisdom) and Barakah (divine blessing). These early lessons have informed my exploration of wisdom in my work, reminding me of the intrinsic connection between environment, heritage, and the wisdom passed down through generations.

Growing up immersed in this cultural environment, I absorbed values emphasising history, heritage, and cultural continuity—lived experiences that shaped my worldview. The essence of our origins, much like the unique aroma of Iranian saffron, remains potent when connected to its native soil. It serves as a reminder that our cultural roots, though carried far, are best nurtured by staying connected to where they first grew (Artistic interpretation of this is shown in Figure 2.2). This connection, both to place and heritage, allows us to reclaim and flourish in our true potential.

Figure 2.2 - The Story of Saffron.

This illustration visualises the importance of roots and origin in one's identity.

Note. Illustration by Zohreh Shirazi (2021) for this exegesis.

In the video titled Who am I? I explore my identity and positioning as a researcher. This reflective piece is an integral part of my research journey, helping me explore the personal and cultural factors that shape my academic perspective and approach. By articulating aspects of my identity, such as my cultural heritage, personal experiences, and intellectual growth, the video serves as a visual exploration of how these elements inform my research (refer to Figure 2.3). The video underscores the role of self-awareness and reflexivity in practice-oriented research, where the researcher's background and worldview actively shape the direction and outcomes of the study. The video serves both as a personal narrative and a methodological tool, grounding my research within the broader framework of identity, culture, and intellectual heritage.

Figure 2.3 - Identity.

This illustrates my life events and aspects of my character.

Note. Illustrated by Zohreh Shirazi (2020) for this exegesis. Copyright 2020 by Zohreh Shirazi.

Watch the '*who am I?'* video here: https://vimeo.com/1008354565 or Who am I? .

2.2.2. Iranian Traditions and Values

The core Iranian values of hospitality, respect for elders, and emphasis on family ties have been influencing my thought process. Hospitality (مهمان نوازی) is ingrained in the social fabric of Iran, often described as an act of cultural pride that transcends mere generosity, symbolising community cohesion and mutual respect (Seyfi et al., 2021; Simpson-Hebert, 1987). This value, combined with the deep reverence for elders, exemplifies a societal structure that places significant weight on intergenerational wisdom, seen as crucial for maintaining familial and societal continuity (Cheraghi et al., 2015; Dortaj & Daneshpayeh, 2022).

Cultural celebrations like NowRuz (نوروز) and Yaldā/Chella Night (شب یَلدا یا شب چلّه), rooted in Zoroastrian traditions, are more than festive occasions; they are moments of reflection and familial bonding. NowRuz, marking the Persian New Year, symbolises renewal and the cycles of life. It has taught me the significance of continuity and change, as it represents the eternal renewal of nature and human life (Boyce, 2009; Zamani-Farahani, 2013). Similarly, Yalda Night, which celebrates the triumph of light over darkness on the winter solstice, instils a sense of hope and perseverance—qualities essential in the often challenging journey of academic research (Jassim, 2024; Lyden, 2020). These moments are steeped in both Zoroastrian and Islamic heritage, serving as windows into the Iranian spirit of kinship, respect, and joy (Foltz, 2013).

Art, poetry, and literature are deeply embedded in the daily life of Iranians. Intricate carpets and handcrafted items can be found in almost every home. Iranians often use poetry and literary expressions to communicate complex ideas succinctly. Furthermore, Iranian families place an immense value on education, reflecting the cultural emphasis on the pursuit of knowledge. This commitment is deeply embedded in both Zoroastrian and Islamic teachings, where seeking knowledge is seen as a spiritual obligation. Such a cultural backdrop has driven my commitment to academic excellence and intellectual curiosity, fostering a sense of responsibility that actively shapes my research. It ensures that cultural sensitivity and ethical reflection remain central to my research methodology, aligning with the rich intellectual traditions of Iran.

2.2.3. Philosophical and Intellectual Heritage

My research is passionately rooted in the intellectual heritage of Iran, weaving together ancient Persian philosophy, Zoroastrian principles, and insights from the Islamic Golden Age with contemporary thought. Central to this is the concept of unity in multiplicity (Illustrated in Figure 2.4 and 2.5), a recurring theme in Iranian philosophy that aligns with my pursuit of a holistic understanding in my studies. *The Conference of the Birds* (منطق الطیر, written in 1177 by ʿAṭṭār of Nishapur, 1145-1221) vividly illustrates this principle. The birds' journey leads them to realise that they collectively embody the *Simurgh*[12] (Illustrated in Figure 2.5), symbolising unity found within diversity—a concept that shapes my research approach (Attar, 1177/1984).

Suhrawardi (1154-1191), the founder of the Illuminationist school, is a pivotal figure in this intellectual tradition. He seamlessly blends pre-Islamic and Islamic wisdom, preserving ancient knowledge while developing a new philosophical system that emphasises inner illumination and spiritual insight. This synthesis of diverse intellectual traditions is foundational to my research methodology, as I strive to integrate various perspectives to achieve a more comprehensive understanding of complex issues.

Rumi's teachings (1207-1273)[13] further inspire my work, particularly his ideas on transformation and enlightenment, which echo the themes of self-discovery and self-though philosophy. Just as the birds in Attar's poem seek their sovereign outside only to discover the divine lies within themselves, my research journey mirrors this process of internal discovery and the realisation that true understanding originates within.

[12] The Simurgh is a mythical bird in Persian mythology, often symbolising wisdom, unity, and transcendence. In Attar's *The Conference of the Birds*, the Simurgh represents the ultimate truth or divine essence that the birds seek on their spiritual journey. After overcoming numerous challenges, the remaining thirty birds realise that the Simurgh they were seeking is a reflection of themselves, thus highlighting the Sufi concept that divinity lies within. The name "Simurgh" itself plays on the Persian words si ("thirty") and murgh ("bird"), reinforcing the idea of unity through multiplicity. This profound allegory illustrates the mystical journey towards self-realisation and the interconnectedness of all beings.

[13] Rumi is called Mowlana مولانا in Persian literature, meaning 'our master'.

Figure 2.4 - The Concept of Unity in Multiplicity.

Note. Illustration created by Zohreh Shirazi (2021) based on concepts by Ali Taheri. Copyright 2021 by Zohreh Shirazi & Ali Taheri. Reprinted with permission.

Figure 2.5 - Si-murgh becoming Simurgh.

Note. Illustrated by Zohreh Shirazi (2019) based on existing concepts in the public domain. No copyright claimed.

Moreover, my work draws on the concept of perennial philosophy, a timeless body of knowledge that transcends cultural and historical boundaries and emphasises the fundamental unity of all existence. This wisdom, reflected in spiritual traditions such as Hinduism, Buddhism, Taoism, Sufism, and Western mystical traditions like Neoplatonism, underscores the idea of a single, underlying metaphysical reality (Beringer, 2006; Davar & Salamian, 2021; Huxley, 1945; R. H. Jones; 2022).

My personal history is not a separate entity from my professional aspirations; rather, it is intertwined with my academic pursuits. The values, traditions, and philosophical insights that have shaped my upbringing are deeply woven into the themes I explore. They shape the questions I raise and the methodologies I employ in my research, imbuing my work with a sense of continuity and purpose that bridges the past with contemporary inquiry.

My cultural, familial, and intellectual heritage forms the foundation of my research perspective, shaping how I explore and understand the complexities of reality and human experience through my work. This heritage provides a glimpse into the various elements that influence my work, offering a transparent and reflective account of the lens through which I view my research. By drawing on my cultural background, I am able to integrate historical and philosophical insights into modern contexts, creating a research approach that is both grounded in ancient wisdom and adaptable to contemporary challenges. This holistic foundation allows me to view my work through a lens of continuity, bridging past intellectual traditions with present-day inquiry.

In summary, Iranian and the broader regional philosophical traditions, such as perennial ideas, Zoroastrianism, Islamic Hikmah, and Sufism, combined with the synthesis of pre-Islamic and Islamic thought exemplified by figures like Suhrawardi, have instilled in me a profound respect for my cultural heritage. It has also shaped my understanding of the intricate relationships between different knowledge systems. My background encourages me to search for interdisciplinary and transdisciplinary approaches that transcend narrow academic boundaries.

2.2.4. Educational Background - Lifelong Learning

My educational trajectory and the synthesis of various disciplines into my research paradigm and methodology are significantly influenced by the polymath culture in which I was raised. This reflects a tradition of holistic inquiry that dates back to the ancient wisdom cultivated in Iran and its neighbouring regions. This cultural ethos, emphasising self-learning and lifelong education, has shaped my approach to knowledge acquisition, resonating with the epistemological practices of renowned scholars such as Ibn Sina (known in the West as Avicenna, 980-1037) and Ibn Tufail (1105-1185). Their works, both named, 'Ḥayy ibn Yaqẓān'[14], written in early 11 and 12 century, serve as seminal texts that underscore the value of autodidacticism[15] and the pursuit of wisdom through a blend of empirical observation and philosophical contemplation (Elmarsafy, 2009; Goodman 2005; Goodman, 2013; Gutas, 2014).

The self-taught philosopher's journey (Ḥayy ibn Yaqẓān by Ibn Tufail) was one of the highlights of and mentored me towards enlightenment and understanding. This story, transcending mere allegory, offers profound insights into the process of intellectual discovery and the synthesis of knowledge across diverse realms. Inspired by these figures, my research approach is imbued with a similar quest for innovation, seeking to merge visuals with the transcendental in the creation of meaningful digital experiences.

This interdisciplinary and transdisciplinary attitude can be seen in my academic background. My diverse educational foundation has provided me with a unique methodological perspective, enabling me to explore eXtended Reality technology and Human-Computer Interaction from various perspectives. This includes artistic, technological, philosophical, and scientific viewpoints. A deep narrative and aesthetic sensibilities honed through my studies in filmmaking and photography, combined with the analytical rigour derived from engineering and computer science, facilitate a comprehensive approach to technological design that is both innovative and affective.

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[14] Arabic: حي بن يقظان, lit. 'Alive son of Awake'; also known as The Self-Taught Philosopher.

[15] The process of self-directed learning

Beyond formal education, my dedication to lifelong learning has propelled me into a myriad of hobbies and interests that further inform my research. From photography and videography to the exploration of electronic boards, embedded systems, and XR technology, projection mapping, and 3D interaction design, these pursuits are integral to my academic inquiry. These interests embody the spirit of exploration and innovation that was prevalent among polymath scholars in the past, who often ventured beyond the boundaries of their immediate fields to seek knowledge in its most expansive form.

Figure 2.6 - The Polymath

This illustrates my lifelong learning interests, highlighting the two aspects of heart (emotion) and logic (reason) in my epistemological stance.

Note. Illustrated by Zohreh Shirazi (2020) for this exegesis. Copyright 2020 by Zohreh Shirazi.

In essence, my educational background and approach to research are intertwined with the intellectual traditions of perennial philosophy, drawing upon the heritage of polymathy and the pursuit of knowledge across disciplines. By embracing the principles of autodidacticism and transdisciplinary exploration, I aim to contribute to the fields of Human-Computer Interaction (HCI) and immersive interactive media.

2.3. Illumination

The Ishraqi (illuminationist) tradition in Iran, a philosophical movement originating in the 12th century with the work of Shahab al-Din Suhrawardi, has influenced both my personal worldview and my research. This tradition, known as *Ishraq* or *Illuminationism*, posits light as the fundamental reality, symbolising knowledge, consciousness, and the divine. It represents a shift from the purely abstract metaphysics of earlier Islamic philosophy to a more experiential and intuitive approach to understanding the nature of being and the cosmos. In Illuminationism tradition, light is not merely a physical phenomenon but a metaphysical principle that underpins all existence, representing the continuous emanation of divine wisdom. The emphasis on light as both a metaphysical principle and a symbol of divine illumination has deep roots in Iranian culture and thought, resonating with the broader spiritual and philosophical heritage of the region.

Personal Impact: My engagement with the illuminationist tradition has been transformative, offering a lens through which to view knowledge and existence that transcends the limitations of empirical observation and logical deduction. This perspective has nurtured in me an appreciation for the mystical and intangible aspects of reality, encouraging a holistic approach to understanding the world that encompasses both the seen and the unseen. It has instilled a sense of wonder and curiosity, driving me to explore the intersections between technology, cognition, and spirituality in my work. Furthermore, this engagement has profoundly transformed my structural-functional organisation, reshaping the way I approach and integrate diverse systems of thought. It has inspired a deeper alignment between my intellectual pursuits and personal values, fostering a balance between analytical precision and intuitive insight in both my research and daily life.

Influence on Research: In the context of my research, the illuminationist tradition has been influential in shaping my approach to exploring 4E+ Cognition and spiritual knowledge within the realm of eXtended Reality (XR) interaction design. The tradition's emphasis on light as a metaphor for knowledge and insight has direct parallels in the immersive environments created by XR technologies, where light and visual perception play central roles in shaping user experience. This philosophical framework has inspired me to consider how XR can be designed to augment physical reality while enriching our understanding of and engagement with the metaphysical aspects of existence.

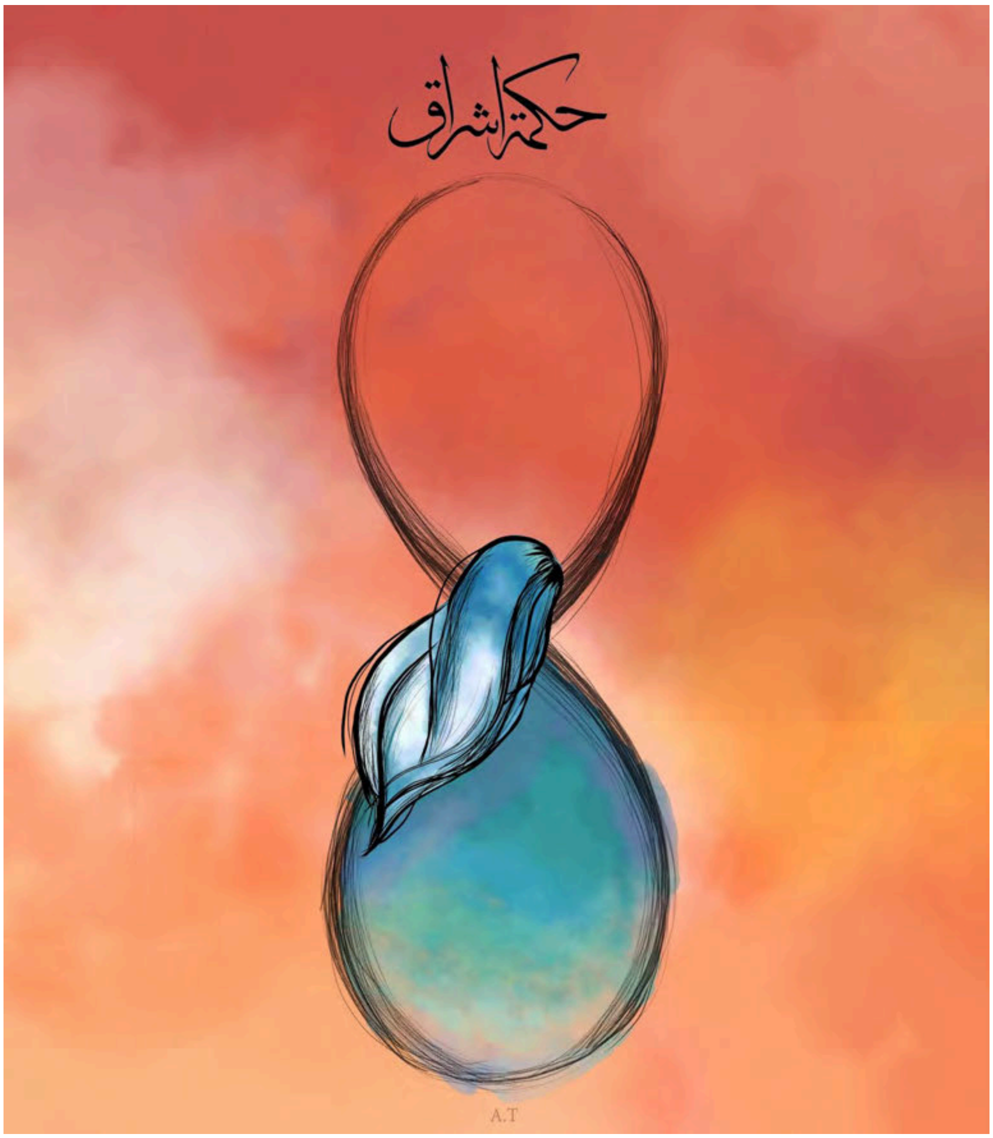

Figure 2.7 - Illuminationism (Ishraq Hikmah) and Sufi Dance.

This figure visualises the concept of Illuminationism with the Sufi dance, using the infinity sign to reflect the harmonious flow of body movements and the boundless nature of Sufi wisdom.

Note. Illustration by Zohreh Shirazi (2019) based on concepts by Ali Taheri, created for this exegesis. Copyright 2021 by Zohreh Shirazi & Ali Taheri. Reprinted with permission.

By getting inspired by the principles of Neoplatonism and illuminationism into my research, I aim to bridge the gap between the ancient and the modern, exploring how contemporary technologies can be employed to facilitate experiences of illumination and insight. This involves designing XR experiences that are immersive and engaging from a sensory perspective, while also being meaningful.

The approach aligns with the principles discussed in the LINK 2021 Conference presentations (Taheri & Aguayo, 2021), where the focus was on creating embodied immersive designs that promote experience-based learning and self-illumination. The integration of these concepts within XR design enhances user engagement while fostering a deeper understanding of one's relationship with the environment and the cosmos, resonating with the philosophical foundations of illuminationism and 4E Cognition.

The holistic worldview promoted by the illuminationist tradition challenges the reductionist and mechanistic paradigms that often dominate technology design. It advocates for a more integrated approach that considers the emotional, spiritual, and cognitive dimensions of human experience. In my work, this has translated into a commitment to creating XR interactions and experiences that are not only technically innovative but also spiritually and philosophically enriching, offering users opportunities for reflection, insight, and illumination.

In summary, the illuminationist tradition of Iran has profoundly impacted both my personal development and my academic research. It has provided a philosophical foundation for exploring the potential of XR technologies to create meaningful, enriching experiences that transcend the boundaries of the physical world, inviting users into a deeper engagement with the metaphysical dimensions of existence.

2.4. Aotearoa

In the initial phase of my PhD at the Auckland University of Technology's School of Art and Design (2018-2019), I realised that modern society’s shift of its cultural essence into the digital realm has led to a significant disconnection, where wisdom and knowledge are increasingly separated from the individual’s heart and mind. While digital storage offers a way to archive cultural information, it lacks the emotional and experiential connections that are vital to truly preserving knowledge.

Incorporating cultural elements into digital, interactive, and experience-driven platforms like XR enhances the authenticity and emotional richness of these technologies. Engaging with culturally infused content allows users to forge a deeper connection with the experience, fostering greater empathy, affect, understanding, and appreciation for cultural depth (Kalantzis & Cope, 2012). This aligns with the goals of my research, which seeks to explore how we can create immersive experiences that go beyond mere entertainment and distraction and foster meaningful human connections and affective understanding.

Furthermore, It allows for the adaptation and reinterpretation of ancient practices in ways that resonate with contemporary audiences, ensuring that these traditions remain relevant and continue to evolve. This dynamic preservation is crucial for the survival of cultural practices in a rapidly changing world and supports the argument that heritage is not static but rather a continuously evolving process (Harvey, 2001; Lowenthal, 2015).

In my time living in Aotearoa, I experienced a profound cultural transformation that deepened my connection to my roots and increased my appreciation for traditions. Initially focused on the technological aspects of interactive media, my research shifted towards understanding the importance of cultural heritage. My cultural awareness deepened through my involvement in culturally significant projects at AUT AppLab which is homed in the Faculty of Māori & Indigenous Development, Te Ara Poutama. My work with AppLab strengthened my commitment to cultural preservation and promotion.

Figure 2.8 - Aotearoa

This figure illustrates me arriving in carrying my heart and mind in each hand.

Note. Illustration by Zohreh Shirazi (2020) based on concepts by Ali Taheri, created for this exegesis. Copyright 2020 by Zohreh Shirazi & Ali Taheri. Reprinted with permission.

Reflecting on my journey, I recognise how my departure from my homeland, and the subsequent immersion in a foreign land, catalysed an awakening of my cultural consciousness (Figure 2.8). This introspection was further deepened by the realisation that modern technological advancements often lead to the erosion of cultural practices and wisdom.

The loss of these cultural elements not only diminishes historical knowledge but also severs connections to the spiritual and intellectual foundations that have shaped societies for centuries. This erosion of cultural heritage further increases the growing struggle of individuals and communities to find purpose and connection in a rapidly changing world, further exacerbating the disconnection from the profound wisdom and traditions that have long provided a sense of identity and continuity.

The experiences I encountered in Aotearoa, specifically in relation to Māori culture, have enriched my understanding of cultural preservation. They have also highlighted the importance of reconnecting with one's roots and integrating this wisdom into contemporary contexts. This journey has woven together my passions for technology, art, and cultural heritage, fuelling my commitment to using technology as a means to reconnect with our global cultural family and to help build a wiser, more enlightened future.

2.5. The Ontological Transition

Throughout my academic and personal journey, I have undergone a significant ontological shift, moving from a Cartesian dualistic worldview, which separates mind and body, to a more integrated and holistic understanding of human cognition. This transformation is informed by concepts such as autopoiesis, embodied cognition, the 4E+ Cognition framework, Neoplatonism, and perennial philosophy, which emphasise the interconnectedness of mind, body, culture, and environment. This shift has enriched my perspective and expanded my awareness of diverse ontological and epistemological views, shaping my approach to research and design.

During my research in Aotearoa New Zealand, especially during the isolation brought on by the COVID-19 pandemic, I found myself confronting profound shifts in my understanding of self, knowledge, and the interconnectedness of existence, which deeply influenced the direction and depth of my work. This transformation was driven by the experience of being away from home, immersed in the diverse cultural landscape of

Aotearoa, and navigating the unprecedented global upheaval caused by the pandemic while trying to make progress with my research.

The physical and psychological isolation I experienced during the pandemic, compounded by the geographical and cultural distance from my homeland, mirrored the situation of the main character in the classic philosophical tale of Ḥayy ibn Yaqẓān. Like Ḥayy, who finds himself alone on an isolated island, forced to seek understanding and meaning through introspection and observation, I too was driven to explore deeper layers of my identity, spirituality, and connection to the world around me. This period of solitude became a catalyst for profound self-reflection, leading me to draw parallels between my own journey and Ḥayy's quest for knowledge and enlightenment, ultimately shaping the direction of my research and personal growth.

This period of solitude and self-reflection became a crucible for my ontological transformation, echoing Clark E. Moustakas' (1961/2016) insights on loneliness as "a condition of human life, an experience of being human which enables the individual to sustain, extend, and deepen his humanity" (p. xi). Moustakas (1961/2016) suggested that loneliness, far from being just a state of despair, can be a transformative experience, fostering self-discovery and growth. During this time, the solitude heightened my awareness of internal processes while underscoring the crucial role of external interactions in shaping identity and understanding. This blend of internal reflection and external influence led to a profound realisation of the dynamic interplay between self and the world, further reinforcing my shift away from Cartesian dualism.

The cultural environment in Aotearoa, which places a strong emphasis on community and collective well-being, sharply contrasted with the individualistic and mechanistic views I had developed over time. Despite Iran's rich cultural and philosophical heritage, my upbringing in the urban, globalised environment of Tehran Metropolitan increasingly aligned me with Western individualism and Cartesian thinking. This shift was further reinforced by the pressures of modern education and the fast-paced, competitive nature of urban life. This shift in perspective, shaped by the demands of my environment and societal expectations, gradually distanced me from the communal values that are integral to Iranian culture, replacing them with a more self-centred and analytical approach to life. My experience in Aotearoa reignited and deepened my understanding of cognition and existence as being fundamentally embedded and enacted within one's environment. While these insights were present in my earlier reflections, it was the community-oriented values I encountered in Aotearoa that brought them back to the forefront. Hence, shaping my ontological shift and enriching my perspective on how deeply interconnected human existence is with its surroundings. This shift aligns with the principles of embodied cognition articulated by Varela et al. (1991), who emphasised that cognition is not merely a process occurring within the mind but is fundamentally shaped by our physical and social interactions with the world around us.

The global crisis underscored the limitations of traditional HCI models that often ignore the embodied and situated nature of human experience. The reliance on digital technologies for connection during this time highlighted the extended aspect of cognition—how our minds extend beyond our brains to include the devices and technologies we use. This realisation was pivotal in my transition to embracing 4E+ Cognition as a framework for understanding and designing HCI, especially within the context of XR technologies, which encompasses embodied, embedded, enactive, extended (i.e., the four ‘E’s of cognition), and emotional aspects of cognition (i.e., the ‘+’ component complementing the 4E approach into 4E+ Cognition) (Aguayo, 2023).

My exploration of autopoiesis and embodied cognition naturally extended into the broader framework of 4E+ Cognition. This framework offers a comprehensive lens through which to view human cognition and interaction as it emphasises the interconnection of mind, body, culture and environment (Newen et al., 2018). It underscores the limitation of traditional HCI approaches that often neglect these dimensions, highlighting the potential for XR technologies to create more holistic and meaningful interactions by leveraging the full spectrum of human cognitive and emotional capabilities.

As I go further into these transformative experiences, each 'E' of the 4E+ approach becomes increasingly relevant. The embodied aspect highlights how cognition is shaped by our physical bodies and interactions with the world. The embedded dimension emphasises the influence of our environment and social context on cognitive processes. The enacted aspect reflects the active role we play in shaping our cognitive experiences through our actions. The extended component underscores how our cognitive processes extend to the tools and technologies we use, while the affective element considers the emotional dimensions of cognition. Together, these principles form a holistic framework that positions cognition as an intricate interplay between the individual, their body, their environment, and their tools—a perspective that has shaped my research and its implications for XR design.

By moving beyond Cartesian reduction and algorithmic analytic thinking and embracing autopoiesis, 4E+ Cognition, and spiritual wisdom, I have acquired a more holistic understanding of human-technology interaction. This transition has enriched my theoretical knowledge and also informed my practical work, enabling the creation of XR experiences that better align with the complexities of human cognition. It has opened new pathways for innovation in HCI, fostering designs that are more empathetic, inclusive, and effective in bridging the gap between humans and technology. This requisite transformation has fundamentally affected my structural-functional organisation (my being) concerning intellect and epistemology. This reorganisation allows me to navigate and synthesise diverse frameworks with greater coherence, enabling a better engagement with both theoretical paradigms and practical applications in my field.

2.6. Into the Exegesis - Positioning the Research

Positioning the research within the exegesis requires a deliberate and reflective understanding of how the study situates itself within the broader academic discourse, its relevance, and its potential contributions. This section delineates the theoretical and methodological foundations of the research while critically engaging with the researcher's positionality and its influence on the research trajectory, framing, and outcomes.

This section positions the research within the exegesis by articulating—systematically and explicitly—my role as an academic–researcher and the methodological architecture through which the study generated knowledge. It responds to the core concern that emerged in the oral examination: that the thesis requires a clear, thorough account of methodology and method, including alternative methodological routes considered and why they were not ultimately chosen.

The thesis sits at the intersection of Human–Computer Interaction, eXtended reality, creative practice research, and philosophical inquiry. The central concern is not only how XR systems function, but how XR can be designed as a distinct medium for meaningful experience—an arena in which perception, action, affect, and cultural significance become entangled in ways that exceed conventional interaction paradigms (McCarthy & Wright, 2004). This motivates a research design that can support both the production of artefacts and the articulation of transferable knowledge from practice.

The goal of this research is to develop a design framework that harnesses the capabilities of recent XR technologies while integrating cultural and philosophical insights. Additionally, it explores the practical applications and potential impact of incorporating the 4E+ Cognition model in designing experiences and Human-Computer Interactions for XR. This is achieved by proposing a set of design principles informed by best practices and tailored to the unique demands of this emerging field of HCI.

Paradigmatically, the research is fundamentally rooted in the unity of intellect and Illuminationism, drawing on Neoplatonic levels of intelligibility and 4E+ Cognition theories. This transdisciplinary approach blends artistic inquiry with practice-oriented research to investigate how XR experiences can engage users cognitively while also fostering spiritual insights.

The methodology employed in this study is holistic, integrating a heuristic and illuminationist (Ishraqi) approach to understand the potential of XR as an immersive, experience-based medium. This illuminationist heuristic methodology, combined with the principles of cybernetics (the art of steering), guides the exploration, allowing for dynamic adjustments and refinements as new insights are obtained.

Illuminationist wisdom underscores the value of direct, personal experience in the quest for truth, resonating with the experiential nature of XR, where users engage and internalise knowledge through immersive environments. By weaving 4E+, Neoplatonism, and illuminationism together, I strive to blend ancient wisdom with modern technology. This approach aspires to craft XR experiences that go beyond sensory immersion, offering profound opportunities for introspection, encouraging users to reflect on their place in the universe and their intrinsic connection to the cosmos.

The practice-oriented nature of this research is embedded in real-world projects, notably those developed at AUT's AppLab. Within this context, the AppLab was a supportive environment but more importantly an integral part of the research process. The AppLab offers a creative space where theoretical insights are translated into practical, tangible artefacts. These projects are themselves part of the research methodology, reflecting the iterative process of inquiry and the dynamic interplay between theory and practice.

By engaging with real-world challenges and opportunities, these projects provide a fertile ground for testing and refining the concepts of 4E+ Cognition and Illuminationism within emerging immersive technologies. The importance of real-world projects in practice-oriented research cannot be overstated. These projects serve as a bridge between theoretical exploration and practical application, allowing for the development of XR environments that are both innovative and grounded in the realities of user experience. The AppLab projects, which range from cultural heritage gamification to experience-based education, provide a fertile ground for testing and refining theoretical concepts.

These initiatives reflect the transdisciplinary and practice-oriented approach of the study, showcasing how the integration of 4E+ Cognition and philosophical perspectives can inform the design of XR environments and experiences. The artefacts created in these projects serve as the tangible embodiments of theoretical insights. They offer user experiences that are not only immersive but also cognitively, emotionally, and spiritually resonant, bridging the gap between digital environments and underlying philosophical principles.

Additionally, the research includes the development of XR applications aimed at preserving and revitalising cultural heritage. These applications use the immersive qualities of XR to allow users to experience and interact with historical and cultural content in ways that are both innovative and respectful. This work is grounded in the principles of digital preservation and cultural sensitivity, ensuring that the technology serves as a bridge between past and present, and not as a replacement of cultural memory.

By reflecting on the personal and professional experiences that shape this research, this exegesis illuminates the unique perspective the researcher (myself) brings to the study. This reflective synthesis contextualises the approach taken for this study and highlights the innovative contributions this research makes to the fields of HCI and XR medium, as well as the broader landscape of interactive design.

This research advances the field of creative technology by exploring how immersive technologies can deepen human experience. It underscores the value of embedding philosophical and cultural insights into technological innovation, advocating for a design approach that honours human cognition and spiritual wisdom. The study offers a framework to improve problem-solving and design processes within emerging interactive media, with potential applications in art, research, and industry. A key outcome is the effective use of interactive platforms for gamifying cultural and natural heritage, aiming to engage younger audiences with diverse cultural and philosophical perspectives.

In positioning the research, I frame the study within a humanistic HCI. This orientation aligns with accounts of third-wave HCI that emphasise lived experience, meaning, value, and situatedness beyond traditional task-centred paradigms (Bødker, 2006; Harrison, Tatar, & Sengers, 2007), and with humanistic HCI arguments that legitimise aesthetics, ethics, cultural meaning, and authorial stance as central objects of HCI research (Bardzell & Bardzell, 2016). Within this frame, the thesis develops and defends an Ishraqi–Heuristic methodology: a practice-oriented, philosophically grounded research design that uses iterative artefact-making, reflexive capture, and cross-case synthesis to generate design principles for XR.

The section proceeds as follows. I first position myself as an academic–researcher and explain how that positionality shaped the study. I then articulate the research paradigm (ontology and epistemology) that anchors methodological decisions. Next, I describe the methodology and methods in detail, with particular emphasis on the two-tier epistemic movement that structures the research process: top-down emanation (imaginal orientation) and bottom-up emergence (constraint-driven correction). I then explain how this approach generates academic knowledge. Finally, I discuss alternative methodological approaches explored during the doctorate and provide reasoned grounds for not adopting them as the primary methodological frame.

Positioning Myself as Academic–Researcher

My academic trajectory began in mathematics and physics, continued into electrical engineering and computer science, and then, around the age of twenty, pivoted decisively towards philosophy and storytelling. This shift was not a rejection of rigour. It was a search for a form of inquiry capable of approaching meaning, not only mechanism. I found that cinematic art, and later interactive media, offered such a space: a place where inquiry could be embodied, affective, symbolic, and dialogical.

The starting point of this PhD was an exploration of experimental VR documentaries. That early work drew heavily on my tacit knowledge of visual arts, editing grammar, cinematic rhythm, and aesthetic composition. Through it, I began asking a question that would eventually shape the entire doctorate: what does it mean to design affective experiences, rather than merely deliver information? This question shifted the centre of gravity of the research. It became increasingly clear to me that XR should not be understood as the future of cinema, nor as the future of gaming. It is its own medium, with its own logic of presence, agency, participation, and transformation.

My embedding in AppLab early in the doctoral journey ensured that this research would remain practice-oriented rather than hypothetical. Working on live projects in cultural, educational, and interactive settings meant that ideas could be tested under real constraints: cultural responsibilities, stakeholder expectations, technical limitations, production budgets, collaborative processes, and audience needs. This mattered because it prevented the thesis from becoming a purely speculative philosophical exercise. Instead, philosophy had to earn its place by shaping design decisions in actual projects. In this capacity, I do not occupy the stance of a detached observer, instead, I operate as a reflective designer-researcher for whom practice is not a mere object of description but a mode of knowledge production (Schön, 1983; Smith & Dean, 2009).

At the same time, my artistic background—my love of cinema, poetic videogames, symbolic narrative, and immersive storytelling—shaped the way I approached inquiry itself. The heart of the thesis lies in experience design and interaction design. Philosophy, cognitive science, technology, and media theory serve as transdisciplinary bridges that deepen design thinking, rather than as ends in themselves. My role as academic–researcher in this study is therefore not to stand outside the process as a detached observer, but to act as a reflective designer-researcher whose making, sensing, interpretation, and critical judgement are part of the research instrument.

This positionality matters because the thesis's epistemic stance treats the self as internal to knowing and the methodology employed here assumes that the researcher is not external to the production of knowledge. My inner stance, attentional habits, philosophical commitments, and tacit capacities are not private background material; they are part of the epistemic conditions under which the work unfolds.

Ways of Doing: Positioning the Research

Positioning the research within the exegesis requires a deliberate and reflective account of how the study situates itself within wider academic discourse, how it understands its own relevance, and how it claims to generate new knowledge. This thesis is located at the intersection of Human–Computer Interaction (HCI), XR design, creative practice research, and philosophical inquiry. Its central aim is to develop a design framework for XR that draws not only on recent technological capabilities, but also on cultural, ethical, and philosophical insight—particularly through the integration of 4E+ cognition and spiritual wisdom traditions.

The immediate goal of the research is to investigate how XR can be designed as a medium of meaningful experience rather than simply as a vehicle for information, novelty, or simulation. More specifically, it explores how 4E+ cognition can inform the design of immersive interactions that are cognitively, emotionally, culturally, and spiritually resonant. From this, it seeks to articulate design principles that may support a more holistic account of experience and interaction design in XR.

This places the study within a humanistic HCI orientation. Rather than treating HCI solely as a discipline of efficiency, utility, or optimisation, the thesis deploys humanistic epistemologies and methodologies—including conceptual analysis, critical reflection on design processes, philosophical framing, and emancipatory critique—in service of design practice and HCI knowledge-making (Bardzell & Bardzell, 2016). In that sense, the thesis does not reject HCI; it expands it. It asks what HCI becomes when it takes seriously embodiment, affect, meaning, beauty, cultural context, and the formation of the self. This moves the thesis into what is often called third-wave HCI: an HCI orientation concerned with experience, meaning, values, and situated cultural practice (Bødker, 2006; Harrison et al., 2007).

On one side lies the mainstream positivist or quasi-positivist approach, where knowledge is often tied to measurable outcomes, procedural validation, and generalisable intervention logic. On the other lies purely interpretive or critical work that may offer powerful analysis but remains distant from the design of actual artefacts. My approach occupies a third space: design as inquiry, where artefacts, creative processes, and philosophical reflection operate together as mutually informing modes of thought. Here, the artefact is not merely an output, nor is theory a detached commentary. Each becomes part of the research process.

The practice-oriented nature of the project is therefore not incidental. It is central. Much of the work was embedded in real-world projects, especially within AUT's AppLab, where theoretical claims could be tested through actual design and production rather than hypothetical speculation. In this context, AppLab functioned not merely as a supportive environment but as an integral part of the research process: a site where theory became design, and design in turn generated reflection.

This methodological orientation is consistent with established arguments in Research-through-Design and related practice-oriented traditions, which claim that the making of artefacts can function as inquiry, and that knowledge may emerge through iterative cycles of design, reflection, and articulation (Gaver, 2012; Zimmerman, Forlizzi, & Evenson, 2007). It is also consistent with broader practice-oriented research frameworks that formalise the reciprocal relationship between creative practice and scholarly investigation (Smith & Dean, 2009).

Research Paradigm: Ontology and Epistemology

The methodological architecture of this thesis follows from its research paradigm. In other words, the method follows ontology and epistemology. At the most fundamental level, this research proceeds from the view—shared in different ways by Aristotle, Plato, Plotinus, Suhrawardi, and contemporary 4E+ cognition—that knowing is not merely representational. It is participatory, embodied, and often transformative.

4E+ Cognition and the Self as the Starting Point of Knowing

4E cognition argues that cognition is embodied, embedded, enacted, and extended; many contemporary accounts also emphasise affect as integral to sense-making (Varela, Thompson, & Rosch, 1991; Thompson, 2007; Gallagher, 2017). This framework reframes knowledge as emerging through active coupling between agent and environment rather than through detached internal representation alone. The self-in-the-world becomes foundational to intelligibility: what becomes meaningful depends on bodily capacities, situated contexts, enacted engagement, and affective attunement.

The 4E+ framework provides an important contemporary foundation for this thesis. It rejects the picture of mind as a detached internal processor that simply constructs representations of an external world. Instead, it understands cognition as something that happens through active engagement between agent and environment. Meaning is not merely “in the head”; it emerges in the dynamic relation between body, world, action, and affect.

This is philosophically significant because it foregrounds the role of the self in epistemology. The way one perceives, attends, feels, and acts is not secondary to knowledge; it is constitutive of it. In this sense, 4E+ cognition resonates strongly with Neoplatonic and Illuminationist perspectives: who we are is not external to how reality becomes intelligible. The self is not an obstacle to knowing that must be bracketed away; it is the locus through which intelligibility is disclosed.

Aristotle’s Conformity Account and Contact Epistemology

Aristotle’s account of knowing offers a critical contrast to the modern Cartesian model. In the Cartesian picture, the researcher is imagined as being “inside” the mind, while the world remains “outside”, accessible only through representations. Knowledge then becomes the assembly of internal pictures or conceptual postcards. This view creates a distance between knower and known.

Aristotle offers something different. To know, in the Aristotelian sense, is for knower and known to share the same form—to have a corresponding structural-functional organisation. In later scholastic language, this becomes *adequatio intellectus et rei*: the adequation of intellect and thing. On this account, knowing is not merely describing reality from afar; it is a kind of contact, conformity, or actualisation. One knows not only by representing, but by being able to participate in, actualise, or instantiate the relevant form.

While this thesis does not claim scholastic metaphysics wholesale, it draws from this contact-oriented orientation to knowing: deep understanding entails an ability to participate in or actualise the relevant structures, not merely to describe them. This aligns naturally with design inquiry; in a design-led inquiry, one does not only describe interaction. One makes it. Design becomes a mode of knowing precisely because making requires the designer to conform to the structural conditions of the experience being designed.

Anagoge and the Neoplatonic Transformation of Knowing

Plato's account of ascent (anagoge) offers a complementary dimension: the psyche can become better aligned, thereby disclosing deeper patterns in reality. Knowing is not only conformity at the level of representation; it is a movement of the psyche towards deeper alignment with reality. Plotinus, and the wider Neoplatonic tradition, weld Aristotle's conformity and Plato's ascent together. At lower levels, knowledge may still be representational; at higher levels, however, it becomes participatory and transformative.

In the *Enneads*, knowledge becomes progressively less representational as the soul ascends. At the highest level, Nous knows not by representing Forms but by being identical with them. This means that knowledge is not merely the possession of correct concepts. It is the transformation of the knower. One becomes more real by becoming more aligned with what is more real.

This notion is central to the thesis because it provides a philosophical language for understanding why design, when properly conceived, can be more than interface engineering. It can become a medium through which perception, action, and meaning are arranged so as to support deeper forms of attunement.

Suhrawardi and Knowledge by Presence

Suhrawardi's Illuminationist philosophy sharpens this insight through the distinction between *hussuli* knowledge (acquired, representational knowledge) and *hudhuri* knowledge (knowledge by presence). At lower levels, representational knowledge remains valid and necessary. At higher levels, however, true knowledge is immediate and luminous: one knows through direct participation in presence, not through holding an image or concept.

This is closely aligned with the Neoplatonic understanding that higher knowledge is non-representational and participatory. It also provides a crucial conceptual bridge to the methodology of this thesis, which seeks to preserve a place for direct, affective, tacit, and imaginal insight within a rigorous research process.

Rationality as Dialogical

A further paradigmatic implication is that rationality is dialogical. Rather than treating reason as the solitary manipulation of representations, the thesis treats rationality as a disciplined dialogue between intuition and critique, vision and constraint, top-down orientation and bottom-up correction. This dialogical rationality is particularly important in practice-based research, where the artefact "talks back" through resistance, failure, and emergent behaviour (Schön, 1983).

This is significant because the methodology employed in this study is not anti-rational; rather, it advances a broader and more rigorous conception of rationality. It requires that insight be generated, examined, refined, and articulated through an ongoing dialogue between philosophical reflection, academic inquiry, and practical engagement. This point is developed further in Chapter 4.2.4, Practice-Led Research and Research-Led Practice.

Intelligibility, Inner Alignment, and the Hermeneutic of Beauty

The paradigm outlined above also has consequences for how intelligibility itself is understood.

This thesis assumes that intelligibility is not simply the accumulation of more information. Rather, it depends on the proper proportioning of attention, salience, and inner alignment. When the self is disordered, what appears salient is often superficial, reactive, or fragmented. When the self becomes more ordered, deeper patterns become discernible.

One way of understanding this is through the three broad levels of the psyche: first, the urgent biological level oriented around pleasure, pain, and immediate reaction; second, the social and enculturated level oriented around honour, status, and group belonging; and third, the broader rational level capable of long-horizon understanding and reflective judgement. The task is not to deny these levels, but to bring them into proportion. When the higher rational orientation allies with the social and disciplining capacities of the second level, the more impulsive and fragmenting tendencies of the first level can be trained and integrated. As inner conflict decreases, salience becomes better proportioned to reality.

This is methodologically relevant because, in such a condition, one becomes better able to perceive real patterns and asymmetric dependence: to see that some phenomena depend on others for their intelligibility. This is what I mean by levels of intelligibility. It is also why beauty becomes more than surface appeal. In the Platonic sense, beauty is not mere smoothness, polish, or consumability. Beauty is what properly proportions appearance to underlying reality so that reality is disclosed through appearance. It draws one into depth.

This understanding informs the design orientation of the thesis. XR, as a medium of embodied and affective participation, can either reinforce superficial stimulation or cultivate deeper forms of attentional disclosure. The research aims at the latter. This is where the thesis locates its account of beauty as well; beauty is not treated as surface smoothness or consumable aesthetic pleasure. In a Platonic register, beauty is disclosure: the proper proportioning of appearance to reality such that reality becomes visible through appearance. In XR, where appearances are actively authored, design becomes a philosophical practice of shaping disclosure.

Methodology: The Ishraqi–Heuristic Approach

The methodology developed for this research is holistic, transdisciplinary, and practice-oriented. I describe it as an Ishraqi–Heuristic methodology: an illumination-guided heuristic inquiry that is cybernetically steered between theory and practice.

This methodology does not offer a fixed procedural recipe. Instead, it offers an intellectual and affective scaffold: a systematic way of thinking, sensing, making, testing, and reflecting that can be adapted to context. This is important. Artistic inquiry, especially in XR, resists full algorithmic reduction because it works with emergence, materiality, embodiment, affect, and symbolic form. A rigid protocol would under-sample precisely the dimensions the thesis seeks to investigate.

At the same time, the methodology is not vague. It is disciplined through a clear logic, a defined cycle of operations, explicit documentation practices, and transparent analysis. Its contribution lies not in offering a universal script, but in articulating a coherent stance and repeatable pattern of inquiry.

Methods Approach: Top-Down Emanation & Bottom-Up Emergence

The core approach in the methods is the deliberate alternation between top-down emanation and bottom-up emergence. This oscillation reflects the two-tier epistemology already outlined in the philosophical framework: higher-order participatory disclosure on the one hand, and lower-order representational adequation on the other.

Top-down (Emanation/Imaginal):

Top-down emanation refers to the process by which higher-order structures, orienting frameworks, and imaginal practices shape perception, ideation, and design formation. In the context of this thesis, it names a deliberately cultivated phase of inquiry in which I reduce the amount of detail and constraint taken in at the outset of a project so that premature bottom-up fixation does not foreclose imaginative possibility.

This is not carelessness. It is an epistemic technique. By temporarily bracketing excessive detail, the designer-researcher can quieten analytic clutter and allow the imaginal, metaphorical, affective, and philosophical core of an experience to emerge more fully. In this mode, the task is not yet to solve every practical constraint; it is to allow the “shape” of the experience—its ethical arc, aesthetic force, embodied rhythm, and affective disclosure—to present itself.

In practical terms, this phase involved forms of indwelling, contemplative orientation, intuitive sketching, storyboard work, conceptual prompts, empty-scene XR reflection, walking reflection, imaginal ideation, and in some cases altered states of attentional openness such as near-sleep ideation or dream capture. The purpose of these practices was not mystification. It was to preserve a space in which originality, symbolic coherence, and deeper design intuition could arise before being prematurely rationalised into the obvious.

For this I intentionally reduce incoming constraints (“bracketing details”) to open imaginal space. Here I sketch, storyboard, and compose experiences guided by philosophical lenses (4E+; Neoplatonic/Ishraqi aesthetics of presence and beauty). Top-Down Emanation refers to the process by which higher-order structures, principles, or forms influence and shape the organisation and behaviour of lower-level components within a system. In cognitive science, it can be seen as the influence of global predictive models, intentions, or conceptual frameworks on perception, attention, and action (Friston, 2010; Vervaeke, 2017). Philosophically, it resonates with metaphysical notions of emanation, where higher levels of reality or abstraction instantiate and guide patterns at lower levels. In the context of this thesis, top-down emanation is used to describe how overarching cognitive or conceptual frameworks modulate relevance detection and meaning-making processes.

Bottom-up (Emergence/Error-Correction):

Bottom-up emergence refers to the way meaning, form, and refinement arise through the reintroduction of detail, context, testing, and constraint. Once the imaginal core had been allowed to emerge, project requirements, user needs, cultural responsibilities, technical limitations, stakeholder input, and environmental realities were deliberately brought back into the process.

Here the methodology becomes more recognisably design-research in the conventional sense: field research, stakeholder discussions, co-design, prototyping, playtesting, iterative adjustment, production planning, implementation, and post-production review. This is where emergent behaviour, unforeseen issues, and contextual pressures “talk back” to the design, forcing revision.

This phase is best understood as error-correction. The imaginal design does not remain sovereign. It must measure up to reality. It must conform, adapt, and become accountable. In Aristotelian terms, this is the phase of adequation. In cybernetic terms, it is the feedback loop that prevents visionary work from collapsing into ungrounded fantasy.

I re-introduce constraints and data—user needs, cultural tikanga, environmental and technical limits—using fieldwork, co-design, and prototyping to shape and test the imaginal vision. Bottom-Up Emergence is the process by which complex properties, patterns, or behaviours arise from the interactions of simpler components without being explicitly imposed by higher-level structures. In cognitive systems, this refers to how sensory inputs, local neural interactions, or micro-level behaviours give rise to perception, cognition, or adaptive responses (Clark, 2013; Vervaeke, 2017). Emergent phenomena are often unpredictable from the properties of individual components alone, highlighting the self-organising and context-sensitive nature of complex systems. Within this thesis, bottom-up emergence frames how relevance and meaning can spontaneously arise from the interplay of attentional, emotional, and environmental factors.

Here I distinguish two complementary modes of cognition and method I used deliberately and sequentially: top-down emanation and bottom-up emergence. In the top-down mode, the mind is oriented to *imaginal generation*—it suspends premature constraint and cultivates states in which patterns, metaphors, and design gestalts can present themselves as wholes. The methods are therefore *attunement practices*, not data procedures: an ecology of practices (short contemplative sits, breath-led centering, walking reflection), guided/active imagination, lucid-dream journaling, hypnagogic sketching, and occasional somatic/meditative protocols that quiet analytic chatter so that anagogic insight (the “shape” of an experience, its aesthetic/ethical arc) can appear. By contrast, the bottom-up mode is *emergent and corrective*: it brings constraint, evidence, and context back in. The methods here are the familiar *heuristic and project-development tools*: stakeholder conversations; contextual inquiry; field notes; moodboards; interaction sketches; lightweight prototyping; playtesting; usability walkthroughs; and iterative adjustments guided by affordances, accessibility, and device constraints. Either sequence is possible—one may start bottom-up and use top-down only to unstick ideation, or run them in parallel. My research chose a third path: I intentionally began with as little project information as possible (bracketing requirements to avoid premature closure), went fully top-down to surface the *imaginal core* (presence, affect, ethical and cultural salience), and only then reintroduced bottom-up methods as error-correction and fidelity checks—testing, constraining, and refining the imaginal results until they conformed to user, cultural, and technical realities. This asymmetric sequencing protected originality and depth of meaning, while ensuring the outcomes were accountable to context and craft.

Either sequence is in principle possible. One may begin bottom-up and use top-down methods only to unblock ideation, or run both in parallel. In this thesis, however, I chose a deliberate asymmetry: I often began with minimal project information, allowed the top-down imaginal core to surface first, and then introduced bottom-up methods as correction and fidelity checks. This sequencing protected the originality, symbolic depth, and affective force of the work while ensuring it remained accountable to context, culture, users, and craft.

This is one of the most distinctive features of the methodology. It gives formal structure to a process many artists intuitively perform but rarely theorise. It also provides a way of understanding artistic design not as irrational spontaneity, but as disciplined oscillation between higher-order orientation and lower-order correction.

Methods: What I Did, How I Captured It, How I Analysed It

While the methodology provides the overall epistemic and philosophical logic, the study employed concrete methods that can be grouped according to the top-down / bottom-up cycle.

Generative (Top-Down/Imaginal):

The top-down phase used methods designed to cultivate attunement, symbolic coherence, and imaginal emergence. These included:

- **Philosophical Insight prompts:** short cards (e.g., embodied salience, hudhūrī presence, narrative-as-parable) placed on the desk during sketching to keep the epistemic lens live.
- **Ecology of Practices (Meditations):** structured arrangement of meaningful practices designed to stimulate mental, spiritual, and physical connections
- **Experimental visualisation and imaginal ideation techniques:** including Near-Sleep note-taking technique to open the Mind Box and altered attentional states where appropriate.
- **Lucid Dreaming and Out of Body Experience:** These altered states of consciousness provide a rich terrain for exploring the boundaries of perception, creativity
- **Indwelling & immersion:** timed contemplative walks; headset "empty-scene" sessions to attend to **felt affordances**.

Data from this phase were captured through notebooks, digital sketches, voice memos, dated logs, reflective memos, and recorded design rationale notes. These all are gathered in the dedicated website for this PhD (https://www.beingalitaheri.com/) and in The Brain mindmap of this Research (https://www.beingalitaheri.com/knowledge-base/postgraduate-study/). The detailed information on these methods can be found in Chapter 4 and in the Appendix 4.

Concretisation (Bottom-Up/Emergence)

The bottom-up phase employed more familiar design and research methods:

- **Field research & co-design:** stakeholder conversations and contextual inquiry, site visits, where relevant engagement with cultural experts and tikanga-informed dialogue.

- **Prototype sprints:** low-fi to hi-fi builds; scene walkthroughs; think-alouds; observation notes; short exit interviews where appropriate.

- **Heuristic evaluation & playtesting:** comfort, legibility, agency, and affective engagement probes; capture of incidents and design rationales.

- **Production pipeline:** standard XR pre-production/production/post, version control comments, change rationale, and implementation logs.

- **Screen recording of the process:** I edited these later to a single long video to a long video that shows the project's progress from start to finish. I used these videos later to reflect on how the project got better and better over time but also it shows the sudden effect of those top-down emanation decisions and creative ideas.

A particularly valuable method in this study was the screen recording of the process. I recorded design development over time and later revisited these process videos to reflect on how projects evolved. This was especially useful for identifying the sudden, disproportionate effects of top-down design decisions—moments where a single imaginal insight reshaped the whole trajectory of the work.

Reflexive Capture and Documentation

Across both phases, reflexive journalling and reflective vlogs were used to capture immediate responses, evolving intuitions, theoretical links, and decision rationales. These reflexive materials were not treated as diary-like extras. They were part of the data of the research, because they documented how design insights emerged, shifted, were challenged, and became articulated.

Analysis and Synthesis

The analysis proceeded through a combination of thematic consolidation, theoretical triangulation, and design rationale writing.

- Reflective memos, artefact traces, and process notes were examined for recurring themes relating to embodiment, embeddedness, enaction, extension, affect, presence, beauty-as-disclosure, and ethical-cultural fit.
- Insights were triangulated across three domains: practice traces, philosophical lenses, and the literature: practice traces ↔ philosophical lens ↔ literature.
- Short design rationale essays were developed around specific iterations, linking design choices—such as locomotion, pacing, gesture structure, sound design, spatial arrangement, or ritual timing—to the philosophical and cognitive commitments of the thesis.
- Across multiple projects, these traces were then synthesised into transferable design principles.

Collaboration, Rigour, Validity, and Ethics:

Because many AppLab projects were collaborative, it was essential to make my own contribution transparent. To address this, I maintained:

- A contribution matrix identifying roles across concept, design intent, prototyping, implementation, aesthetic direction, philosophical framing, and writing. (Refer to the Table 4.5 and 4.6)
- Versioned artefacts, where possible linked to my decisions;
- Design-decision logs explaining why specific choices served the philosophical and experiential lens of the research.

Rigour in this thesis does not rest on statistical generalisation. It rests on traceability, coherence, iterative refinement, triangulation, and transparency. The audit trail of artefact evolution, the reflexive documentation, the cross-case consolidation into design principles, and the explicit connection between theory and design choices provide the basis for validity.

Ethically, the research integrated cultural sensitivity, stakeholder care, and context-specific responsibilities from the outset rather than as afterthoughts. This was especially important in projects involving cultural heritage, educational engagement, or tikanga-informed contexts. The bottom-up corrective phase was crucial here, as it prevented philosophical abstraction from overriding situated ethical realities.

A Worked Pattern: From Vision to Error-Correction

1. Emanation: brief is bracketed; I hold the philosophical cards (embodiment, presence, beauty-as-disclosure) and sketch an experience arc.
2. Emergence: I bring back constraints—audience, tikanga, device limits, safety; run walkthroughs; log issues.
3. Error-correction: adjust locomotion/gestures/audio to match 4E+ affordances and cultural fit; document the rationale.
4. Synthesis: record what principle this iteration supports (e.g., *design for hudhūrī presence by aligning spatial audio with ritual temporality*).
5. Repeat.

How this Research Generates New Knowledge and Produces Transferable Outcomes

This thesis generates knowledge in a way that differs from conventional positivist accounts, but it does not abandon academic accountability.

First, it generates design knowledge through artefact-making. Each artefact functions as a material argument: a concrete instantiation of philosophical and cognitive commitments tested through practice.

Second, it generates process knowledge by documenting how insights emerge through the alternation between top-down imaginal orientation and bottom-up correction. This is not merely a description of a personal workflow. It is an articulation of a research logic that can be examined, adapted, and critiqued by others.

Third, it generates principled knowledge by consolidating recurring insights across projects into design principles relevant to XR and HCI. These principles make tacit, embodied, and situated knowledge more explicit and portable.

Fourth, it generates methodological knowledge by demonstrating that a practice-oriented, heuristic, illumination-informed framework can produce rigorous, traceable, and conceptually rich research outcomes in a field where affect, presence, embodiment, and cultural meaning are central but not easily quantifiable.

The knowledge produced is therefore not a universal formula. It is a conceptual and experiential scaffold: a systematic way of thinking, sensing, and acting that others may adopt, adapt, test, or contest.

The thesis does not claim a universal recipe; it offers a conceptual and experiential scaffold—a systematic way of thinking, sensing, and acting—that others can adopt and adapt:

- Lenses: 4E+ + Illumination/Neoplatonism (knowledge-as-transformation).
- Cycle: top-down imaginal generation ↔ bottom-up testing/refinement.
- Methods pack: the concrete practices listed above.
- Outputs: principles/tables that make the tacit explicit for XR/HCI.

Related Methodological Precedents

Although my Ishraqi–Heuristic approach is uncommon, it stands within a recognisable lineage of rigorous creative-practice research in HCI and the arts.
Research-through-Design (RtD) has long argued that artefacts and the process of making can function as inquiry (e.g., Zimmerman, Forlizzi & Evenson; Gaver's cultural probes and ambiguity as a resource for design). Humanistic HCI (e.g., Bardzell & Bardzell) explicitly validates aesthetics, ethics, and authorial voice as legitimate lenses for knowledge. Phenomenological and performative approaches in interactive art and performance studies (e.g., Kozel's somatic/phenomenological method; McCarthy & Wright's "technology as experience") foreground felt presence, embodiment, and meaning. In creative arts scholarship, practice-as-research (e.g., Nelson; Candy & Edmonds; Sullivan; Smith & Dean) formalises cycles of making–reflection–theorising, positioning reflective documentation as data and design rationales as arguments. And in broader design theory, Schön's reflective practitioner and Ingold's attention to making show how tacit, situated, embodied cognition becomes methodological. My work is aligned with these trajectories, but extends them by explicitly integrating 4E+ cognition with Neoplatonic/Illuminationist epistemology and by operationalising a top-down (emanation) ↔ bottom-up (emergence) cycle as a deliberate research engine.

What is distinctive is not "intuition" per se, but the explicit scaffolding that legitimises intuition within a two-tier epistemology: (1) top-down imaginal generation (anagogic orientation, hudhūrī/presence-based knowing) followed by (2) bottom-up emergence and error-correction (adequatio/conformity to constraints, data, and context). This makes my method replicable as a stance rather than as a recipe: others can adopt the cycle (bracket details → imaginal sketching → reflective capture → reintroduce constraints → prototype/test → extract principles) and the rigour apparatus (audit trail, contribution matrices, design-decision logs, triangulation with literature and cultural review). For XR, where presence, embodiment, and cultural meaning are central but hard to quantify, this framework lets designers generate the right kinds of hypotheses (affective/experiential) and then discipline them through iterative testing. It is therefore useful to artists and HCI practitioners who need both freedom to discover and structures to justify.

Research-through-Design traditions have long argued that artefacts and the process of making can function as modes of inquiry. Humanistic HCI has explicitly validated aesthetics, ethics, affect, and authorial voice as legitimate dimensions of research. Phenomenological and performative approaches in interactive art and technology studies have foregrounded felt presence, embodiment, and lived meaning. In creative arts scholarship more broadly, practice-oriented research, practice-as-research, and reflective practitioner models have formalised the idea that making, reflection, and theorisation can operate together as systematic inquiry.

My work aligns with these trajectories, but extends them in a distinctive way. Its uniqueness does not lie simply in valuing intuition. Many creative methodologies do that. What is distinctive is the explicit integration of:

- 4E+ cognition,
- Neoplatonic ascent and intelligibility,
- Illuminationist knowledge by presence,
- A top-down / bottom-up methodological engine.

This makes the approach replicable as a stance rather than as a rigid recipe. Others may not reproduce my exact process, but they can adopt the logic: bracket detail, allow imaginal coherence to emerge, document insight, reintroduce context and constraint, iterate through testing, and consolidate recurring insights into principles.

For artists and HCI practitioners working in XR, this is especially useful because the medium foregrounds presence, embodiment, and affective participation—precisely those dimensions that are often poorly served by methods designed primarily for efficiency or formal intervention evaluation.

Alternative Methodologies Considered and Why They Were Not Chosen

The final framework was not chosen by default. Several more conventional methodologies were seriously considered during this research. Each offered something valuable. Each was ultimately set aside because it did not fully match the paradigm and aims of the research.

Affordance-Centred Design (Gibson/Norman lineage).

Affordance theory, especially in the Gibson–Norman lineage, was useful as an analytic lens. It helped explain perception–action coupling, legibility, interaction possibilities, and the relation between users and environments. This is clearly relevant to XR.

However, affordance theory alone could not serve as the primary methodology. It tends to privilege functional interaction and perceptual ergonomics. My research questions extended further: towards presence, affective disclosure, ethical-cultural fit, anagoge, and transformation. Affordance analysis could help evaluate aspects of interaction, but it could not adequately account for the deeper existential and symbolic dimensions central to the thesis.

Grounded Theory (GT).

I experimented with open and axial coding across journals, artefact traces, and reflective notes, and grounded theory was initially attractive because it promises emergent insight from iterative practice. However, a strictly inductive grounded theory approach conflicts with a lens-led inquiry already grounded in explicit philosophical commitments, namely 4E+ cognition and Illuminationist thought. My aim was not to neutralise prior theory and let categories emerge in a vacuum. Rather, it was to test, refine, and operationalise a philosophical framework through practice. I retained a form of thematic consolidation for transparency, but not grounded theory as the governing methodology.

Design-Based Research (DBR).

Design-Based Research was seriously considered, especially because it informed standard AppLab practice in some contexts. DBR offers many strengths: iterative cycles, work in authentic settings, theory-building through intervention, and the production of mid-range design theories that may travel across implementations.

However, DBR ultimately proved ill-suited as the primary framework for this thesis. First, it is time- and cost-intensive, especially when pursued in its fuller form with extended interventions, formal evaluation cycles, and systematic implementation studies. Within the constraints of the doctoral project, such a commitment would have significantly narrowed the space for philosophical depth and artistic exploration.

Second, and more importantly, DBR can be hand-tightening for artistic vision. Its strength lies in structured iteration, but that structure often pulls inquiry towards what can be formalised, evaluated, and generalised through intervention logic. My commitment, by contrast, was to a heuristic, practice-oriented inquiry grounded in 4E+ cognition and Illuminationist epistemology, where presence, intuition, embodiment, and symbolic disclosure are central and not easily reducible to DBR's evaluation rubrics. I retained DBR's spirit of iterative work in authentic settings, but not its full procedural architecture.

Analytic Autoethnography

Analytic autoethnography offered a potentially recognisable qualitative route because the research is deeply situated and my own practice is central to the inquiry. However, it risked over-disciplining the tacit, affective, symbolic, and spiritual registers that needed to surface in the work. For that reason, I leaned instead towards a more heuristic and evocative mode. This did not mean abandoning rigour. Rigour was maintained through traceable artefact iterations, reflexive logs, process capture, design-decision documentation, and cross-case synthesis into design principles. What changed was the status of the self: not as the primary narrative object, but as the instrument through which the research could unfold.

Narrative Inquiry or Arts-Based Research as the Sole Frame

Narrative and arts-based modes are integral to the thesis. Indeed, metaphor and parable are treated here as legitimate epistemic tools. A proper parable often appears to be only a story, only to reconfigure the entire field of understanding from within. This indirect mode of disclosure is especially important where layered, affective, and symbolic meanings resist full capture in conventional analytic prose.

Yet narrative or arts-based research alone could not serve as the sole framework. On their own, they risk producing rich accounts without sufficient operational leverage. The thesis needed not only to interpret and narrate, but also to generate design principles that others can test and adapt. That is why the final framework became an Ishraqi–Heuristic scaffold: practice-oriented and research-led cycles, reflexive capture, thematic consolidation, and principled articulation.

Why not a fixed, procedural method?

A stepwise, prescriptive protocol would contradict the emergent, presence-based nature of artistic XR inquiry and under-sample affect, cultural meaning, and situated embodiment. The top-down → bottom-up alternation deliberately *protects* imaginal discovery before subjecting it to constraints, feedback, and error-correction—balancing freedom with accountability.

A fixed, stepwise protocol would have contradicted the emergent, presence-based nature of the inquiry. It would have under-sampled affect, embodiment, symbolic resonance, cultural meaning, and the imaginal dimension of XR design. More simply: it would have answered a different kind of question than the one this thesis actually asks. This does not mean procedural methods are invalid. It means they were not sufficient for this particular problem.

Why the Presented Framework Was Ultimately Chosen

Because it matches the problem. The RQs demand a method that can (i) generate imaginal designs aligned with presence and anagoge, (ii) test them ethically in real contexts, and (iii) articulate transferable principles. The Ishraqi–Heuristic design, operating through top-down emanation → bottom-up emergence/error-correction cycles, does exactly this while maintaining rigour, transparency, and cultural care. The Ishraqi–Heuristic framework was chosen because it best matched the research problem.

The research questions required a methodology capable of:

- Generating original imaginal designs aligned with presence, embodiment, and anagogic depth;
- Testing and refining those designs in real contexts with ethical and cultural care;
- Producing transferable design principles for XR and HCI without flattening the phenomena into what is easiest to measure.

The final framework accomplishes this through its central cycle: top-down emanation, bottom-up emergence, and iterative error-correction. It allows intuition to operate, but not unchecked. It preserves originality, but not at the expense of accountability. It accepts the situated and personal nature of the research, but it does not collapse into private impressionism.

In this sense, its unusualness is not a weakness. It is precisely what allows the methodology to remain faithful to the ontology, epistemology, and medium under investigation.

Limitations of the Chosen Framework

This approach privileges depth of lived engagement over controlled generalisation. Some insights remain highly situated and emerge from specific projects, contexts, and collaborations. Because the methodology values embodied and experiential knowledge, certain dimensions of the work also exceed full textual capture. In addition, the practical realities of time, budget, and collaborative production inevitably shaped the kinds of artefacts that could be built and evaluated. Nevertheless, the methodological value of the work remains strong because of the explicit audit trail, the traceability of design iterations, the triangulation of practice and theory, and the extraction of principled outcomes from across cases.

Concluding

This chapter has clarified my position as an academic–researcher and the methodological architecture of the thesis. The central claim is that this research could not have been adequately conducted through a purely procedural, positivist, or representational model of inquiry, because its underlying view of knowing is different. Drawing on Aristotle, Plato, Plotinus, Suhrawardi, and 4E+ cognition, the thesis understands knowing as participatory and transformative. That paradigm demanded a methodology capable of holding together embodiment, intuition, practice, reflection, cultural responsibility, and conceptual rigour.

Having now established the researcher's perspective within the framework of this study, the next chapter explores into the Review of Contextual Knowledge, aiming to provide a comprehensive understanding of the foundational theories and literature that inform this research.

Figure 2.9 - Illuminationism (Ishraq) and The Tree of Knowledge.
Illustration created by Zohreh Shirazi & Ali Taheri (2024) using Midjourney GenerativeAI.
No copyright claimed.

Note. Illustration created by Zohreh Shirazi & Ali Taheri (2024) by uploading a hand drawing image to Midjourney GenerativeAI. No copyright claimed.

Chapter 3: Contextual Review of Knowledge

This chapter, aptly titled Review of Contextual Knowledge, diverges from the traditional literature review format. It unfolds five distinct but interrelated strands of knowledge that intricately blend into the design process and principles of the practical project. This journey is transdisciplinary, weaving through the realms of literature, technology, philosophy, artistic practice, and media ecology. This specific contextual review of knowledge adds a multi-faceted perspective to the research, offering insights into the design process and principles that guide my practical projects. There will be five sections in this chapter:

Section 3.1**:** The first section, Technological Explorations in XR, explores the evolution and impact of eXtended Reality by focusing on XR Technology as a pivotal element of the Fourth Industrial Revolution (4IR). This part of the discussion examines the development and progressive integration of XR technologies within 4IR, illustrating how it has expanded and transformed in response to technological advances.

Section 3.2**:** The second section examines the contributions of Cinema and Video Games to the expanding body of knowledge in this field. Here, I examine the contribution of cinematic and video game storytelling to XR, emphasising the enhancement of user experience and interaction.

Section 3.3**:** The theoretical framework around Human-Computer Interaction (HCI) and the dynamics between users and digital interfaces are discussed in the third section. The philosophy of cognition and philosophy of HCI are also examined, offering a deeper understanding of the cognitive processes that underlie human interaction with technology. This section serves to illuminate the philosophical foundations that shape the research, particularly focusing on the concepts of 4E+ Cognition and spiritual wisdom, and how these paradigms influence the approach to technology and HCI.

Section 3.4**:** The final section focuses on XR as an emergent and transformative medium, examined through the theoretical framework of Marshall McLuhan. In particular, with regard to the medium's influence on the message. By examining XR through McLuhan's theories, the chapter highlights the necessity of understanding the medium's inherent characteristics to fully grasp its potential impact on society and culture.

3.1. Technological Explorations in XR

In the realm of eXtended Reality (XR), a transformative journey unfolds, much like a story of technological evolution and discovery. This exploration, grounded in extensive research, ventures into the diverse and dynamic world of XR. Here, the tale begins with a foundation laid by pioneers like Milgram and Kishino (1994), who conceptualised the blend of real and virtual worlds, setting the stage for what XR would become (Figure 3.1).

Figure 3.1 - Virtuality Continuum.

Note. This figure is adopted from Milgram & Kishino (1994).

This section underscores XR's potential for revolutionising various sectors, setting the groundwork for understanding its application in my research on XR interaction experience design. The exploration in this section is going to serve as a crucial backdrop for my research. By examining the historical development, classification, and integration of XR with the Internet of Things (IoT) and AI, we gain a nuanced perspective on XR's transformative potential. This understanding is key in formulating design principles that come later.

As the narrative progresses, we enter the era of the fourth industrial revolution, a time marked by significant technological advancements. In this landscape, XR emerges not just as a tool but as a key player reshaping human interactions within both the virtual and the physical realms. It is a story of integration and transformation, where XR technologies, as highlighted by Schwab (2017) and Rampolla and Kipper (2012), are not mere additions to our world but catalysts that redefine our experience of reality.

While in this section I will focus on the technological aspects of interactive immersive media, it is important to remember that from a conceptual perspective, my research views XR not merely as a tool and technology, but as transformative mediums that enable a deeper, embodied engagement with digital content, facilitating an integrative experience that bridges the physical and virtual worlds.

3.1.1. Personal Reflection on the Technological Progression

The evolution of eXtended Reality represents a confluence of human ingenuity and technological progress. This journey, from rudimentary virtual environments to sophisticated immersive experiences, mirrors humanity's quest for deeper connections with the digital realm. Years ago, I embarked on an exploration of interactive experiences, specifically focusing on the emerging field of XR, during the concluding year of my master's degree.

My interest in this field became more pronounced approximately two years after my Master, coinciding with the surge in popularity of the Oculus Rift and Samsung phone-based Virtual Reality (VR) headsets, which garnered significant attention from global audiences. During that period, my primary area of concentration revolved around the practice of 'Experimental VR Documentary Filmmaking' employing 360 cameras, which is referred to as Augmented Virtuality (AV) (Jerald, 2015).

Back then (around 2015-2016), I anticipated that there would be a notable proliferation of light field cameras and maybe even lidar-enabled video cameras by the year 2020, and this rapid and widespread increase or growth of technology would therefore lead to the general accessibility and availability of these technologies for consumer acquisition! However, as I progressed through my initial year of research, I came to acknowledge the naivety of my initial expectations and early assumptions.

During the first stages of my PhD research, approximately six months after I started, I came to the realisation that the attempt to incorporate filmmaking into virtual reality was not a viable idea. The insight I gained, inherently subjective, led me to understand that incorporating one medium, such as traditional cinema, filmmaking, or video games, into another medium, like VR or, more broadly, XR, may not be entirely appropriate. This realisation stems from recognising that XR possesses unique qualities that markedly distinguish it from existing platforms.

This perspective echoes a similar sentiment that emerged during the evolution of mobile learning in the early 2010s, where the focus shifted towards leveraging the unique affordances of mobile technologies rather than merely extending traditional educational methods into the mobile context (Traxler & Kukulska-Hulme, 2007). This shift underscores the importance of appreciating and utilising the inherent capabilities of an emerging new medium to enhance user experiences distinctively. This approach of exploiting the opportunities afforded by the technology itself is critical in XR development, where the immersive and interactive nature of the medium can offer novel ways to engage with content that go beyond the static viewing experience of films or the controlled interactivity of video games.

By leveraging the unique characteristics of XR, designers and developers can craft experiences that are both innovative and fully aligned with the technology's capabilities, resulting in more engaging user interactions. The development and production of content for XR necessitate the implementation of a core approach that capitalises on the immersive attributes of this medium (Bowman et al., 2006). Thus, XR-specific designs can yield enthralling experiences that validate the commitment of resources.

It is important to analyse this emerging medium from several angles and consider its appropriate application and specific media language, based on its special characteristics. While it is possible to find comparisons and extract lessons from other forms of media, it is important to recognise the subtle variations that exist within each medium (Helsper et al., 2010; Manovich, 2002). While the feasibility of adapting conventional media techniques to XR should be acknowledged, it is important to avoid oversimplifying and misaligning this unique medium by imposing old paradigms upon it (Ryan, 2001; 2015).

Within the context of XR, Mixed Reality (MR) emerges as a sophisticated technology that creates a dynamic environment by amalgamating tangible and virtual domains. In other words, MR allows for the interaction between virtual entities and real-world objects, as well as the reciprocal effect of actual things on virtual representations. This bidirectional interplay culminates in a multifaceted and immersive experience that has the potential to blur the distinction between the physical and digital realms (Azuma, 1997; Milgram & Kishino, 1994). For me, the contemplation of MR transcends mere associations with particular headsets or the envisioning of an all-encompassing futuristic device. Rather, MR signifies a complex system—or perhaps more fittingly, an ecosystem[16]—where the physical, commonly atoms, intertwines seamlessly with the digital or virtual, commonly termed 'bits' (Ishii & Ullmer, 1997; Milgram & Kishino, 1994). Within this intricately constructed ecosystem, a reciprocal and symbiotic relationship emerges between the tangible physical environment (the atomic world) and the abstract virtual domain (the bit world), forging a paradigm of interaction. (Benyon, 2022; Kallinikos et al., 2013).

The term *eXtended* also refers to the extended mind theory introduced by Clark and Chalmers (1998), which argues that cognitive processes extend beyond the individual's mind to incorporate external tools and environments. This is also where, later in this and the next chapter, I will connect XR technologies to 4E+ cognitive science. From the perspective of this research, XR is conceptualised as the Virtuality Continuum, which encompasses real-to-virtual experiences that integrate seamlessly to offer users a unified and cohesive experience (Milgram & Kishino, 1994). In the context of this research, XR serves as both the medium and the theoretical framework underpinning this cohesive MR experience. The subsequent sections will delve into the historical development and evolution of XR from the technological view, tracing its trajectory from conceptual inception to practical implementation.

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[16] In adopting the perspective of biological ecosystems and the concept of autopoiesis as postulated by Maturana and Varela (1980), an enlightening parallel may be drawn. The term 'autopoiesis' delineates a system endowed with the capacity to both reproduce and sustain itself, a concept prevalently employed to elucidate the self-maintaining and self-organising attributes of living cells (Capra & Luisi, 2014). Analogously, biological ecosystems embody a complex web of interactions among diverse organisms, forging a self-regulating and self-perpetuating environment (Odum, 1971). This systemic view holds profound implications for understanding the underlying dynamics of various interactive mediums, a subject that will be expanded upon in the ensuing sections.

3.1.2. The Taxonomy and Terminology of XR in 2024

Understanding the key terms is essential for grasping this chapter and future chapters. The definitions provided in the 'Definitions of Keywords' aim to clarify the complex and evolving landscape of emerging technologies, immersive technologies, and XR. As that section has already provided a comprehensive list of concepts and terminologies related to XR, this section will be short.

Immersive technologies include various devices and methods that create a strong sense of presence[17] in virtual or augmented environments (Lombard, 1997; Slater & Wilbur, 1997). This includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), as well as haptic feedback devices for tactile sensations (L. A. Jones & Sarter, 2008), spatial audio for enhanced spatial presence (Larsson et al., 2019a), and eye-tracking for more natural interactions (X. Cao 2023; Jacob & Karn, 2003). These technologies aim to bridge the virtual and real worlds, providing experiences that are sensory and cognitive. For me and in this exegesis, eXtended Reality, from a technological view, represents a comprehensive term that includes the full range of immersive technologies. The taxonomy and terminology of XR serve to categorise and also to clarify the various types of immersive experiences and the technologies used to create them. The use of XR to create unique and immersive experiences can transform it into a medium of experiential engagement, merging virtual and real elements into a shared environment for collaborative interactions (Billinghurst & Kato, 1999). This integration allows virtual entities to interact with physical spaces, offering users a seamless blend of digital and physical interactions (Ishii & Ullmer,1997). Examples of this include virtual art exhibits where visitors can interact with digital artworks in real museum spaces, or augmented reality apps that overlay historical information on physical landmarks, enhancing the visitor's experience (Carrozzino & Bergamasco, 2010). These capabilities highlight XR's unique attributes, setting it apart as a significant medium for experiential interfaces.

[17] In the context of immersive media, presence refers to the subjective feeling of being fully present in a virtual environment and having the sense as if it were real. Achieving a sense of presence is one of the main goals of immersive technologies as it can enhance the user's emotional engagement and sense of immersion in the virtual world (Sanchez-Vives & Slater, 2005; Slater & Wilbur, 1997). More on *Present* in the next section; 3.2. The Role of Cinematic Arts and Games in Advancing XR.

3.1.3. The Fourth Industrial Revolution

This section explores the transformative nature of the Fourth Industrial Revolution (4IR), which is characterised by the integration of digital, biological, and physical technologies. The technological opportunities that come with this fusion are reshaping industries, economies, and societies by blurring the lines between physical and digital spheres, leading to unprecedented efficiencies and new business models.

In the following, I outline the core aspects of 4IR, its overlap with emerging technologies, and the pivotal roles of IoT, AI, and XR. The discussion highlights how XR merges physical and virtual realms to enhance immersive experiences, the synergy between XR and IoT in forging interconnected environments, and how XR and AI collaborate to create intelligent experiences.

The ongoing emergence of technology involves developing, adopting, and integrating innovations that continuously redefine our living, working, and interaction patterns. This dynamic process, marked by rapid advancements and the convergence of diverse technological domains, significantly affects industries, economies, and daily life through the invention, application, and diffusion of new tools.

The progression of industrial revolutions, as illustrated in Figure 3.2 below, began with the First Industrial Revolution (1760-1840), which introduced mechanisation. The Second Industrial Revolution (1863-1947) advanced mass production, followed by the Third Industrial Revolution (1970-2000), which ushered in automated production. The Fourth Industrial Revolution (2010–present) is distinguished by the fusion of emerging technologies (Sharma & Singh, 2020).

The Fourth Industrial Revolution marks a paradigm shift driven by the integration of digital technologies across various sectors, fundamentally altering how we live, work, and interact (Morrar et al., 2017; Xu et al., 2018). This transformation is fuelled by key technological advancements such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data, and Spatial Computing (Craig & Georgieva, 2020; M. Zhang et al., 2012; Merendino et al., 2018; Ranga, 2024). These innovations extend beyond economic changes, poised to reshape human cognition and our understanding of knowledge.

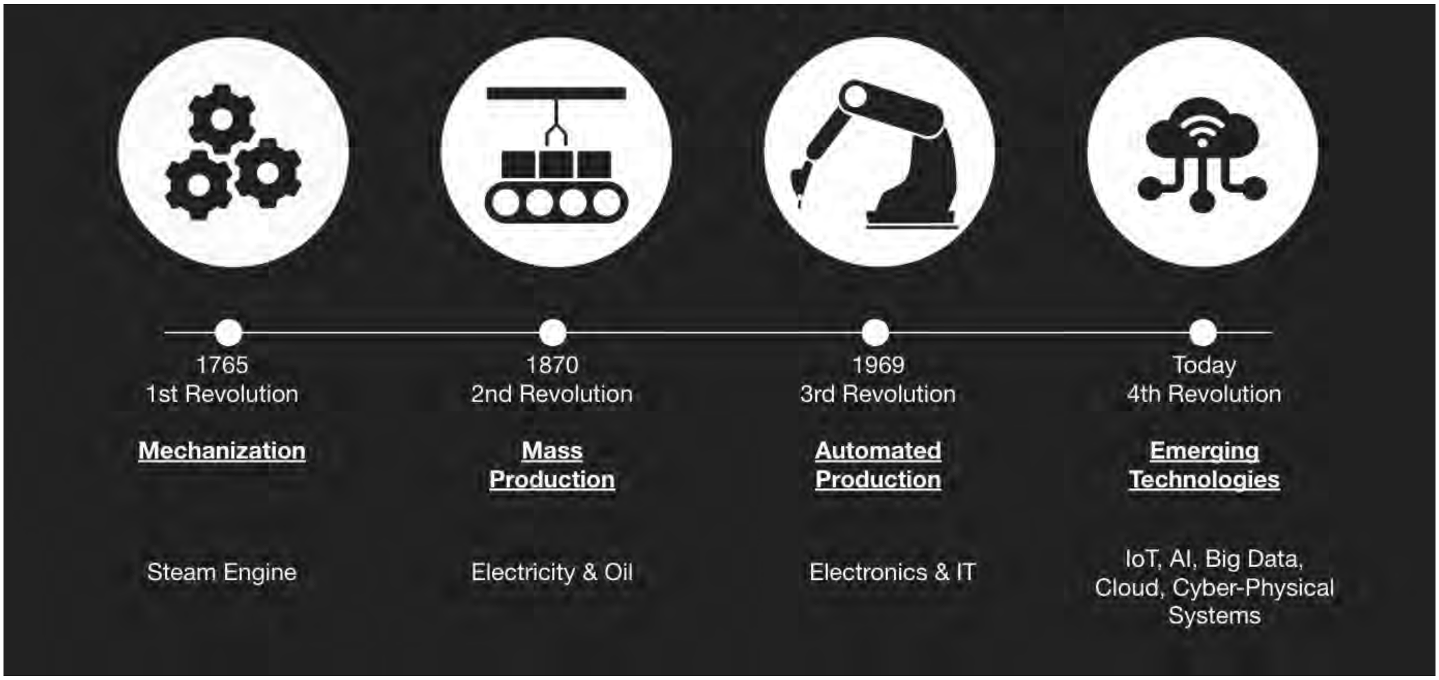


Figure 3.2 - Industrial Revolutions
Illustration of the chronological progression of the four industrial revolutions.

The Fourth Industrial Revolution can be pictured as Lego sets, with emerging technologies such as AI, IoT, big data, and XR as its pieces. These can be assembled to create new systems or solve specific problems, allowing for adaptable and continuous potential solutions to complex issues. The 4IR is characterised by its ability to seamlessly integrate the physical, digital, and biological realms, fostering the development of smart, autonomous systems (Kagermann et al., 2011; 2016). Figure 3.3 shows an overview of 4IR's dimensions, highlighting its various interconnected aspects that together define this transformative industrial paradigm.

The synergy of IoT and AI with XR enhances immersive experiences by providing real-time sensory data and intelligent interactions, improving operational efficiency, safety, and personalisation in various sectors (Pappas, 2021; Z. Zhang et al., 2022). XR also can revolutionise Big Data visualisation, transforming complex datasets into three-dimensional, interactive experiences (Donalek et al., 2014; Flatken et al., 2024, Xie et al., 2016), which is crucial for approaching wicked problems and hyperobjects (Morton, 2013).

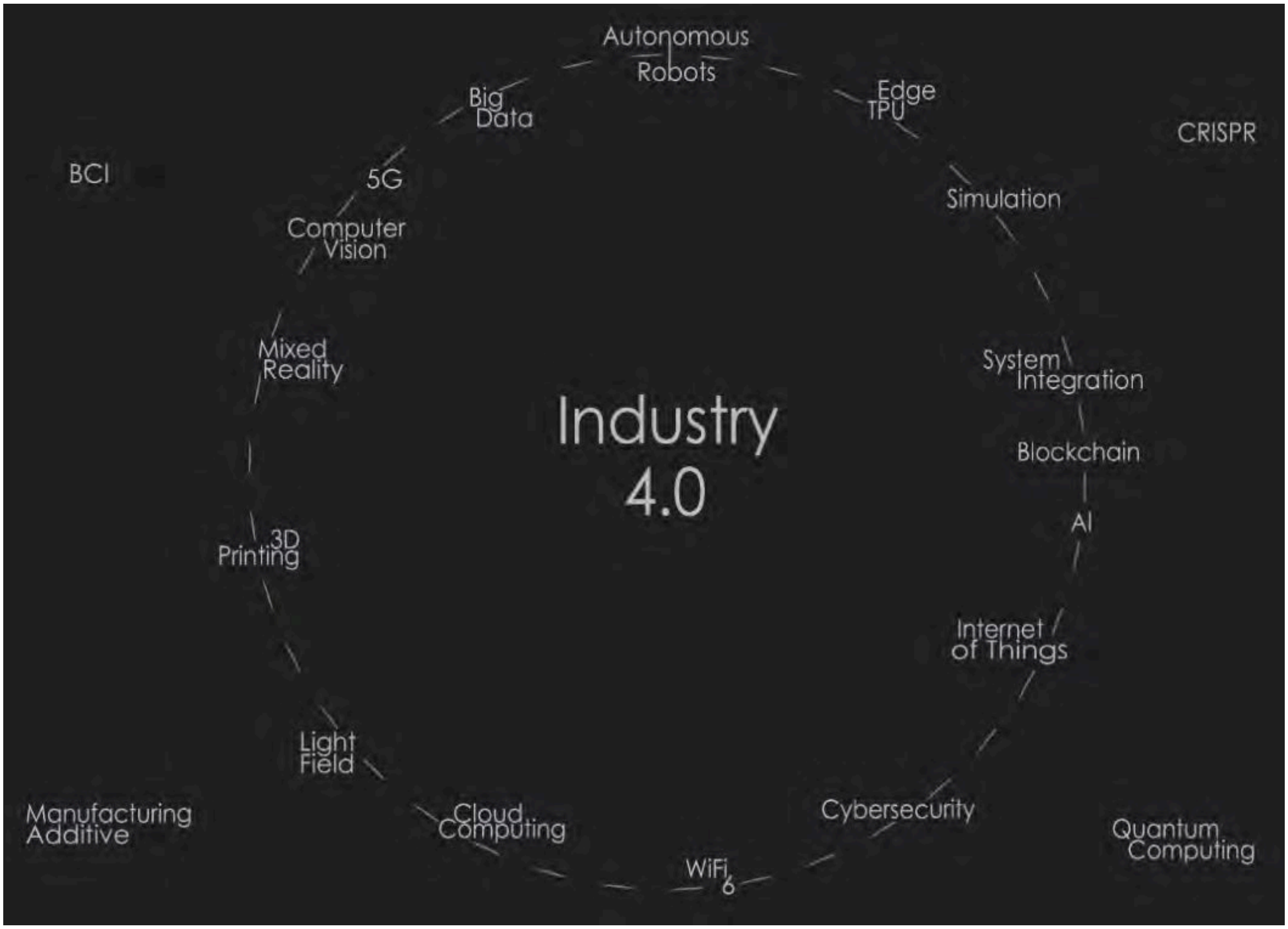


Figure 3.3 - Interconnected Dimensions of 4IR

By integrating IoT and AI, XR experiences become more dynamic, personalised, and efficient, fostering advancements across various sectors. Concurrently, the convergent epistemology and transdisciplinary methodologies drawn from cybernetics, systems theory, and philosophical wisdom underscore the necessity of a multifaceted approach to effectively navigate the complexities of the 4IR (Cardenas-Robledo, 2022).

As I go deeper into the transformative landscape of the Fourth Industrial Revolution, it is imperative to explore the key technological advancements that are reshaping our interactions within both real and virtual environments. Table 3.1 presents an overview of the four principal domains of 4IR that are closely intertwined with eXtended Reality.

Table 3.1 - Key Domains of 4IR Related to XR

Key Areas	Description	Key Authors
IoT	IoT stands as a cornerstone of 4IR, enabling devices across the globe to connect, collect, and exchange data. This interconnectedness facilitates the creation of smart objects, where machinery and equipment can communicate. Spatial computing leverages IoT to enhance the accuracy and functionality of real-world interactions within eXtended Reality applications. This convergence allows for more dynamic and interactive experiences, where physical objects are simulated in digital spaces and also interact reciprocally with digital systems in context-aware ways.	Y. K. Chen, 2012. Kaarlela et al., 2022. Lampropoulos et al., 2019. Munirathinam, 2020. Tao et al., 2018.
Big Data	The proliferation of IoT devices and digital systems has led to an explosion of data. Big Data analytics employs advanced techniques to process and analyse these large data sets, revealing hidden patterns, correlations, and insights that drive decision-making and strategic planning in the Fourth Industrial Revolution. The complexity of Big Data mirrors that of hyperobjects, which are vast and intricate entities that elude full comprehension.	Alias et al., 2018. Bousdekis et al., 2021. Manyika et al., 2011.
AI	Artificial Intelligence (AI) is a backbone of the 4IR. Machine Learning (ML) algorithms, a subset of AI, analyse the vast amounts of data generated by IoT devices, enabling the automation of complex decision-making processes. In 4IR, AI contributes to the development of intelligent manufacturing systems that can adapt to changing conditions. The recent advancements in AI span various domains, with a particular impact on spatial computing by providing more precise environmental understanding, object recognition, and interaction possibilities. The integration of AI with spatial computing also enables more sophisticated simulations and virtual environments that can personalise interactions in real-time.	Alkatheiri, 2022. Guo et al., 2020. Jan et al., 2023. Jayaraman et al., 2022. Li et al., 2021. Reiners et al., 2021. Russell & Norvig, 2016. Sahu et al., 2021.

Spatial Computing	Spatial computing leverages immersive technologies to seamlessly merge digital and physical realms, playing a pivotal role within the 4IR framework. It revolutionises industry interactions with digital content and complex systems by enabling innovative, seamless integration of digital and physical elements. This transformative capability is key to evolving traditional industrial practices into more dynamic, interactive, and efficient workflows. Moreover, spatial computing enhances collaboration by allowing multiple users to interact with the same digital content simultaneously from different locations, fostering better communication and decision-making processes.	Alhakamy, 2024. Azuma, 1997. Billinghurst & Kato, 1999. H. Cao, 2024. K. Kim et al., 2018.

XR technologies can offer innovative paradigms for human-technology and digital-biology interaction, thereby contributing significantly to the 4IR transformative impact on various aspects of daily communication. That is why highlighting the spiritual and cultural roles of communication tools and media technologies is essential to ensure that the advancements in emerging media during the 4IR contribute positively to societal well-being (Klenke, 2007; Munteanu et al., 2015). This approach emphasises global well-being and the ethical use of digital technologies, empowering communities to harness these innovations constructively (Aguayo, Videla, López-Cortés et al., 2023).

The role of eXtended Reality within the context of the 4IR is multifaceted, bridging the gap between digital information and human experience through immersive technologies. As the 4IR propels industries towards digitalisation, automation, and interconnectedness, XR technologies emerge as critical tools in enhancing operational efficiency, training, customer experience, and innovation (Anthes, 2016; Fan et al., 2022; Porter et al., 2017). XR technologies can open up novel avenues for collaboration, communication, educational pedagogy (Aguayo, Videla, & Veloz, 2023; Akçayır & Akçayır, 2017), entertainment, and industry innovation (Egger et al., 2020), thereby reshaping our lived experiences and work modalities in the digital epoch (Flavián et al., 2019). Table 3.2 showcases examples of how XR can play a role in various sectors.

Table 3.2 - eXtended Reality Role

XR Role	**Description**	**Key Authors**
Cultural Preservation and Education	Cultural gamification involves applying game design elements and principles to cultural education to boost engagement, motivation, and learning outcomes. By integrating XR into cultural learning, educators can craft interactive and immersive experiences, making cultural topics more accessible and enjoyable. This approach facilitates immersive learning and fosters greater cultural awareness.	Buratti et al., 2021. Champion, 2016. Marques et al., 2022, Marques et al., 2023, Sylaiou et al., 2010. Styliani et al., 2009.
Education and Training	XR holds the capability to redefine educational paradigms through the use of virtual simulations, interactive pedagogical techniques, and immersive content. Such a shift could harmonise the educational system with the evolving prerequisites of the 4IR.	Aguayo, 2021. Aguayo & Eames, 2023. Eames et al., 2020. Hamilton et al., 2021. Radianti et al,. 2020.
Enhanced Training and Simulation	XR technologies create immersive training environments, allowing employees to gain practical experience safely, which is particularly beneficial in high-risk industries like manufacturing, healthcare, and construction.	Bower, 2019. Jensen & Konradsen, 2018. Larsen et al., 2009. Suh & Prophet, 2018.
Remote Assistance and Maintenance	XR enables precise remote repairs by visualising complex instructions, supports remote collaboration and virtual training, and enhances productivity while reducing travel costs. It provides real-time guidance during maintenance tasks, improving efficiency and reducing downtime.	Bailenson, 2018. Fiorentino et al., 2014. Obermair et al., 2020. Paelke, 2014.
Smart Cities and	XR aids in visualising and planning urban	Goulding et al., 2014.

Urban Planning	development projects by allowing stakeholders to experience proposed changes in a virtual environment before implementation. This enhances decision-making and promotes sustainable, efficient city planning.	Portman et al., 2015. Whyte, 2003.
Data Visualisation and Analytics	XR can enable immersive visualisation of complex data sets, allowing users to interact with data in three-dimensional space, enhancing understanding and insights crucial for data-driven decision-making.	Bach et al., 2017. Cordeil et al., 2016.
Tourism and Hospitality	XR can offer virtual tours of destinations, hotels, and attractions, enabling potential visitors to explore these experiences before making a booking. Additionally, it enhances on-site experiences by providing augmented information, revolutionising the tourism and hospitality industry.	Khoo-Lattimore, 2019. tom Dieck et al., 2016. Yung et al., 2021.
Art and Creative Expression	XR can serve as a powerful tool for both creation and consumption. XR enables artists to explore new dimensions of creativity by allowing them to craft immersive, multi-sensory artworks that transcend the limitations of traditional media. Artists can create interactive installations where viewers become participants, influencing the artwork through their actions and choices.	Cabero-Almenara et al., 2022. Wang et al., 2024.
Virtual Assistants and AI Integration	XR interfaces enhance interactions with AI and virtual assistants, providing more natural and immersive ways to access information and perform tasks, improving the user experience with technology.	Billinghurst et al., 2015. Mohamed et al., 2024. Pidel, & Ackermann, 2020.

Another key dimension of 4IR is the Internet of Things; the convergence of XR and IoT represents a pivotal advancement in digital technology. This advancement has the potential to enable unprecedented levels of interaction, analysis, and control over physical and virtual environments. Table 3.3 provides a detailed exploration of the various aspects of the IoT and its interconnections with the 4IR and XR.

Table 3.3. eXtended Reality and Internet of Things.

XR & IoT	**Description**	**Key Authors and Examples**
Digital Twins	Digital Twins serve as virtual models of real-world systems or processes, facilitated by a continuous data exchange between the physical and virtual realms via IoT sensors and devices (Tao et al., 2018). XR technologies enhance the visualisation and interaction with these replicas, offering immersive experiences previously unattainable. These twins integrate XR and IoT to create real-time digital replicas of physical assets, systems, or processes, enabling advanced monitoring and simulation. When incorporated into XR environments, digital twins provide operators with real-time, intuitively presented information, enhancing both understanding and operational efficiency. Figure 3.4 shows an example of a Digital Twin training environment.	Tao et al., 2018. Kaarlela et al., 2022. Grieves & Vickers, 2017. Digital Twin … Leveraging …
Enchanted Objects	Enchanted objects are everyday items enhanced with technology to perform additional functions, communicate, and offer intuitive user experiences. These objects blend utility with a sense of magic, making technology feel more natural and human-centric. In this sense, media can be considered extensions of human senses and faculties, allowing these enchanted objects to extend human cognition.	Bell & Dourish, 2007. Ishii & Ullmer, 1997. Rose, D., 2014; 2015. Enchanted O…

3D Data Visualisation	XR technologies enable immersive and interactive visualisation of collected data. Sensor data can be vividly displayed in AR or VR environments for more intuitive analytics (C. Chen et al., 2018). XR also facilitates the visualisation of Digital Twins, for example, with AR overlaying real-time data or visuals onto the physical environment to enhance understanding and decision-making.	Bach et al., 2017. C. Chen et al., 2018. C. P. Chen & Zhang, 2014. Dwyer et al., 2018.
User Experience Enhancement	The integration of IoT-enabled devices with XR enhances user engagement by creating immersive experiences. IoT sensors collect environmental data, which can then be incorporated into visualisation or interactive environments. This ensures that the virtual environment mirrors real-world conditions, thereby enhancing the user's sense of presence and immersion.	Chatzopoulos et al., 2017. Javornik, 2016. Lv, 2020. Z. Zhang et al., 2022.

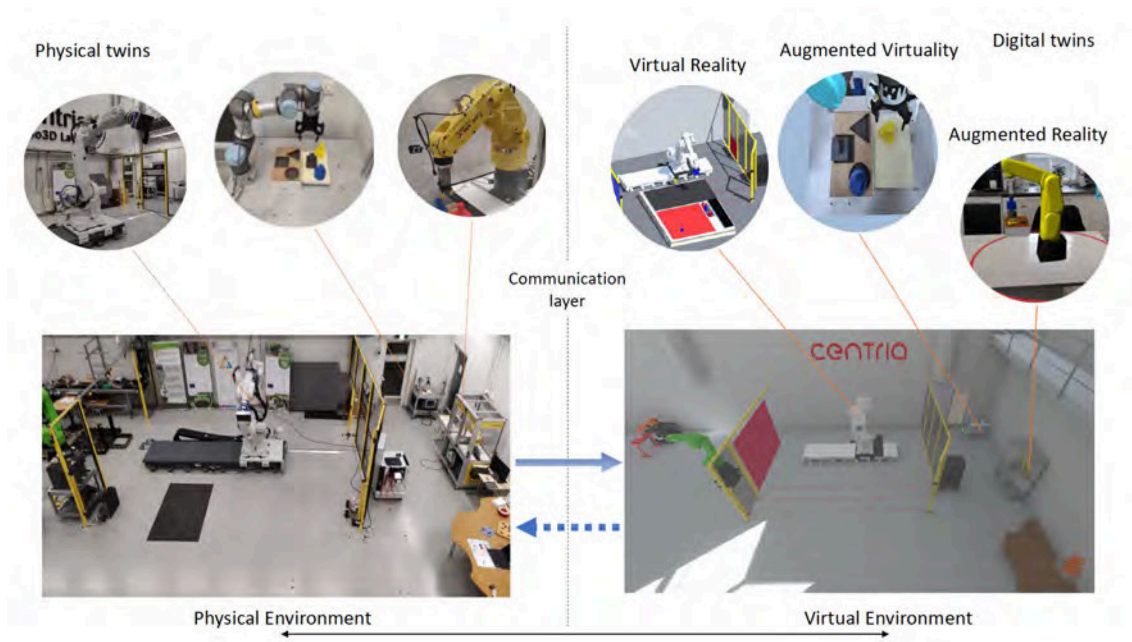


Figure 3.4 - Digital Twin Training Environment.
Note. This figure was produced by Kaarlela, et al., 2022, p15. Copyright 2022 by MDPI.

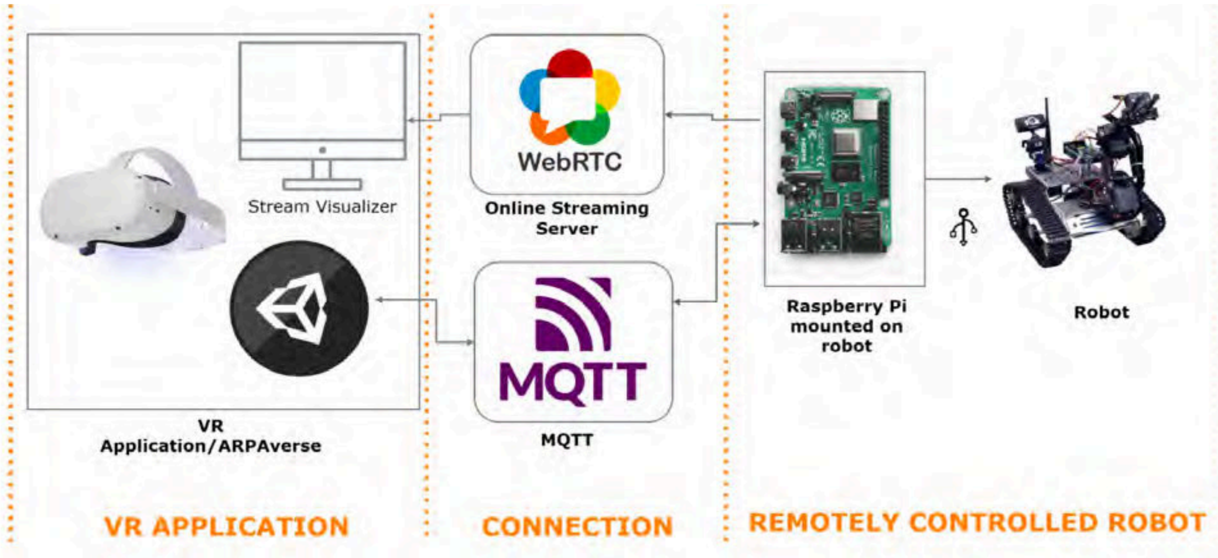


Figure 3.5 - Architecture of IoT and VR Platform integration.
Note. This figure was produced by Kaarlela et al., 2023, p. 14, Copyright 2023 by MDPI.

The integration of XR and IoT, as illustrated in Figure 3.5, showcases the architecture of the TUAS VR Social Platform developed by Kaarlela et al. (2022, p. 219). This figure depicts a system where IoT devices are connected to a virtual reality environment, enabling real-time data exchange between the physical and virtual worlds. The architecture includes components such as IoT sensors and actuators, data processing units, network interfaces, and the VR application layer. Users can interact within a VR environment that accurately reflects real-world conditions monitored by IoT devices, allowing for immersive visualisation and management of IoT data and devices. This fusion offers innovative ways to visualise and manage IoT systems, potentially redefining interactions with both digital and physical environments across various sectors.

Building upon this integration, my own experience with the NIWA Airbox project further exemplifies the transformative potential of combining XR and IoT technologies. The NIWA Airbox, a collaborative project between NIWA, AUT, Massey University, and Curious Minds, aimed to educate New Zealand school children about air quality using Augmented Reality (AR) technology. This project is discussed in more detail in Chapters 4 and 5, where its technical implementation and educational impact are further explored.

Another critical element of the 4IR, closely associated with the IoT, is Big Data. Characterised by substantial volume, velocity, variety, and veracity, Big Data poses significant analytical challenges and often exceeds human processing capabilities in traditional two-dimensional formats (C. Chen et al., 2018; Y. K. Chen, 2012). XR addresses these challenges by providing immersive environments that enable more intuitive exploration of Big Data, helping users uncover obscured patterns, trends, and insights (C. P. Chen & Zhang, 2014).

Big Data's complexity parallels that of hyperobjects, a concept introduced by Morton (2013) to describe vast and intricate entities that are difficult to fully comprehend, such as climate change or the internet. XR technologies effectively transform these massive datasets into interactive, three-dimensional visualisations, enhancing accessibility and cognitive understanding, and aiding stakeholders in making informed decisions. While XR technologies excel in rendering Big Data's complexities into accessible and interactive three-dimensional visualisations, the role of AI becomes crucial in elevating these capabilities further.

Last but not least, Artificial Intelligence encompasses a broad spectrum of technologies and concepts, including machine learning, natural language processing, and robotics, each contributing to the transformative potential of AI. The integration of XR with such diverse AI capabilities significantly reshapes various sectors by enhancing XR through intelligent data processing, real-time analytics, and adaptive learning environments. This powerful synergy offers personalised and responsive user experiences, setting the stage for a revolution in digital interactions and industry-wide innovation and efficiency.

The integration of AI and XR presents a transformative synergy with dual objectives: AI serving XR and XR serving AI (see Figure 3.6). AI can enhance XR by utilising machine deep learning (DL), learning (ML), natural language processing (NLP), and computer vision to detect patterns in XR-generated data and improve user experiences through responsive and intuitive interactions.

Conversely, XR can aid AI by generating high-quality, AI-ready data that addresses common data deficiencies, facilitating faster and more comprehensive training of AI systems in simulated environments before real-world deployment. This dual relationship enhances XR experiences while also improving AI performance and training efficiency across various domains, including medical education, gaming, and autonomous systems (Reiners et al., 2021).

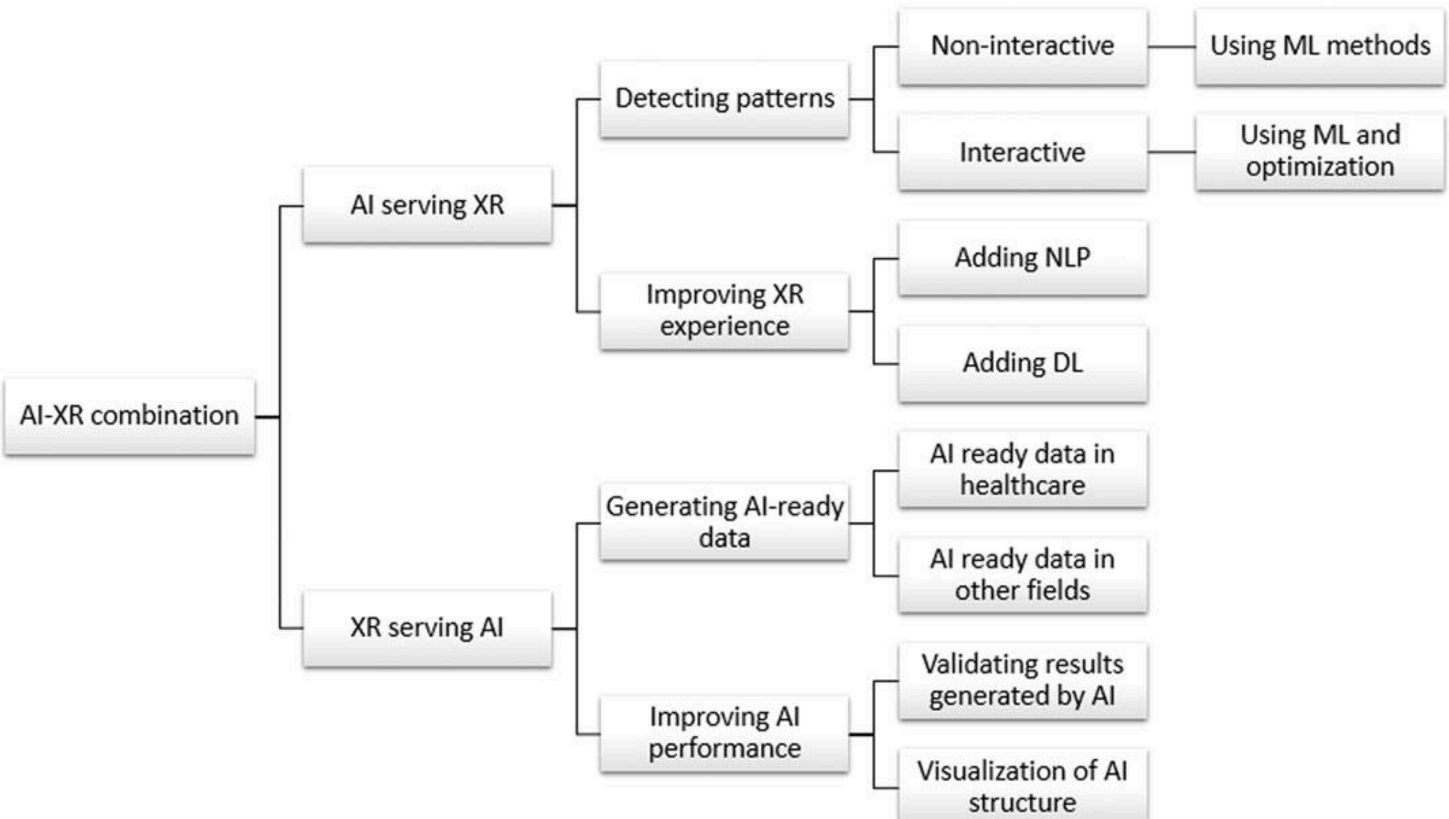


Figure 3.6 - AI serving and assisting XR and XR serving and assisting AI.
Note. This figure was produced by Reiners et al, 2021. Copyright 2021 by Reiners.

These developments illustrate the powerful convergence of AI and XR, showcasing how these technologies are redefining digital interaction, enhancing accessibility, and elevating user engagement across platforms. The integration of XR and AI significantly amplifies the capabilities of each technology, opening up new avenues for immersive, interactive, and personalised experiences across various domains. As these technologies evolve, their combined potential will lead to breakthroughs in how we learn, work, and interact with digital content.

AI further has the potential to revolutionise User Experience (UX) and Interaction Design (IxD) by creating context-aware interfaces that dynamically adjust to user environments and needs, thereby streamlining interactions (Grubert et al., 2016; Kheder, 2023; Pushpakumar et al., 2023; Sun et al., 2024). Additionally, AI improves XR accessibility by adapting interfaces and content to diverse user needs, such as modifying sensory elements to accommodate users with impairments (He et al., 2018).

AI can enhance XR design by enabling adaptive UIs that adjust to user behaviour in real-time, ensuring natural interactions (Shneiderman, 2020). NLP and voice interfaces facilitate seamless communication within XR environments (Kranzlmüller et al., 2001), while predictive analytics optimise UX by analysing user interactions to improve engagement and satisfaction.

In recent years, the integration of AI into game engines has revolutionised the way games are designed and played. AI algorithms enhance the responsiveness and complexity of game environments, enabling characters and scenarios to react dynamically to player actions. This technology not only improves gameplay but also allows for more personalised and immersive gaming experiences (see Figure 3.7).

One notable advancement in this field is the development of Unity ML-Agents (https://github.com/Unity-Technologies/ml-agents), an open-source toolkit provided by Unity Technologies. The MLAgents toolkit enables developers to implement and train AI models within the Unity engine, using deep reinforcement learning, imitation learning, and other machine learning methods. The ML-Agents toolkit allows for the creation of complex AI behaviours that are both sophisticated and scalable, suitable for a variety of applications beyond gaming, including simulations and research. Moreover, AI-driven techniques like natural language processing and deep learning (DL), a subset of ML, enhance XR environments by enabling virtual characters to respond dynamically to user inputs, which is crucial for XR applications in training and education (Reiners et al., 2021).

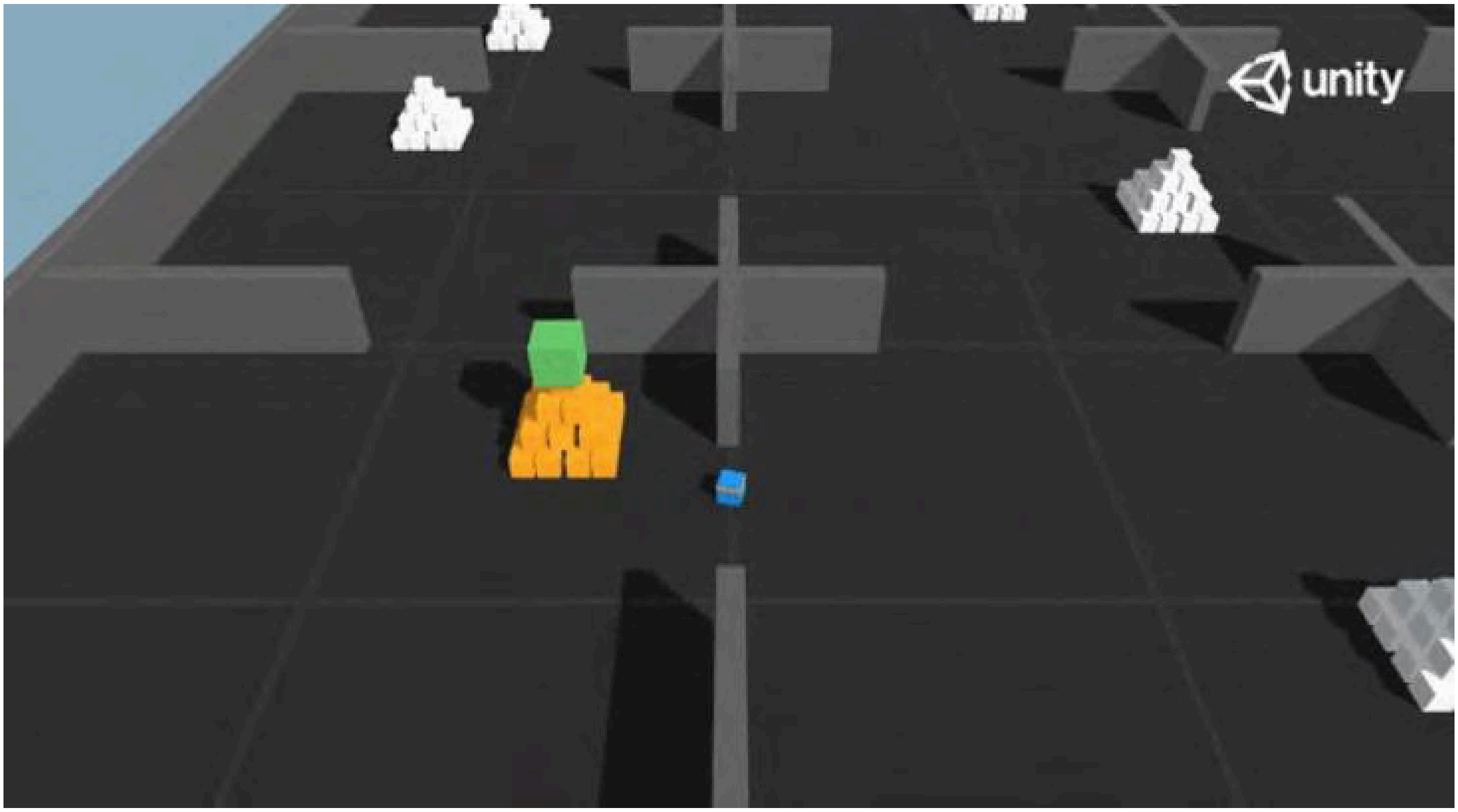


Figure 3.7 - Unity ML-Agents in Action.
A trained agent searching, finding, and solving a problem on its own.
Source: An Introduction to Unity ML-Agents on huggingface
https://huggingface.co/learn/deep-rl-course/unit5/introduction.

However, integrating AI in XR raises ethical concerns about data privacy, bias, and accountability. Addressing these issues is crucial for the responsible development and deployment of these technologies, ensuring they benefit users while respecting their rights and dignity (Giarmoleo et al., 2024). As such, a strong emphasis on responsible and ethical use of AI is crucial to enhance the user experience and also to ensure these advancements contribute positively to society. Ethical frameworks and regulatory measures need to be developed and rigorously applied to manage these risks effectively, as highlighted by Mittelstadt et al. (2016). This approach will help in harnessing the full potential of XR applications while minimising potential harms and ensuring equitable benefits.

3.1.4. Bringing it All Together

This section examines the integration of XR with IoT, Big Data, and AI, highlighting XR's transformative impact across industries. These insights are essential to my research on XR interaction design, informing the study's technological framework and exploration of new dimensions in Human-Computer Interaction. IoT connects devices globally, enabling real-time data exchange and analysis. This connectivity supports smart industries through predictive maintenance and optimised operations. Big Data, fuelled by IoT, applies advanced analytics to vast datasets, improving decision-making and process efficiency. AI processes this data with minimal human oversight, automating complex decisions and enhancing the adaptability of systems across industries. Together, these technologies revolutionise industries by fostering responsive, efficient, and intelligent systems.

A nuanced understanding of XR's affordances and applications provides a solid foundation for crafting innovative design strategies. Such strategies help harness the technological advancements while enabling experience and interaction designers to meaningfully integrate cultural and philosophical insights into their practice. Viewing XR as an ecosystem illuminates the complex web of interactions between our digital and physical realms, underscoring the necessity of contextual and relational approaches in comprehending and navigating sophisticated systems within XR practice and research. This perspective is vital for appreciating the intricate interdependencies and for fostering a more holistic approach to the integration of technology into the fabric of everyday life.

Building on this technological foundation, we now turn to the cultural and aesthetic dimensions that animate and give depth to these innovations. While the convergence of XR with IoT, Big Data, and AI provides the scaffolding for intelligent and adaptive systems, it is through the narrative, visual, and experiential languages of cinematic arts and games that these technologies become truly immersive and resonant.

3.2. The Role of Cinematic Arts and Games in Advancing XR

Shifting focus from the technological investigation discussed in the preceding section, this section examines the emerging creative fusion of cinema and interactive digital entertainments (Video Games) with immersive interactive media. This convergence is instrumental in forging innovative avenues for affective storytelling and interactive experiences, integrating elements such as emotion, affective interaction, and sensory engagement. The integration of these components facilitates a more immersive user experience, enhancing the narrative potential and emotional depth of XR environments.

While cinematic art and game design are inherently distinct fields, their integration within immersive environments highlights significant similarities. This juxtaposition is pivotal in creating new pathways for affective storytelling and enhanced interactivity, incorporating elements like emotion, affective interaction, and sensory engagement. Such integration enriches user experiences, amplifying the narrative complexity and emotional resonance within XR environments, thereby expanding the possibilities for more profound user engagement and storytelling depth. Here I explore the integration of existing media within the realms of experience design and interaction, focusing on the significant contributions that cinema and video games can make to the interactive immersive landscape. This exploration encompasses advancements in visual storytelling, spatial audio, and interactive narratives, all of which have been significantly influenced by the history of cinematic art and the computer and video game industry. These contributions shape the evolving realm of immersive interactive media, laying the groundwork for innovative experiences that blend the sensory and narrative techniques from these established areas with the cutting-edge possibilities of XR technologies.

Cinematic contributions, such as the art of visual storytelling and advanced VFX, are pivotal in creating XR environments that are both realistic and emotionally captivating. Sound design and spatial audio further enrich the visual virtual spaces, giving them an authentic and dynamic aura. Meanwhile, video games introduce interactive narratives, where user choices shape outcomes, and their sophisticated world-building techniques foster expansive, navigable environments. Additionally, the emphasis on embodied interaction design—a principle revered in both domains—underscores the significance of physical user engagement in XR, augmenting both the sensory and cognitive dimensions of the experience. The affective dimension plays a critical role in these integrations. Cinematic techniques such as lighting, music, and editing are used to evoke emotions and create an immersive atmosphere. Similarly, video games employ dynamic feedback systems and interactive storytelling to engage users emotionally, making the experience more compelling and personal (Grodal, 2009; Plantinga & Smith, 1999).

The cinematic arts provide a foundation for storytelling, which is a crucial element in creating compelling XR experiences. Techniques from film, such as narrative structure, pacing, and visual composition, are integral to crafting immersive and emotionally resonant XR content. The use of motion capture technology, which has roots in film, allows for realistic character animations and interactions, enhancing the sense of presence and intimacy in VR environments (Reiners et al., 2021). For instance, in VR storytelling, the direction and choreography of motion-captured performances can create a sense of spatial intimacy similar to that of a live theatre experience. This approach not only enhances the connection between characters and the audience but also brings a layer of depth and realism to the narrative, making the virtual world more believable and engaging (He et al., 2018; Lennox & Mason, 2022).

Video games have long been pioneers in interactive entertainment, and they can be a source of inspiration for XR interaction and experience design (Leung, 2009). The principles of game design—such as user agency, feedback loops, and interactive environments—are essential for developing engaging XR experiences. Non-XR games like The Legend of Zelda: Breath of the Wild (Nintendo, 2017) and Journey (Thatgamecompany, 2012) showcase innovative interaction mechanics and open-world exploration that can inspire XR developers in creating immersive and interactive environments. VR games such as Half-Life: Alyx (Valve, 2020) demonstrate how sophisticated game mechanics and storytelling can be effectively integrated into VR, offering players an interactive and deeply engaging experience.

Adapting cinematic arts and video game techniques can significantly enhance immersive XR experiences by adding depth and broadening creative possibilities. This transdisciplinary approach enriches XR by enhancing engagement, realism, and interactive storytelling. However, it is crucial not to merely transpose paradigms from established media like cinema and video games to XR. Instead, XR should be explored through diverse perspectives to develop its unique language and applications. While insights from other media are valuable, adapting them to XR requires care to avoid oversimplification or misalignment with the medium's distinct characteristics.

3.2.1. Leveraging VFX and Game Technologies

The integration of Visual Effects (VFX) and video game technologies into XR can represent a significant advancement in the creation of immersive environments. This fusion is crucial for enhancing the realism and believability of XR experiences. Techniques such as motion capture, 3D modelling, and particle effects—especially in the era of AI-enhanced tools—allow for the design of complex virtual worlds that can either mimic the physical world or extend beyond its limits. The application of these technologies improves the visual fidelity of XR environments while also expanding the possibilities for creating experiences that were once unimaginable.

VFX technology, originating from the film industry, is renowned for creating lifelike visuals that captivate audiences. When integrated into XR, these techniques enhance the realism of virtual environments, making them more immersive and convincing for users. High-quality cinematic VFX in XR bridges the gap between reality and virtuality, fostering a stronger sense of presence within the virtual space (Slater & Wilbur, 1997). Techniques such as photogrammetry, 3D scanning, and cinematic VFX post-production contribute to creating 3D environments that closely replicate the real world, thereby elevating the overall user experience. Combining VFX with XR also enables the development of highly realistic training simulations across various sectors, including healthcare, military, and industrial applications. This integration allows for accurate replication of real-world scenarios, improving the efficacy of training programs by providing immersive and interactive environments where users can safely practise and refine their skills.

Integrating VFX into XR presents significant challenges, primarily due to the high computational demands of rendering real-time, high-quality effects, which necessitate advanced hardware and optimisation techniques. Additionally, creating interactive VFX requires expertise in both VFX production and user-centred design principles crucial to XR. Despite these hurdles, VFX technology holds immense potential for enhancing XR experiences. As hardware improves and developers gain proficiency in merging VFX with interactive environments, we can anticipate XR experiences to become increasingly realistic, emotionally engaging, and responsive. Figure 3.8, illustrating the VFX Graph in Unity, exemplifies how advanced VFX and game technologies can significantly enhance the development of eXtended Reality experiences. The VFX Graph enables developers to create complex visual effects that run efficiently in real-time, which is essential for immersive XR applications. By providing a node-based visual workflow, it simplifies the process of crafting intricate VFX, allowing for greater creativity and efficiency in developing stunning visuals that enhance user immersion.

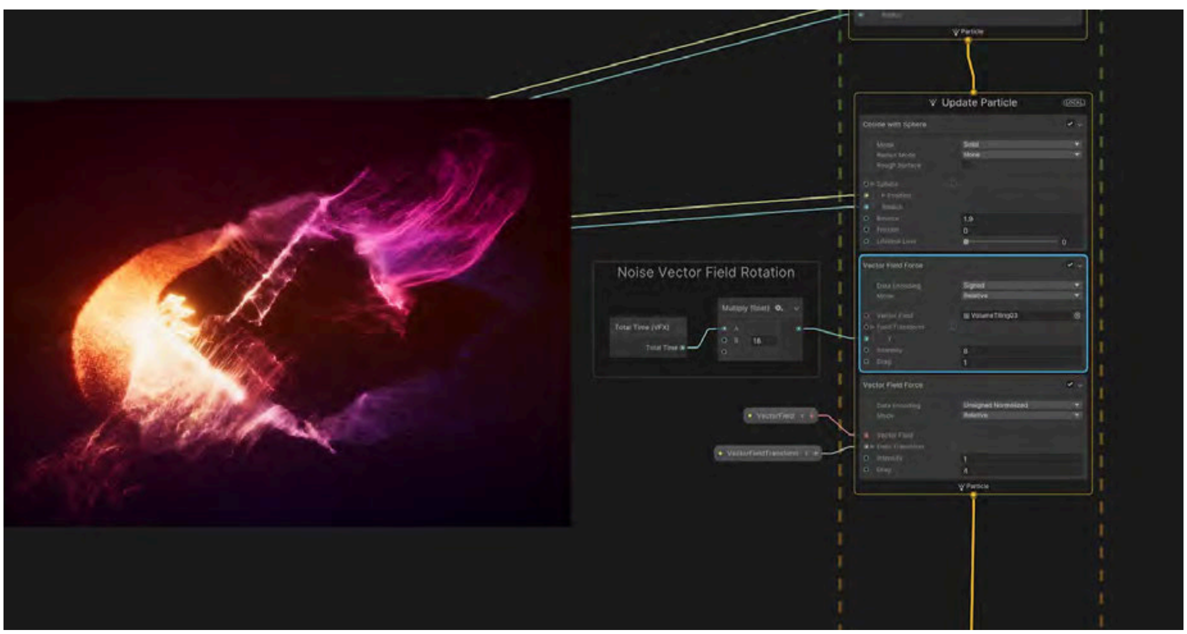


Figure 3.8 - The VFX Graph in Unity.
The SpaceshipHoloTable from the Unity Spaceship Demo, available on [GitHub](https://github.com/Unity-Technologies/SpaceshipDemo?tab=readme-ov-file)
(https://github.com/Unity-Technologies/SpaceshipDemo?tab=readme-ov-file).
Note. This figure was produced by Zachariah, 2022. Taken form
https://unity.com/blog/games/create-spellbinding-visual-effects-with-advanced-vfx-guide

Furthermore, the ongoing AI revolution promises advancements in both hardware and software, further supporting researchers and developers. Figure 3.9 showcases Unity ML-Agents, another game technology that is revolutionising the industry. Unity Machine Learning Agents enable developers to teach agents through deep reinforcement learning and imitation learning, rather than manually coding behaviours. This approach allows for the creation of more sophisticated and compelling gameplay experiences. By integrating intelligent agents that can learn and adapt, XR environments become more dynamic and responsive to user interactions, offering more engaging experiences.

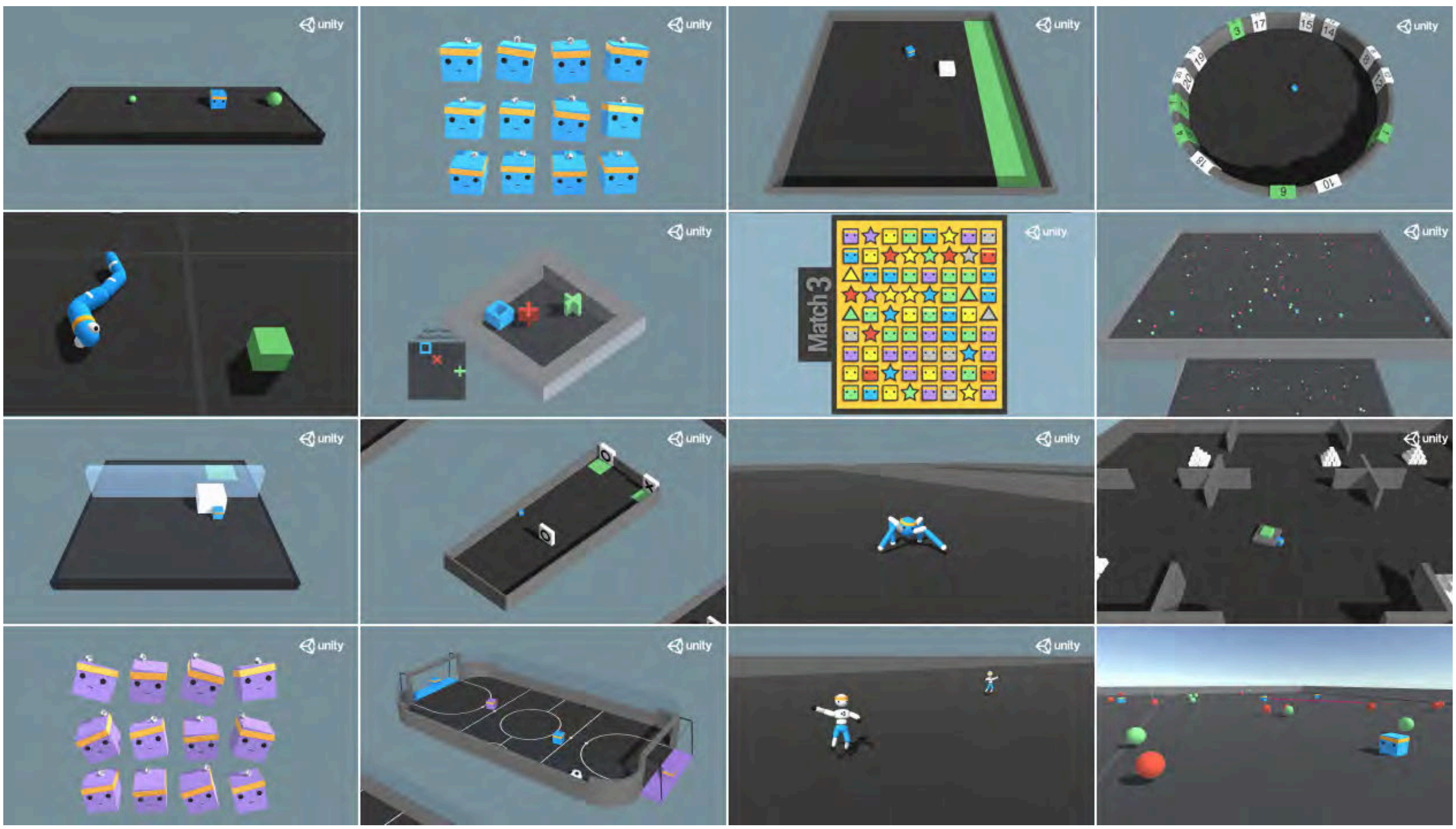


Figure 3.9 - MLAgents example environments.

Source: Unity ML-Agents Toolkit (https://github.com/Unity-Technologies/ml-agents), under this url: https://github.com/Unity-Technologies/ml-agents/blob/main/docs/images/example-envs.png

Copyright 2021 by Unity Technologies.

By leveraging tools like the VFX Graph and ML-Agents, developers can overcome some of the computational and design challenges associated with high-quality, interactive VFX in XR. These technologies contribute to making XR experiences more dynamic, interactive, and lifelike, pushing the boundaries of what is possible in immersive environments. As a result, the fusion of advanced VFX and AI-driven technologies is instrumental in shaping the future of XR, opening new horizons for innovation in interaction design and user experience.

Moreover, advanced lighting techniques and 3D modelling methods—such as UV mapping, displacement mapping, light mapping, and normal mapping—are essential for enhancing the visual fidelity and realism of XR environments. These techniques enable the creation of highly detailed textures, accurate surface representations, and sophisticated lighting effects that contribute significantly to user immersion. For instance, UV mapping allows textures to be applied precisely to 3D models, while normal and displacement maps add depth and detail without excessive polygon counts. Light mapping enhances the realism of lighting within a scene by pre-calculating light interactions. While these technologies substantially elevate the quality of XR experiences, an in-depth discussion of these methods is beyond the scope of this exegesis.

There are numerous other cinematic VFX technologies and game development tools, such as Unreal Engine's Nanite virtualised geometry and Lumen global lighting system capabilities to motion capture systems, that can be leveraged to enhance XR experiences. Additionally, techniques like global illumination, ambient occlusion, and physically based rendering further contribute to creating lifelike virtual environments. Emerging techniques like real-time ray tracing and volumetric lighting further elevate visual realism by simulating complex light interactions and atmospheric effects with high accuracy. Furthermore, advanced shader programming can enable the creation of dynamic materials and effects, such as reflections and refractions, contributing to more immersive and responsive environments. Procedural generation tools also can allow for the creation of vast, detailed virtual worlds with less manual effort, increasing efficiency in content production. However, exploring these in detail falls outside the purview of this document.

3.2.2. Insights from Cinematic Arts and Design

Filmmaking and VFX design can contribute to XR through the art of visual storytelling to engage users emotionally and cognitively. The narrative structures and sophisticated visual language developed in cinema—such as character development, plot progression, thematic exploration, and symbolic imagery—can be adapted to interactive immersive experiences in the XR medium, providing a framework for creating compelling story-driven experiences (Kymäläinen, 2020; Page, 1999). In Table 3.4, I identify and describe the narrative structures, visual language, and design principles of filmmaking art and design that can be used to enhance the narrative depth and emotional engagement of XR experiences.

Table 3.4 - Insights from Cinematic Arts and Design

Title	**Description**	**Key Authors**
Leveraging Cinematic Techniques for XR	Cinematic techniques such as lighting, and camera movement have long been used to guide viewer attention, convey mood, and enhance storytelling. In the context of XR, these techniques can be reimagined to create a sense of presence and immersion, guiding user attention within 360-degree environments and influencing emotional responses through visual cues.	Bordwell et al., 2010. Lee et al., 2013. Mateer, 2017. Takatalo, 2002.
Narrative Structures in XR	The narrative structures developed in cinema offer a blueprint for creating compelling XR experiences. Traditional storytelling techniques, including linear narratives, branching stories, and interactive plotlines, can be adapted to XR to engage users in unique, immersive stories. By employing these narrative frameworks, XR experiences can transport users into magnificently crafted worlds where their choices and interactions contribute to the unfolding story, thereby fostering a deeper connection with the content.	Bruni et al., 2022. Bucher, 2017. Jenkins, 2004. Ryan, 2015.

Integrating VFX Design Principles	Visual effect (VFX) design offers profound insights into enhancing narrative depth and emotional engagement in XR experiences by creating immersive, visually rich environments that foster a strong sense of presence, making users feel part of the story. By symbolising internal states and thematic elements, VFX conveys emotions and supports storytelling, enhancing emotional resonance and providing a more profound user experience. It emphasises directing user attention through subtle cues like light beams, particle effects, or movement, which is essential in XR where users can freely look and move, ensuring engagement with key narrative elements without overt direction. Moreover, a cohesive visual language—with consistent visual style, effects, and environmental details—establishes a believable world, sets the tone, and aligns with the narrative's emotional arc, enhancing the overall impact. Lastly, by experimenting with surreal or fantastical effects, VFX design can evoke sensory and emotional responses such as wonder, curiosity, or discomfort, which is key to creating memorable XR experiences that resonate deeply with users. An example of these principles in action is illustrated in Figure 3.10, which showcases the AUT Marae project designed and developed by the author at AppLab.	Cummings & Bailenson, 2016. Grau, 2004. Jerald, 2015. McDonnell et al., 2012. Slater & Wilbur, 1997. Sanchez-Vives & Slater, 2005.
Emotional Resonance through Visual Storytelling	The emotional power of visual storytelling can be harnessed in XR to create deeply resonant experiences. By drawing on cinematic principles of character development, conflict, and resolution, XR designers can craft experiences that both entertain and provoke thought and evoke empathy. The immersive nature of XR amplifies the impact of these stories, allowing users to experience narratives in a more personal and impactful way.	Coburn, 2001. Mühlhoff, 2019. Slater & Sanchez-Vives, 2016.

Figure 3.10 - Screenshot from *AUT Virtual Marae* VR Project.
This figure depicts how the use of visual effects—such as dynamic lighting, particle effects, and a cohesive visual language—can enhance narrative depth and emotional engagement, creating an immersive experience that deeply resonates with users.
Note. Image created by the author, taken from the side exploration of *AUT Marae Project*.

Techniques such as spatial storytelling, where the environment itself conveys narrative information, and the use of temporal dynamics like pacing and rhythm, help in maintaining user engagement within virtual environments. By thoughtfully designing the virtual space and the events that unfold within it, developers can create XR experiences that are both emotionally impactful and intuitively navigable. Elements such as colour, lighting, and symbolism play crucial roles in evoking emotional responses from the audience. In the context of XR, these visual storytelling principles can be employed to create environments that communicate narrative cues and emotional tones effectively. By manipulating visual elements, XR experiences can guide user attention, suggest mood, and reinforce the thematic content of the narrative.

3.2.3. Lessons from Audio Design for XR Experiences

Sound is a fundamental aspect of immersion, emotional resonance, and narrative cohesion. The integration of cinematic SFX from movies and spatial audio design from video games into XR is important for creating immersive auditory environments that complement visual elements and enhance user engagement (Candusso, 2015; Chandrasekera, 2015; Whittington, 2007). Sound plays a crucial role in shaping the user's perception of virtual spaces, influencing emotions, and providing contextual information within XR experiences. This section explores the adaptation of cinematic SFX and spatial audio design principles to XR, highlighting their importance in crafting compelling, immersive experiences (Rajguru, 2020). Figures 3.11 and 3.12 visually represent the concept that sound can mimic tactile sensations, thereby adding a layer of sensory depth to any visual and auditory experiences. The exploration of haptic auditory design and its implications for creating more intuitive and emotionally resonant XR experiences will be addressed in section 3.2.5.

Figure 3.11 - Sound is Touch.

Note. Image generated by Ali Taheri using Midjourney AI for the visualisation purpose only. No copyright claimed.

Figure 3.12 - Hearing the Texture.
From Microsoft's Sound Design as Sensory Design YT Video, 2019.
Copyright 2019 by Matthew Bennett and Microsoft.

By leveraging techniques such as dynamic audio mixing, environmental reverb, and spatial cueing, XR can create soundscapes that react in real-time to user movements and interactions, enhancing the sense of presence and immersion. Furthermore, the strategic use of silence and ambient sound can serve to heighten emotional tension or provide cues for user engagement, thereby making the virtual experience more intuitive and emotionally impactful. These adaptations allow for a more nuanced auditory landscape, where sound complements visual elements and at the same time plays a critical role in shaping user interaction and perception. These auditory adaptations allow for a more nuanced and layered auditory landscape, where sound complements visual elements and also plays a critical role in shaping user interaction and perception. In storytelling applications, sound can convey subtle narrative details and character emotions that might not be as easily expressed through visuals alone, enriching the overall narrative depth.

Table 3.5 summarises these key insights, illustrating how sound design elements from cinema and video games can be effectively integrated into XR to enhance immersion, emotional engagement, and narrative depth.

Table 3.5 - From Sound Design to XR

Concept	**Description**	**Key Authors**
The Role of Sound in Immersive Environments	Sound effects and spatial audio are instrumental in creating a sense of presence and immersion in virtual environments. They offer signals that assist users in navigating and interacting within the virtual environment, thereby increasing the realism and depth of the experience. In XR, the use of spatial audio techniques allows sound to emanate from specific locations in the environment, mirroring the way sound behaves in the real world. This auditory illusion can significantly enhance the user's sense of spatial awareness and immersion within the virtual space.	Kaplan & Ullmer, 2020. Serafin et al., 2018. The Senses: D... The Sound of Touch
Adaptation of Cinematic SFX to XR	Cinematic sound design history offers a palette of sounds, designed to evoke specific emotions and reactions from the audience. These effects can be adapted to XR to enrich the narrative and aesthetic dimensions of virtual environments. For example, the use of ambient sounds can create a sense of place, while targeted SFX can signal interactions or changes within the virtual space. The challenge lies in seamlessly integrating these sounds into the XR environment, ensuring they are responsive to user actions and the dynamics of the virtual world.	Candusso, 2015. Chaurasia & Majhi, 2023. Grimshaw & Schott, 2018. Kaplan & Ullmer, 2020.

Spatial Audio Design in XR	Spatial audio design, a technique that simulates the three-dimensional characteristics of sound, is critical for achieving a high level of immersion in XR. By employing spatial audio, designers can position sounds in specific locations within the virtual environment, resulting in a more realistic and immersive auditory experience. This approach enhances the believability of the virtual world while also aids in storytelling by using sound to direct user attention and convey emotional content.	Larsson et al., 2019b. Rajguru, 2020 Microsoft 3D S… Using Project Acoustics with HoloLens 2
Using wave physics for interactive acoustics	Project Acoustics is a wave acoustics engine designed for 3D interactive environments, enabling realistic sound effects such as occlusion, obstruction, portaling, and reverberation without manual zoning or resource-heavy ray tracing. It integrates seamlessly with game engines and audio middleware, adopting a philosophy akin to static lighting: complex physics are processed offline, providing a robust physical baseline, while a lightweight runtime with flexible design controls ensures the acoustics meet your artistic goals. Microsoft's next-gen, physics-based acoustical modelling plugin highlights its capabilities and integration.	Hohmann et al., 2024. Jörgensson, 2020. Schröder, 2011. Microsoft Proje…
Emotional Resonance and Atmosphere	Crafting soundscapes can create mood, atmosphere, and emotional resonance in XR experiences. Drawing inspiration from cinematic soundscapes, designers can incorporate ambient sounds, dynamic audio layering, and spatial audio	Chandrasekera et al,. 2015. Chion, 2019. Hruby, 2019. Juslin & Sloboda,

	techniques to create a sense of depth and realism. By utilising ambient sounds XR environments become more immersive and believable.	2011. Kalinak, 2023.
Interactive Audio Design	Creating audio that responds to user actions, mirroring interactive elements in video games and certain movies, introduces an additional engagement layer in XR. Innovations in voice interaction, inspired by AI interactions, can lead to novel voice-based interactions within XR environments.	Collins, 2008. Mohamed et al., 2024. Połap, 2018. Taylor et al., 2009.

Integrating cinematic SFX and spatial audio into XR presents several challenges, including the technical complexity of simulating realistic soundscapes and the need for audio content to adapt dynamically to user interactions and movements within the virtual space. However, these challenges also offer opportunities for innovation in XR audio design, pushing the boundaries of how sound can enhance virtual experiences. Advances in audio technology and algorithms for real-time sound processing and spatialisation continue to expand the possibilities for creating dynamic soundscapes in XR (Z. Gao et al., 2022; Turchet et al., 2023). By drawing from the traditions of cinema and video game development, XR developers can enhance the sensory depth and narrative engagement of virtual environments.

The adaptation of cinematic SFX and spatial audio design principles for eXtended Reality is essential for creating immersive, engaging virtual experiences. Sound design complements the visual elements while at the same time playing a critical role in conveying information, evoking emotions, and enhancing the sense of presence within virtual environments. As XR technology continues to evolve, the integration of advanced audio techniques will remain a key factor in the development of compelling and immersive virtual experiences.

3.2.4. Insights from Interaction Designs in Cinema and Games

Immersive technologies are fundamentally transforming user interaction by fully engaging users' bodies—especially through hand tracking—and seamlessly blending physical and virtual environments. By leveraging natural movements and perceptions, XR technologies can create more intuitive and engaging experiences that transcend traditional interaction paradigms (Jerald, 2015; Slater & Sanchez-Vives, 2016). Hand tracking, for instance, allows users to manipulate virtual objects with almost the same ease and precision as they would in the real world, enhancing the sense of presence and control within the virtual space. Additionally, the integration of spatial awareness and gesture recognition enables more fluid and natural interactions, reducing the learning curve typically associated with new technologies.

The integration of filmmaking and video game design principles into XR interaction design offers a strategic pathway to developing immersive and emotionally engaging experiences. Here I explore the integration of principles from filmmaking and game interaction design into XR, highlighting their potential to enhance user engagement and narrative immersion. The fusion of these disciplines encourages a multidisciplinary approach to XR design, where the strengths of each field are harnessed to overcome the limitations of others. Filmmaking's emphasis on narrative coherence and emotional impact can be combined with game design's focus on interactivity and user control to create XR experiences that are both emotionally compelling and highly interactive. By drawing on the extensive expertise of filmmaking and video game design, XR interaction design can achieve a higher level of sophistication and effectiveness. These interdisciplinary influences enable the creation of XR experiences that are visually and technically impressive and are engaging in narrative depth and emotional resonance. (Jenkins, 2004; Salen & Zimmerman, 2003).

Table 3.6 and 3.7 presents a detailed exploration of how to more explicitly adopt and integrate the principles of interaction design derived from cinema and interactive mediums, integrating them into the immersive sphere.

Table 3.6 - Interaction Design from Cinema

Title	Description	Key Authors
Narrative Engagement	Filmmaking excels in narrative construction, utilising techniques such as camera angles, editing, and sound design to guide viewer attention and evoke emotional responses. In XR, similar techniques can be adapted to direct user attention within immersive environments and enhance narrative engagement. For instance, spatial audio cues and visual effects can signal important narrative elements or interactions, guiding users through the story in a manner that feels intuitive and engaging.	Baur, 2016. Bordwell et al., 2010. Morandini, 2021. Ryan, 2004; 2015.
High Visual Opulence and Intricate Narrative Structures	Visual effects (VFX) play a crucial role in creating believable and immersive cinematic worlds. In XR, the application of VFX techniques can enhance the realism and visual appeal of virtual environments, making them more engaging and immersive for users. Real-time VFX, such as particle effects and lighting, can be used to develop responsive environments that react to user interactions, thereby increasing the sense of presence and the feeling of being there in the virtual world.	Cauquis et al., 2022. H. Kim et al., 2021. Zyda, 2005.
World-Building Strategies	Crafting detailed and believable universes that extend beyond the immediate storyline, providing depth and context. This includes creating histories, cultures, and environments that make the world feel alive. In XR, comprehensive world-building allows users to explore and interact meaningfully with the environment.	Jenkins (2004);
Interaction Metaphors	Incorporating concepts derived from futuristic and sci-fi cinema can serve as foundational models for XR interaction	Cheung & Antle, 2020.

	design, proposing advanced and intuitive paradigms such as gesture-based controls and holographic interfaces. By leveraging the visionary ideas presented in science fiction films, designers can enhance user experiences through more seamless and immersive interaction techniques, thereby advancing the field of XR.	Kang, 2017. Marcus, 2013; 2014; 2015. Troiano et al., 2016.

Table 3.7 - Interaction Design from Interactive Mediums

Title	**Description**	**Key Authors**
Game Design Principles	Game design offers valuable insights into creating engaging and interactive experiences. Principles such as challenge, exploration, and feedback are central to game design and can be applied to XR to enhance user engagement and satisfaction. By incorporating game mechanics and interactive elements into XR environments, designers can create experiences that are not only immersive but also rewarding and fun for users. Furthermore, game design principles can inform the development of XR interfaces that are intuitive and easy to navigate, enhancing the overall user experience.	Bjoerner & Hansen, 2010. Butler, 2014. Deterding et al., 2011. Schell, 2008. Salen Tekinbas & Zimmerman, 2003.
User Agency and Choice	Allowing players to make meaningful decisions that impact the game world or narrative. In XR, this increases immersion and personalization, making users feel their actions have significant consequences, thus enhancing emotional investment. The power of invisible choices can deeply affect the user's experience without explicit instructions.	Andreen, 2017. Nguyen & Ruberg, 2020. Stang, 2019.

Feedback Mechanisms	Critical in video games, feedback loops provide players with immediate responses to their actions. This can include visual, auditory, or haptic feedback, which informs the player about the consequences of their actions, helping them learn and adapt within the game environment. Effective feedback loops are vital for maintaining player engagement and immersion.	de Sales et al., 2022. Hunicke et al., 2004. Lyons, 2015.
Affordances and Signifiers	Interaction design in games often involves the careful placement of affordances—cues that suggest possible interactions—and signifiers—indicators that guide the player on how to interact with these affordances. For example, a glowing object in a game might signal to the player that it can be picked up or used, guiding their interaction in an intuitive way.	Gibson, 2014. Nur Fauzan, 2023. Ocasio, 2019.
Worldbuilding and Immersion - Environmental Storytelling	The worldbuilding techniques in video games, which focus on creating detailed and believable environments, can be effectively applied to the design of virtual spaces in XR. By adapting VFX methods to simulate realistic settings, the immersion and authenticity of XR worlds are significantly enhanced. Additionally, the spatial design and framing principles from filmmaking can inform the layout of XR environments, guiding user attention and promoting intuitive interaction.	Ayyildiz, 2020. Breuleux et al., 2019. Jenkins, 2004. Tarnowetzki, 2015. Urchison & Hays, 2021.

By adopting cinematic techniques, XR environments can direct user attention more effectively and evoke deeper emotional responses. In the practical component of this research, insights were leveraged from the domain of cinema and video games to inform the development of compelling and emotionally resonant interaction designs for eXtended Reality experiences.

While creating the practical elements of this research, I was particularly inspired by the visually rich cinematic techniques employed in films such as *Prometheus* (R. Scott, 2012), *Blade Runner 2049* (Villeneuve, 2017), and *The Fountain* (Aronofsky, 2006), all of which exemplify high visual opulence and intricate narrative structures. Similarly, influential works within the science fiction genre, such as *Foundation* (Asimov, 1951), *Neuromancer* (Gibson, 1984), provided a foundational basis for exploring complex thematic content and world-building strategies using stories. By drawing upon the traditions of video games, XR designers can access a wealth of inspiration and methodologies that elevate the field to new artistic and functional heights. The integration of narrative techniques, visual aesthetics, and interactive elements from the gaming industry into XR can significantly enhance user engagement, narrative immersion, and emotional resonance. The interactive dynamics and immersive storytelling techniques from video games such as *Journey* (Thatgamecompany, 2012), *The Witness* (Blow, 2016), and the VR title *Half-Life: Alyx* (Valve, 2020) significantly contributed to the design considerations as they offered practical insights into user engagement and narrative depth in XR environments. As XR technology continues to evolve, the synergy between these fields will undoubtedly play a pivotal role in shaping the future of interactive and immersive media. This evolving integration promises not only to enhance the technical capabilities of XR systems but also to deepen the emotional and narrative connections that users forge with the virtual environments they explore.

3.2.5. The Role of Affect in Communication Media

The concept of affect in immersive interactive media can be a multifaceted domain that intertwines narrative, visual, auditory, and editorial techniques to create a compelling emotional experience. The following discussion analyses how ‘affect’ influences our experiences across different media platforms, including filmmaking, immersive media, and computing. The exploration highlights how affect serves as a crucial bridge between emotion and technology that can enhance sensory experiences. The discussion further examines specific applications of affect, such as cinematic haptic visuality and its integration within XR environments, to provide a comprehensive understanding of how affective dynamics enhance interactions across various domains.

Affect, which refers to the experience of feeling and emotion, occupies a central place across various communication media, profoundly influencing audience experience by bridging sensory inputs with emotional responses (Lünenborg & Maier, 2018). Affect serves as a bridge between the sensory experiences provided by these media and the emotional responses they elicit from their audiences or users (Hipfl, 2018).

In the philosophy of mind, affect is understood as the sensations of feelings or emotions, which are pivotal to grasping how the mind processes and perceives emotional experiences (Marg, 1995). The concept of affect is essential for understanding the processing and perception of emotional experiences within the human mind.

The term 'affect' in the context of this research is used to refer to the capacity of visuals, sounds, and environmental design to evoke emotional and sensory responses in viewers, thereby influencing their perceptions and experiences (Marks, 2002). Affect operates on a visceral and subjective level, aiming to provoke contemplation, unease, and heightened awareness of the content and its impact on individuals (Shaviro, 2010). It is employed as a means to recalibrate perceptions, disrupt habitual encounters with the world, and facilitate a reconnection with the content (Denton, 2016; Massumi, 2021).

The essence of emotional storytelling in cinema lies in its ability to forge a deep connection with the audience, guiding them through complex emotions such as love, sacrifice, and grief. This is achieved through narrative arcs, character development, and thematic resolutions that resonate on a personal level (Plantinga, 2009). Visual aesthetics and colour theory further enhance this connection by using colour, lighting, and composition strategically to influence mood and narrative tone (Bordwell et al., 2010). Sound design and music add another layer of emotional depth, creating an immersive sensory experience that amplifies the narrative's impact. Together, these elements—storytelling, visual aesthetics, sound, and editing—work in harmony to create a nuanced and emotionally resonant cinematic experience.

In *The Skin of the Film* (2020), Marks and Polan investigated how affect transcends linguistic and cultural boundaries, engaging viewers on a sensory level to elicit profound emotional reactions. Similarly, Shaviro (2010) explored how modern films and media elicit visceral, subjective, and emotional responses, challenging conventional narratives and showcasing the affective power of audiovisual media.

In a practical example, Kuchelmeister et al. (2018) illustrated how immersive VR experiences can cultivate empathy and enhance awareness by immersing users in emotionally charged environments. This innovative use of immersive media highlights the significant role of affect in deepening emotional engagement, thereby opening new avenues for storytelling and artistic innovation in VR.

The integration of affect into computing, termed affective computing by Picard (1999), marks a paradigm shift in the design and interaction of Human-Computer interfaces. This field combines the analytical capabilities of machines with the nuanced spectrum of human emotions, enhancing the interaction between humans and technology by enabling machines to detect, understand, and respond to human emotions. The current section explores the evolution and implications of affect in computing, emphasising its role in creating more empathetic and intuitive technological experiences.

Affective computing developed from recognising emotional intelligence as a vital aspect of human interaction and decision-making. It draws from two primary theoretical models; cognitivism and phenomenology (Hudlicka, 2003). Affective gaming integrates principles of affective computing to create more emotionally engaging and responsive game environments. Hudlicka (2008) explored how affective computing can be leveraged in game design to enhance player experience by recognising and responding to the emotional states of players. Phenomenological approaches, on the other hand, highlight the relational and contextual nature of emotions, suggesting that emotions emerge from interactions with the environment, including interactions with machines (Boehner et al., 2005).

In summary, by evoking emotional and sensory responses, affective elements provoke reflection and disrupt habitual interactions, fostering a stronger connection with the content. This foundational understanding of affect sets the stage for exploring affective interaction, where emotional dimensions are further integrated into design to create more intuitive and meaningful user experiences.

Affective Interaction and Sensory Experiences

From the outset of my research, I was guided by the feeling that the realm of emotion offers superior potential for communication compared to other methods of storytelling. This belief has driven me to explore the concepts of affect and emotion through cinematic, technological, and cognitive lenses. Leveraging my background and tacit expertise in visual art, my investigation focuses on how affective elements—such as visual aesthetics, sound design, and environmental cues—can be strategically employed to evoke profound emotional and sensory responses within XR environments. Affective computing further enhances this approach by enabling XR systems to recognise and respond to users' emotional states, allowing for real-time adaptation and personalised interactions that deepen user engagement. This technological integration aligns with the principles of 4E+ Cognition by emphasising the seamless interaction between the user's physical presence, environmental context, emotional state, and cognitive processes within the virtual experience.

By blending insights from affect in cinema, affective computing, and the 4E+ Cognition framework, my research aims to establish a framework and design principles that can guide practitioners to develop such XR interactions that are intuitive, emotionally engaging, and cognitively seamless. This transdisciplinary integration underscores the importance of emotion in enhancing the sensory and cognitive dimensions of XR.

Affective interaction can mark a paradigm shift in the field of Human-Computer Interaction, moving beyond the confines of traditional computing to embrace a more holistic view of emotions as dynamic, embodied, and socially constructed phenomena (Lottridge et al., 2011). This approach seeks to foster a deeper, more nuanced understanding of the interplay between technology and human emotional experience, challenging conventional models and advocating for systems that reflect the complexity and richness of human affect (Fagerberg et al., 2004; Sundström et al., 2005).

At the heart of affective interaction lies the concept that emotions transcend the individual psyche, intricately weaving together our physical existence, social interactions, cultural contexts, and fundamental worldviews. This perspective challenges conventional views of emotions as mere internal states, advocating for a broader understanding that considers the external influences shaping emotional experiences. Emotions are recognised as fluid and subject to individual interpretation, thereby necessitating the development of systems capable of accommodating a diverse range of emotional states and recognising the subjective variability inherent in emotional experiences. This kind of affective interaction critiques the reduction of emotions to simple models, advocating for a holistic approach that respects emotional complexity (Lottridge et al., 2011). It emphasises user-centric design, enhancing users' understanding and experience of their emotions. Affective interaction emphasises the importance of sensory and contextual elements in shaping emotional experiences. Hence, authentic VR experiences that consider users' attachments and emotional engagements can significantly influence affective responses, making interactions more meaningful and impactful (Lavoie et al., 2021; Lavuri & Akram, 2024; Villani et al., 2009).

Harnessing Haptic Visuality-Auditory for XR

Noel Burch first introduced the concept of *haptic space* to describe cinema's ability to create spatial illusions, particularly evident in the early works of Lumière and Méliès as well as in experimental cinema. In his influential article Burch (1990) emphasised the tactile quality of film images and the spatial composition techniques used in early films, which engage audiences not only visually but also through their sense of touch. He argued that the creation of haptic space transforms the audience into motionless voyagers who navigate the film's spatial dimensions (Burch, 1990). That being said, in interactive media, this concept evolves as the voyager becomes participatory, allowing users to engage actively within the haptic space.

Building on Burch's foundation, Marks (2002) further developed the concept through her notion of *haptic visuality*, which delineates a mode of perception that transcends conventional visual observation to resemble touching or feeling. Contrary to the traditional emphasis on a remote, purely optical visuality, haptic visuality promotes a deeply sensual, embodied interaction with visual media. In the context of cinema, this paradigm is frequently manifested through the employment of cinematic techniques such as close-ups, soft focus, and the incorporation of textured imagery, all of which are designed to invoke tactile sensations, foster a sense of intimacy, and heighten bodily consciousness.

Haptic visuality or auditory stimuli can have a physical effect on the body, causing hair to raise in the arms—a physiological response commonly known as goosebumps. This phenomenon occurs when the tiny muscles at the base of hair follicles contract, often in response to emotional stimuli such as awe, fear, or profound aesthetic experiences (Craig, 2005; McPhetres & Zickfeld, 2022). In the context of communication media, this phenomenon can be elicited when viewers become deeply immersed, experiencing visceral reactions to the content they are engaging with. This physiological response underscores the potency of haptic visuality in evoking tactile sensations without physical contact. The combination of visual cues that suggest texture and depth with auditory elements that resonate physicality can create a multisensory experience that engages the viewer's body and mind. Building upon the concept of haptic visuality and auditory, we can examine how these principles can be applied in the realm of eXtended Reality, where multisensory experiences are integral. By integrating multisensory stimuli, XR designers engage more than just the visual sense, incorporating elements that appeal to touch, sound, and even smell. This multisensory approach enriches the user's engagement with the content, blurring the boundaries between the viewer and the viewed, and fostering a more intimate and immersive connection with the virtual environment. Haptic visuality can play a crucial role in creating immersive experiences in XR. The integration of tactile and multisensory elements not only enriches XR experiences but also bridges the gap between virtual and physical worlds, offering profound implications for future media and design.

Affect, Haptic Space, Involvement, Immersion, Grounding, AND Presence

The concept of ‘*presence*’ is fundamental in understanding user experiences within immersive interactive mediums. Presence, often defined as the sense of ‘being there,’ refers to the phenomenon where users behave and feel as if they are physically present in a virtual environment created by computer displays (Riva et al., 2003; Slater & Wilbur, 1997). It is a state of consciousness that intertwines with immersion, where immersion involves the degree to which the sensory experience of the physical reality is overridden by the virtual environment, and grounding refers to the integration of the user's physical actions and interactions within the virtual space (Sanchez-Vives & Slater, 2005).

Presence is a complex, multi-dimensional construct that encompasses several components, including but not limited to *Spatial Presence*, *Involvement*, and *Judgement of Realness*, in addition to *Immersion* and *Grounding*. Spatial presence pertains to the feeling of being physically located within the virtual environment, involvement relates to the emotional and cognitive engagement of the user, and judgement of realness is the user's assessment of the virtual environment's authenticity and believability (Skarbez et al., 2017).

Immersion describes the degree to which the sensory experience of the real world is replaced by the sensory simulations of the medium (i.e. virtual environment). Grounding involves the integration of the user's physical actions and interactions with the medium through responsive feedback loops, thereby facilitating a seamless connection between the user and the simulation (Lottridge et al., 2011). These components collectively drive the effectiveness of virtual environments by enhancing user engagement, emotional resonance, and the overall immersive experience (Cummings & Bailenson, 2016).

In the evolving landscape of immersive interactive mediums, affect can play a crucial role in creating emotional engagement (one of the aspects of the user’s involvement). Affective interaction plays a pivotal role in achieving a heightened sense of presence by strategically incorporating emotional and sensory elements into XR experiences.

The essence of XR lies in its ability to transcend traditional mediums' boundaries, offering users an unparalleled sense of presence, which in the XR medium can be defined as the amalgamation of immersion and grounding, with the addition of involvement and judgement of realness. To achieve this, designers and creators must meticulously consider how each element within the XR environment—visual, auditory, haptic, and interactive—contributes to the overall emotional journey of the user. Incorporating haptic visuality and haptic auditory can further enrich the strategies for achieving presence by emphasising the tactile and embodied aspects of visual perception.

Furthermore, Kuchelmeister et al. (2018) highlighted the efficacy of VR as an affective medium by examining the relationship between presence and emotions. Their study demonstrated that interacting with emotionally charged virtual environments—designed to evoke anxiety and relaxation—successfully induced corresponding emotional states in users. The findings also revealed a bidirectional relationship between presence and emotions: heightened feelings of presence amplified emotional responses, while the users' emotional states enhanced their sense of presence within the virtual environment. This circular interaction underscores the importance of affective elements in creating immersive experiences that are both emotionally engaging and authentically present.

The integration of multiple sensory modalities greatly aligns with the principles of 4E+ Cognition and emphasises the seamless interaction between the user's physical presence, environmental context, and cognitive processes within the virtual experience (Schubert et al., 1999; Willans et al., 2016). This integration of multiple sensory modalities is fundamental to achieving a high degree of emotional engagement in XR. Visual elements, while critical, represent just one facet of the immersive experience. Auditory cues, from subtle environmental sounds to dramatic musical scores, can significantly amplify the emotional intensity of a virtual environment. Interactive elements, particularly those that allow for naturalistic engagement with the virtual environment, further deepen the emotional impact by providing users with a sense of agency and presence.

Employing haptic visuality-auditory can enhance spatial presence and immersion. For example, utilising detailed textures and visually rich environments can invoke a tactile response, making virtual objects feel more tangible and real. This visual tactility enhances the user's embodied experience, allowing them to 'feel' the virtual space through visual and auditory cues alone. While achieving haptic sensation through visual and auditory elements is preferred, incorporating some degree of subtle physical haptic feedback, if possible, offers a tangible connection to digital worlds, grounding users' experiences in physical reality and heightening emotional responses. Together, these elements coalesce to create a multi-sensory experience that can evoke a broad spectrum of emotions, from awe and wonder to tension and fear.

Achieving a sense of presence is a primary objective for XR developers and content creators, as it significantly enriches user engagement, immersion, and overall enjoyment within virtual environments (Diemer et al., 2015). Through the thoughtful integration of sensory elements, XR designers have the opportunity to create emotional landscapes that engage users on multiple levels. As the field of XR continues to mature, the nuanced understanding of affect and its application in design will undoubtedly lead to innovations that enhance the emotional richness and depth of immersive experiences, setting new benchmarks for engagement in the digital realm.

3.2.6. Bringing it All Together

The convergence of cinematic arts and video game design in XR advances immersive, emotionally engaging experiences. By merging cinema's narrative depth and visual sophistication with the interactivity and user agency of video games, XR designers can create affective environments and tell emotionally engaging stories. Cinematic elements like advanced VFX and haptic visuality enhance realism and emotional resonance, creating lifelike virtual worlds and a stronger sense of presence. Video games contribute interactive narratives and world-building, personalising XR experiences as user choices shape outcomes. Embodied interaction emphasises physical engagement, augmenting sensory dimensions, while advanced sound design crafts auditory environments that influence emotions.

Leveraging technologies like AI-enhanced tools and advanced lighting allows for complex virtual worlds, pushing immersion and realism. Affective interaction bridges emotion and technology; through the use of visual aesthetics, sound design, and environmental cues, designers evoke profound emotional responses. Concepts like haptic visuality engage users tactilely through stimuli, deepening immersion. In summary, the fusion of cinematic arts and video game design enriches XR by creating multi-sensory experiences that engage users emotionally, cognitively, and physically. This interdisciplinary integration enhances narrative depth, emotional resonance, and interactive engagement, leading to more immersive and meaningful XR experiences. By harnessing the strengths of both fields, XR designers are expanding the possibilities for storytelling and user interaction in virtual environments, shaping the future of immersive media.

As I continue to innovate within this space, the insights gained from cinema and gaming will undoubtedly serve as a cornerstone for future developments in XR. By honouring the distinct capabilities and contributions of these mediums and thoughtfully integrating them, I aim to create XR experiences that are not only technologically advanced but also emotionally resonant and narratively engaging. The continuous interplay between these fields, along with a deep appreciation for their unique qualities, will be essential in shaping the future of immersive technologies.

3.3. HCI's Contribution to XR Experience and Interaction Design

Human-Computer Interaction (HCI), User Experience (UX), Interaction Design (IxD), and User Interface (UI); draw on diverse disciplines, including technology, psychology, philosophy, design, and cognitive science, to create interactive systems that resonate with human needs (Carroll, 2003; Hassenzahl & Tractinsky, 2006; Norman, 1988/2013; Wright & McCarthy, 2004). Integrating cognitive, psychological, philosophical, emotional, and even spiritual dimensions into HCI enhances the human experience (Carroll, 2003; Kaptelinin & Nardi, 2009). Such integration strives to bridge the gap between humans and digital technologies by developing interfaces that go beyond mere functionality.

Within HCI itself, this widening of concerns is often described as a movement beyond the earlier, predominantly task- and efficiency-oriented paradigms toward approaches centred on lived experience, meaning-making, and situated practice. Bødker (2006) describes this shift as part of a third wave of HCI, while Harrison, Tatar, and Sengers (2007) argue that different paradigms of HCI imply different assumptions about what counts as knowledge, what design should optimise, and what values are at stake. In this context, a humanistic orientation has become increasingly visible—one that treats aesthetics, ethics, culture, and interpretation as legitimate dimensions of HCI research and design, rather than as secondary 'soft' considerations (Bardzell & Bardzell, 2016; Wright & McCarthy, 2004). I frame this as a third way of HCI: an approach that neither reduces XR design to positivist optimisation and measurement alone, nor remains at the level of critique without making. Instead, it treats design practice itself as a mode of inquiry, where artefacts and experiences are both outputs and arguments—material propositions about what forms of attention, agency, and meaning our technologies cultivate (Harrison et al., 2007; Wright & McCarthy, 2004).

The emergence of eXtended Reality marks a new era for HCI and Interaction Design. XR offers immersive experiences that can either fully immerse users in the virtual world or seamlessly blend the digital (virtual) and physical realms, making interactions more intuitive, instinctual, and 3D (Bowman & McMahan, 2007; McMahan et al., 2006). In this new 3-dimensional world of HCI, cognitive dimensions such as attention and memory are crucial for crafting interfaces that optimise cognitive engagement.

According to Sweller (1988), excessive information processing demands can lead to cognitive overload, hindering the user experience. Effective 3D HCI design must balance immersive content with the user's cognitive capacity to prevent overwhelm and promote sustained engagement (LaViola et al., 2017). Additionally, usability evaluations in AR and VR also highlight the necessity of optimising cognitive engagement while preventing overload (Dey et al., 2018).

XR's potential for storytelling, education, and cultural exploration is significantly augmented by its capacity to engage users emotionally. The affective and emotional dimension of HCI is particularly important in XR, where the immersive nature can elicit strong emotional responses. Research into affective computing and emotional design guides the development of XR experiences that create positive emotional connections, enhancing user engagement and enriching the overall experience (Picard, 1997, 1999).

While HCI addresses the broader aspects of interaction between humans and computers, IxD specifically concentrates on the creation of engaging and intuitive interfaces characterised by well-thought-out behaviours and actions. Effective interaction design leverages technology and the principles of effective communication to shape user experiences that are both satisfying and efficient. This includes the application of established design philosophies such as Donald Norman's principles of design, which emphasise key elements like visibility, feedback, constraints, and consistency in interface design (Norman, 1988/2013).

Philosophical approaches in HCI provide a framework for questioning and critically reflecting on design practices. By integrating philosophy into HCI, designers and researchers can examine the underlying assumptions and values implications of technology (Harrison et al., 2007). This critical reflection enables a deeper understanding of how interactive systems influence human behaviour, societal norms, and cultural values. For instance, ‘phenomenology’ in HCI focuses on users' lived experiences, emphasising the subjective perception of interacting with technology (Dourish, 2001). This approach encourages designers to create interfaces that align with natural human behaviours and thought processes, leading to more intuitive and meaningful user experiences.

Another example is the ‘distributed cognition’, which has important implications for understanding human cognition particularly in the field of HCI. Distributed cognition challenges the notion of the isolated mind, highlighting the interdependence of human cognitive processes with the social and material world (Hollan et al., 2000). This perspective highlights how cognitive processes are distributed across a system comprising humans and technology. By understanding how information flows through this system, designers can develop interfaces that better support collaborative work and complex problem-solving.

The 4E+ Cognition approach is another example here, it signifies a paradigm shift from viewing interaction as merely a cognitive process to acknowledging the intricate interplay between mind, body, and environment, while also incorporating emotional and socio-cultural dimensions (Aguayo, 2023; Goodwin & LeBaron, 2011). The 4E+ framework challenges traditional cognitivist perspectives by emphasising that cognitive processes are deeply intertwined with bodily actions, environmental contexts, and affective states (Gallagher, 2017; Newen et al., 2018).

3.3.1. History of HCI

The field of HCI has evolved significantly since its beginning, with roots tracing back to the early days of computing in the 1960s. Initially focused on optimising the efficiency and usability of computer systems, HCI has expanded to encompass a user-centred design approach, emphasising the importance of understanding user needs and experiences (Karat & Karat, 2003). Notable milestones include the development of the graphical user interface (GUI), which revolutionised the way users interact with computers, making technology more accessible to the general public (Johnson et al., 1989).

The journey of HCI is a compelling narrative that mirrors the evolution of computing technology and its burgeoning role in human life. This narrative is a testament to the interdisciplinary confluence of computer science, cognitive psychology, design, and ergonomics, each contributing to the development of interfaces that facilitate effective, efficient, and enjoyable interactions between humans and computers. Table 3.8 below presents a detailed overview of the history of HCI, tracing its origins and evolution from the 1960s to the present day.

Table 3.8 - HCI History

Title	Description	Key Authors
Origins and Evolution	The genesis of HCI began in the 1960s with large mainframe computers requiring specialised knowledge. A paradigm shift towards personal computing aimed to democratise access, highlighted by Ivan Sutherland's Sketchpad (1964), which introduced user-friendly interfaces and direct interaction with graphical objects on a screen using a light pen. This innovation established foundational principles for graphical user interfaces (GUIs) and direct manipulation, central to HCI.	Sutherland, 1964.
Graphical User Interface (GUI)	In the 1970s and 1980s, HCI advanced significantly with the WIMP (windows, icons, menus, pointer) paradigm. The Xerox Alto, developed at Xerox PARC, introduced key elements like the graphical user interface, mouse, and desktop metaphor. Apple's Lisa and Macintosh computers in the 1980s commercialised these concepts, popularising GUIs and marking a milestone in the accessibility and adoption of personal computing.	Johnson et al., 1989.
User-Centred Design and Usability	In the late 1980s and 1990s, HCI shifted to a user-centric focus, emphasising usability testing and user needs. Jakob Nielsen and Donald Norman contributed significantly with their work on usability heuristics and the psychology of everyday objects. The establishment of international ergonomic standards (ISO 9241) during this period highlighted the importance of user well-being and satisfaction in HCI design.	Nielsen, 1994. Norman, 1988/2013.
The Rise of the Web and Ubiquitous Computing	The new millennium expanded HCI's scope with the rise of the web and ubiquitous computing, requiring new design approaches for interactive web applications and social networking. The launch of Apple's iPhone in 2007, featuring	Abowd & Mynatt, 2000.

	multi-touch technology, revolutionised HCI by introducing new gestures and natural user interfaces.	
HCI in the Era of XR and the 4IR	Today, HCI integrates advanced technologies like virtual and augmented reality, voice and natural language processing, and artificial intelligence into daily interactions, focusing on creating immersive, accessible, and personalised experiences.	Rose, 2014.

The historical trajectory of HCI underscores its continuous evolution, driven by technological innovations, changing user needs, and a profound understanding of human factors that influence interaction design. From the inception of user-friendly graphical interfaces to the sophisticated, multi-modal interactions of the present day, HCI remains at the forefront of shaping human engagement with digital technology. It strives to render these interactions more intuitive, efficient, and meaningful, ensuring that technology serves to enhance, rather than detract from, the human experience.

3.3.2. The Contribution of Technological Advancement to HCI

Over the years, various technologies have played pivotal roles in advancing HCI. Touchscreens, for instance, have made digital interfaces more intuitive, while VR and AR technologies have opened new dimensions for immersive user experiences (Billinghurst et al., 2015; Bowman & McMahan, 2007). More recently, advancements in AI and ML have enabled more personalised and adaptive interfaces, further enhancing user interaction with digital systems (Amershi et al., 2019; Shneiderman, 2020).

The evolution of HCI is intrinsically linked to technological advancements, each wave of innovation bringing us closer to more natural, intuitive, and human-centric forms of interaction. From the inception of graphical user interfaces to the advent of immersive eXtended reality, technology has continually reshaped our interaction paradigms, making digital experiences more accessible and aligned with human needs and capabilities (see Table 3.9 below for detailed technological advancement in HCI).

Table 3.9 - HCI Technological Advancement

Title	**Description**	**Key Authors**
Graphical User Interfaces: A Paradigm Shift	The development of graphical user interfaces (GUIs) in the 1970s and 1980s marked a pivotal shift in HCI, moving from command-line interfaces to visual metaphors and direct manipulation. This period, highlighted by Douglas Engelbart's introduction of the mouse and the Xerox Alto's GUI, democratised computing for a broader audience, laying the groundwork for the desktop computing paradigm and fundamentally changing human-digital interaction.	Johnson et al., 1989. Myers, 1998.
Personal Computing and the Web	The emergence of personal computing devices, notably the Apple Macintosh, further propelled HCI by introducing computing to the masses. This period saw rapid advancements in hardware and software, including the proliferation of personal computers and the advent of the World Wide Web, expanding the scope and impact of HCI. The development of multimedia capabilities enriched digital content, offering more engaging and interactive experiences.	Berners-Lee et al., 1994.
Touchscreens and Mobile Computing	The advent of touchscreens, gesture recognition, and voice interfaces introduced more natural and intuitive forms of interaction, which have since become commonplace in our daily lives. The rise of mobile computing, through smartphones and tablets, transformed our interaction with digital content, emphasising the need for HCI to cater to mobility, immediacy, and context-awareness.	Buxton, 2010. Wigdor & Wixon, 2011.

The Internet of Things (IoT)	The IoT era has embedded computational capabilities into everyday objects and environments, challenging HCI to design seamless and integrated interactions. This ubiquity of connected devices makes technology more ambient and invisible, weaving digital interactions into the fabric of daily life.	Kuniavsky, 2010.
Artificial Intelligence and Personalisation	Advances in AI and machine learning have begun to enable more personalised and adaptive interfaces, capable of learning from and responding to individual user behaviours and preferences. This shift towards user-centric design paradigms represents a move towards technology that anticipates user needs and offers tailored experiences.	Shneiderman, 2020.
XR and Beyond	Looking forward, XR technologies, including VR, AR, and MR, promise to redefine the boundaries of digital experiences, offering new ways to learn, work, and play. These technologies challenge HCI to design experiences that are immersive yet accessible and meaningful, merging the physical and digital worlds.	Flavián, et al., 2019. Ivanov, et al., 2022. Jerald, 2015.
Bio-Interactive Technologies and Future Frontiers	The future of HCI may involve bio-interactive technologies, including but not limited to brain-computer interfaces (BCIs), that interpret biological signals for new forms of interaction, and advancements in quantum computing and nanotechnology, which could revolutionise computing power and interface design, offer new possibilities for HCI research and applications.	Fairclough, 2017. Tan & Nijholt, 2010.

The trajectory of HCI technologies presented above underscores a journey towards creating interactions that are more aligned with human needs and that are intuitive and immersive. As technology continues to evolve, the challenge for HCI lies in leveraging these innovations to enhance the human experience. The future of HCI is set to evolve by both responding to and foreseeing user needs, creating interactions that are technologically sophisticated yet profoundly connected to our human experience.

3.3.3. Philosophical Discussions in HCI

This section explores key philosophical traditions and methodologies that have significantly impacted HCI, highlighting their importance and application within the field. HCI is a multidisciplinary field that integrates diverse philosophical discussions to deepen its theoretical and practical foundations. These philosophical perspectives provide critical insights into the design, implementation, and implications of technology. Philosophical discussions in HCI involve rigorous analysis and contemplation of the core principles, ethics, and ideologies that underpin the field. This philosophical engagement influences our perceptions of design, technology, human nature, and their interconnections. Philosophy brings a depth, variety, and interpretative flexibility that can greatly enhance HCI, anchoring it in a thorough understanding of human experience, ethical considerations, and the broader societal impacts of technology (Fallman, 2011; Harrison et al., 2007).

Philosophical engagement has also become increasingly central to what is often described as third-wave HCI, where the field's attention shifts from narrowly task-centred performance toward questions of experience, meaning, values, and situated cultural practice (Bødker, 2006; Harrison et al., 2007). In this paradigm, HCI does not treat interpretation, aesthetics, and ethics as peripheral concerns but as core components of how interactive systems are designed and evaluated. This orientation resonates with humanistic HCI, which explicitly legitimises philosophical, cultural, and interpretive modes of inquiry as essential for understanding what interactive technologies do to us—and who we become through them—rather than only what they allow us to do efficiently (Bardzell & Bardzell, 2016; Wright & McCarthy, 2004).

The field of technology, in this context HCI, and philosophy has a visible track record of successfully merging into each other across various domains, fostering a deeper understanding of both disciplines (Mitcham 1994/2022; Poel, 2020; Su et al., 2019). For example, Winograd and Flores (1986) advocate for a design approach grounded in linguistic and cognitive theories, highlighting the importance of context and meaning in the development of interactive systems. Similarly, Dourish (2001) emphasises the role of embodiment in HCI, drawing on phenomenological insights to argue that interaction is fundamentally situated and action-oriented. This aligns with Merleau-Ponty's (2013) phenomenology, which posits that human experience is rooted in bodily engagement with the world, thereby influencing the design of more intuitive and immersive user interfaces.

Furthermore, some philosophical discussions around HCI engage deeply with the concept of humans as tool-making animals. This perspective underscores the intrinsic human drive to create and utilise tools, shaping our evolution and technological advancements. Kevin Kelly (2010) extended this idea by suggesting that technology constitutes the real skin of our species, highlighting how deeply integrated technology is with human identity and functioning. Moreover, technology can be considered as an extension of our nervous system, a notion that manifests the concept of the extended mind. Cognitive philosophers Clark and Chalmers (1998) described technology as scaffolding that augments our cognitive capabilities, extending our thoughts, reach, and vision. This symbiotic feedback loop between humans and technology has existed since the dawn of our species, demonstrating that our tools are not merely external aids but integral components of our cognitive processes. Thus, integrating philosophical insights into HCI provides a more nuanced understanding of our interactions with technology, emphasising its profound role in shaping human experience and cognition.

Among the myriad of discussions in HCI, several prominent philosophical frameworks stand out for their profound impact on the field. These include, but are not limited to, phenomenology and pragmatism, Human-Computer symbiosis, embodied cognition and enactivism, the 4E+ approach, technology as an extension of the mind, and Sufism-inspired

HCI. Each of these frameworks offers unique contributions that capture how we understand and interact with technology in increasingly complex and interconnected environments. Table 3.10 provides an exploration of the various philosophical frameworks prevalent in HCI.

Table 3.10 - Philosophical frameworks in HCI

Category	**Description**	**Key authors**
Phenomenology	Phenomenology emphasises the significance of the user's lived experience with technology and the embodiment of consciousness. This approach emphasised the embodied nature of perception, arguing that our understanding of the world is fundamentally linked to our bodily experiences. This perspective is crucial in HCI for understanding how users perceive and interact with technological artefacts. The concepts of ‘ready-to-hand’ and ‘present-at-hand’ influence HCI, describing technology that seamlessly integrates into activities or demands attention during issues, respectively. Winograd and Flores (1986) and Dourish (2001) have applied these ideas to promote intuitive interfaces like touchscreens and wearables that reduce cognitive load and blend naturally into user environments, enhancing human-technology interaction.	Dourish, 2001. Merleau-Ponty et al., 1962/2013. Su et al., 2019. Svanæs, 2013. Prpa et al., 2020. Winograd and Flores, 1986.
Pragmatism	Pragmatism argues that the value of an idea or tool lies in its practical effects and its ability to solve problems and enhance human life. In HCI, this perspective encourages designers to consider the practical benefits of technology and its role in enriching	Su et al., 2019. Svanæs, 2013. Winograd and Flores,

	users' lives. Integrating these philosophies in HCI research promotes the design of technologies that are intuitive, user-centred, and capable of enhancing the overall quality of life, thereby fostering more meaningful interactions (Winograd & Flores, 1986; Svanæs, 2013). Pragmatism and Phenomenology both value direct experience, but Pragmatism is more concerned with the outcomes of actions and how ideas function in practice.	1986. Wright & McCarthy, 2004.
Human-Computer Symbiosis	Inspired by thinkers like Licklider, this concept envisions a partnership between humans and computers where both complement each other's strengths. Licklider (1960) proposed that humans and computers could work collaboratively to solve complex problems, with computers handling routine calculations and data processing while humans focus on creative and strategic tasks. These philosophical debates explore how such symbiosis affects human identity, capability, and evolution. Margulis (1970), proposed the endosymbiotic theory, explaining how eukaryotic cells evolved through symbiotic relationships between different microorganisms. Her ideas emphasise cooperation and integration, which can be analogously applied to the synergy between virtual agents and also between humans and computers in HCI. Ventrella explores virtual reality environments inspired by Margulis biological processes, suggesting that principles of cellular symbiosis can inform the design of immersive, interactive systems in HCI.	Archibald, 2011; 2015. Gray, 2017. Licklider, 1960. Margulis, 1970. Ventrella, 1995.

Cognitive Psychology	Cognitive psychology contributes to HCI by providing insights into how users process information, make decisions, and solve problems. Understanding cognitive processes helps in designing interfaces that align with human memory, attention, perception, and problem-solving capabilities, leading to more effective and user-friendly designs.	Card, 2018. Huesmann, 1984. Olson & Olson, 2003. Su et al., 2019.
Embodied Cognition and Enactivism (4E+)	Recent advances in embodied cognition and enactivism, drawing from Maturana and Varela's (1980) autopoiesis theory, have enriched HCI by emphasising the interplay between bodily engagement and the environment (Shapiro, 2019). This approach views cognition as a product of dynamic interactions between the body, mind, and environment, prompting HCI to design interfaces that exploit human embodiment. This aligns with the 4E+ Cognition framework, which extends cognition to include not only embodied but also embedded, enacted, and extended processes that intertwine with physical and social contexts.	Dourish, 2001. Marshall & Hornecker, 2013. Maturana & Varela, 1980. Rietveld & Kiverstein, 2014. Shapiro, 2019.
Technology as an Extension of the Mind (Distributed Cognition Approach)	The concept of technology as an extension of the human mind suggests that our cognitive processes extend beyond biological boundaries, incorporating technologies that augment our cognitive and physical capabilities. Thinkers like Kelly (2010) and cognitive philosophers Clark and Chalmers (1998) have argued that technology acts as a scaffold, enhancing our interaction with the world and integrating deeply with our cognitive processes to effectively become part of	Anderson, 2022. Clark & Chalmers, 1998. Hollan et al., 2000. Hutchins, 1996.

	our minds. In HCI, posthumanist perspectives, like those of Suchman (2007), propose a co-constitutive relationship between humans and technology, prompting designers to focus on creating intuitive, adaptive, and personalised digital systems that enhance human capabilities in meaningful ways. The Distributed Cognition Approach in HCI and cognitive science considers cognitive processes as extending beyond individuals to interactions with people, environments, and technologies.	Kelly, 2010. Suchman, 2007.

Building upon this exploration of philosophical frameworks within HCI, we deepen our understanding of the discipline which sets the stage for a more nuanced exploration of cognition itself. This foundation prepares us to go into the 4E+ approach in cognitive science and HCI, which builds upon these philosophies by emphasising that cognition is not just a brain-bound process.

3.3.3.1. The 4E+ Approach in Cognitive Science and HCI

The 4E+ approach in cognitive science can represent a paradigm shift in HCI from traditional models of reductionism to the embodied, embedded, enactive, and extended nature of human cognition, with an additional focus on affective and emotional processes (Aguayo, 2023; Newen et al., 2018). This framework challenges the Cartesian dualism of mind and body, proposing instead that cognition arises through the dynamic interaction of the brain with the body, the environment with its artefacts, and the socio-cultural context, in the coming together of human and digital interfaces. In addition, the consideration of emotional processes acknowledges the significant role of affect in shaping cognitive experiences, thereby providing a more holistic understanding of human cognition (Newen et al., 2018).

Table 3.11 further elaborates on the four dimensions of cognition. Embodied cognition posits that cognitive processes are fundamentally grounded in the body's interactions with its surroundings (Clark, 1996). Embedded cognition highlights the influence of the socio-cultural environment, suggesting that our thoughts and actions are significantly shaped by our context (Hutchins, 1996; Rietveld & Kiverstein, 2014). Enactive cognition argues that cognition emerges from a dynamic interaction between the organism and its environment, where perception and action are inseparably linked (Maturana & Varela, 1980; Varela et al., 1991). Extended cognition proposes that external tools, artefacts, and technologies can become integral components of our cognitive processes, enhancing our mental capabilities beyond the brain (Clark & Chalmers, 1998). Last but not least, the affective aspect, or the plus in 4E+, highlights the importance of emotions and the affective dimension in human cognition (Aguayo, 2023). Emotional states are not merely byproducts of cognition but actively shape and influence cognitive activities. This perspective aligns with recent findings in neuroscience from the last three decades, which show that affective processes play a crucial role in decision-making, memory, and learning (Damasio, 1994; Immordino-Yang, 2016).

Table 3.11 - 4E+ Cognition

Area	**Description**	**Key Authors**
Embodied Cognition	Embodied Cognition argues that cognitive processes are profoundly shaped by the body's interactions with the physical world. This perspective contends that the body is not just a passive vessel for the brain but an essential component of the cognitive system. The way we think, reason, and understand the world is shaped by our bodily experiences and sensory-motor capabilities. In HCI, this translates to designing interfaces and experiences that leverage natural movements and gestures, facilitating a more intuitive interaction with technology.	Clark, 1996. Ishii & Ullmer, 1997. Klemmer et al., 2006. Varela et al., 1991.
Embedded Cognition	Embedded underscores the idea that cognition is situated within a physical and social environment. Our cognitive processes are influenced by the context in which they occur,	Dourish, 2001. Hutchins, 1996.

	including the tools, objects, and people that surround us. For HCI, this means creating technologies that seamlessly integrate into users' environments and enhance their natural workflows.	Rietveld & Kiverstein, 2014.
Enactive Cognition	Enactive focuses on the role of action in cognition. It argues that cognition emerges through active engagement with the world, rather than via passive reception of information. This view emphasises the importance of interaction and feedback loops between the individual and their environment. In the realm of HCI, enactive cognition encourages the design of systems that respond to and evolve with user input, creating a dynamic and participatory user experience.	Di Paolo et al., 2010. Fuchs & De Jaegher, 2009. Varela et al., 1991.
Extended Cognition	Extended suggests that cognitive processes are not confined to the brain but extend to include external tools and devices, which augment human intelligence (Clark & Chalmers, 1998). This approach has profound implications for HCI as it suggests that digital technologies can be designed as natural extensions of the human mind, thereby enhancing cognitive capabilities and facilitating new forms of knowledge creation.	Clark & Chalmers, 1998. Hollan et al., 2000.
Affective and Emotional Dimension	Affective-Emotional Dimension acknowledges the critical role of emotions in shaping cognitive processes. Emotions influence attention, memory, decision-making, and problem-solving and ultimately serve as a bridge between cognitive and physical experiences (Picard, 1999). HCI designs informed by affective dimension strive to create emotionally resonant experiences that recognise the power of emotions in driving engagement and facilitate meaningful interactions.	Damasio, 1994. Immordino-Yang et al., 2016. Picard, 1999. Picard et.al, 2001. Scherer, 2005.

Incorporating the 4E+ approach into interaction design challenges designers to consider the full spectrum of human experience. Grounded in the comprehensive framework of 4E+ Cognition, this approach enables the creation of holistic and intuitive digital experiences that enhance usability and satisfaction while fostering deeper connections between users and technology (Aguayo, 2023). By accounting for the interplay between cognitive processes and the physical, social, and technological environments, designers can develop technologies that align with human experiences, capabilities, and needs, resulting in more meaningful and human-centric interactions.

The integration of 4E+ principles has profound implications for HCI and interaction design. By considering the embodied, embedded, enactive, extended, and emotional aspects of cognition, HCI researchers and designers can create technologies that are more aligned with human experiences, characteristics, capabilities, and needs. This holistic perspective ensures that technology is designed to support the full spectrum of human cognitive and emotional activities, leading to more intuitive, effective, and enriching user experiences (Bilda et al., 2007; Boehner et al., 2005; Dourish, 2001). Technologies that incorporate 4E+ principles tend to be more responsive to the user's physical movements and environmental context, enhancing their usability and effectiveness. Additionally, by recognising the role of emotions in cognition, designers can create interfaces that are more engaging and supportive of emotional well-being. This approach not only improves the functionality of technology but also opens up new possibilities for using technology to foster personal and collective well-being (Hornecker & Buur, 2006; Kirsh, 2013).

Going beyond 4E+, Vervaeke's works on spiritual cognition (2024), ‘Relevance Realisation’ (Vervaeke et al., 2012), cognitive science of wisdom (Vervaeke & Ferraro, 2013), and to some extent integrating 4E+ Cognition with Neoplatonism (2019; 2022), can be beneficial. I believe that exploring spirituality from a cognitive science point of view can enhance our comprehension of wisdom and the development of cognitive virtues such as critical thinking, ethical reasoning, and emotional intelligence. It can also offer an extra philosophical foundation for understanding the transformative potential of affective technology on the mind.

Neoplatonism, with its emphasis on the cultivation of wisdom and the pursuit of a higher good, provides a deeper context for exploring how cognitive processes can lead to personal and collective transformation. Vervaeke (2019) argued that the 4E+ framework, when combined with Neoplatonic principles, can deepen our understanding of wisdom and the cultivation of cognitive virtues. Vervaeke's (2019) synthesis suggests that we can benefit from a philosophical perspective that values wisdom, transformation, and the pursuit of a good life. I feel that by integrating Neoplatonic ideas into the design process, technology can be developed for efficiency and usability, and also to foster personal growth and well-being. This enriched spiritual perspective is consistent with the discussion presented in Section 3.2.5, which examines Affect, Affective Interaction, Sensory Experiences, Haptic Visual-Auditory, Haptic Spatiality, and Presence. Spiritual cognition can enhance the role of these elements in XR design, addressing the psychological, emotional, and spiritual dimensions of users on a deeper level.

Incorporating a spiritual perspective also aligns with and expands upon current trends in HCI, particularly those emphasising the user experience and cognitive implications of technology, as identified by Wright and McCarthy (2004). Their framework suggested that understanding technology's role in human life goes beyond assessing usability or efficiency—it involves a deeper consideration of how technology shapes our experiences, behaviours, and even our sense of self and community.

I believe a deep understanding of Vervaeke’s philosophical wisdom, along with that of similar thinkers, can positively impact designers and artists and guide them in crafting spiritual experiences that are both affective and transformative. Such spiritual experiences could have the power to influence users' emotions, perceptions, and cognitions, and potentially even their overarching worldviews.

Building upon the 4E+ Cognition framework and pivoting towards spiritual cognition and the cognitive science of wisdom, the next section explores the domain of spiritually inspired Human-Computer Interaction and Interaction Design. This exploration examines how integrating spiritual and wisdom-based principles can enhance user experiences by fostering deeper emotional and cognitive connections between users and technology. The focus in this section shifts to Sufism—a mystical tradition within Islam that shares foundational principles with Neoplatonism and perennial philosophy.

3.3.3.2. Sufism-Inspired HCI & IxD

Sufism can offer a profound philosophical and spiritual framework that can significantly enrich HCI by emphasising holistic and embodied experiences. Sufism focuses on the unity of mind, body, and spirit, which can inform the design of interactive technologies that support spiritual well-being and deeper human connections. This approach draws on the traditions of Sufi practices, which involve the body in spiritual rituals, thus providing a model for embodied interaction design.

Sufism views the human body as a manifestation of the divine, and this perspective can be leveraged in HCI to create designs that foster holistic user experiences. Sufi practices such as meditation (‘murakaba’), rhythmic movement (‘zikr’), and embodied prayer (‘namaz’) require full body awareness, promoting a deep connection between the physical and the spiritual (K. Scott, 2007). By incorporating these practices into HCI, designers can create technologies that not only facilitate practical tasks but also support users' spiritual and emotional well-being.

Farid Zahi, a Moroccan Islamic studies scholar, offers a modern interpretation of embodiment in Sufism. His phenomenological framework encompasses the physical, social, biological, and spiritual aspects of embodiment, providing a comprehensive model for designing embodied interactions (Kugle, 2011; Tasa & Yurtsever, 2010). The integration of Sufism into the realm of experience and interaction design introduces a profound philosophical and spiritual dimension that transcends conventional design paradigms. Sufism, with its emphasis on unity, mindfulness, inner experience, simplicity, ethics, and a holistic view of existence, offers invaluable insights for creating more meaningful, engaging, and ethically grounded digital experiences. This section explores how Sufism-inspired principles can profoundly influence UX and IxD, drawing upon the innovative model proposed by Tasa and Yurtsever (2010) as a foundational framework.

In their exploration of how Sufism can inspire and be integrated into interaction design, Tasa and Yurtsever (2010) proposed a model for embodied interaction design inspired by Sufism, which revisits and expands traditional views on embodiment. They suggested a four-layered understanding of embodiment—physical, social, biological, and spiritual—and aim to incorporate these four dimensions into design practices. Their model emphasises a holistic approach to human-technology interaction, acknowledging the body's integral role and fostering interconnectedness and deeper engagement with technology. The authors advocated for a redefined concept of embodiment that transcends the physical to include the social, biological, and spiritual dimensions, offering a comprehensive framework for designing interactions that are deeply human-centric and resonate with the essence of Sufism (Tasa & Yurtsever, 2010).

This Sufism-inspired approach to interaction design represents a compelling fusion of ancient wisdom and modern technology. It opens up new pathways and depth within the field of Interaction Design (IxD), paving the way for digital experiences that are not only technologically sophisticated but also enriched with spiritual, ethical, and philosophical dimensions. By integrating these principles into interaction design, we can aspire to craft technologies that enhance the human experience in profound and meaningful ways.

In the exploration of Sufism-inspired interaction design, Farid Zahi's phenomenological interpretation presents a compelling four-dimensional model of embodiment (Kugle, 2011). This model intricately weaves together the physical, social, biological, and spiritual aspects of human experience, offering a holistic framework for interaction design that resonates deeply with the principles of Sufism.

At the foundation of this model lies the concept of “Physical Embodiment”, which acknowledges the primacy and substance of the physical body as the core of human experience. This dimension emphasises the tangible, material aspect of our being, recognising the body's role as the primary medium through which we interact with the world around us. Building upon this, “Social Embodiment” extends the notion of embodiment to include the body's external appearance, movement, and social identity. This dimension highlights the importance of bodily movement and appearance in constructing social identity and facilitating interpersonal interactions, underscoring the body's role in mediating our relationship with society. The “Biological Embodiment” dimension delves into the body's inner chemical and mechanical processes and cognitive mechanisms. By focusing on the biological dynamics that underpin our physical existence, this aspect of the model aligns with cognitive science and ergonomics as it offers insights into how our bodily processes influence and are influenced by our interactions with technology. The most profound dimension, “Spiritual Embodiment”, transcends the physical to connect the corporeal body with ethereal realms, spirituality, interconnectedness, and unity with existence. This dimension invites reflection on the deeper meanings and spiritual connections that emerge from our embodied experience, encouraging a design approach that honours the spiritual aspects of human existence.

The proposed model for Sufism-inspired interaction design synthesises these dimensions into a cohesive framework. It advocates for a design approach that deeply respects and considers the physical embodiment (body matter), acknowledging the foundational role of physical embodiment in shaping our interactions with technology. Furthermore, it adopts a phenomenological approach to human experience and interaction, emphasising the significance of social embodiment in designing technologies that facilitate meaningful social connections.

Additionally, the model integrates principles from cognitive science to align with the body's inner mechanisms, integrating biological embodiment into the design process to create interfaces that are intuitive and in harmony with human physiology. Beyond the physical and social dimensions, the model also reflects on the spiritual dimension of the body, incorporating spiritual embodiment to foster designs that resonate with the deeper, spiritual aspects of human experience. By embedding spiritual embodiment into interaction design, the framework aims to create technologies that support practical usability and personal growth, emotional well-being, and spiritual fulfilment.

By integrating these dimensions, the model offers a unique perspective that bridges the spiritual and technological realms, proposing a fresh approach to interaction design. This Sufism-inspired framework enriches the field of interaction design with its depth and holistic perspective while also aligning with a passion for innovation and exploration in technology and design. It represents a significant step towards creating digital experiences that are technologically advanced and deeply enriching, and spiritually meaningful at the same time.

The integration of Sufism into HCI has several practical applications with significant implications. For example, in the realm of educational technologies, XR environments can incorporate Sufi teachings and practices to create immersive learning experiences that engage users both cognitively and spiritually, thereby enhancing educational outcomes and promoting holistic development. This approach fosters a deeper connection to the material, facilitating a comprehensive educational experience. In terms of cultural heritage preservation, XR can be employed to preserve and revitalise cultural heritage sites, allowing users to virtually explore and interact with significant historical and spiritual locations.

The practical integration of a Sufism worldview into HCI paves the way for an enriching discussion on the broader philosophical and spiritual underpinnings of this research. As we transition from the tangible applications of Sufi principles in HCI to a more expansive exploration of philosophical depths, it becomes evident that the implications of this integration extend well beyond immediate technological advancements.

3.3.4. Bringing it All Together

The exploration of HCI within the context of XR and IxD reveals a multifaceted and evolving discipline that intricately weaves together technological advancements, historical developments, and profound philosophical insights. At its core, HCI seeks to bridge the gap between humans and digital technologies, fostering interactions that are functional, efficient, intuitive, enjoyable, and deeply resonant with human needs and experiences.

Tracing the history of HCI from its inception in the 1960s to the present day underscores a relentless pursuit of enhancing user experiences through innovation. The transition from command-line interfaces to graphical user interfaces (GUIs) democratised access to computing, making technology more accessible and user-friendly. This evolution continued with the advent of touchscreens, mobile computing, and the Internet of Things (IoT), each milestone introducing new interaction paradigms that align more closely with human behaviours and environmental contexts.

HCI's strength lies in its interdisciplinary nature, drawing from fields such as cognitive psychology, design, ergonomics, and social sciences to create holistic and human-centric interfaces. The integration of philosophical perspectives, particularly through frameworks like the 4E+ Cognition approach and Sufism-inspired design, deepens our understanding of the cognitive, emotional, and spiritual dimensions of human-technology interaction. The 4E+ framework—embodied, embedded, enactive, and extended cognition, and the affective dimension—challenges traditional reductionist models by emphasising the dynamic interplay between the mind, body, environment, and technology. This holistic view fosters the creation of interfaces that are cognitively accommodating, emotionally engaging, and socially contextualised.

Similarly, the incorporation of Sufism-inspired principles into HCI and IxD introduces a profound spiritual and ethical dimension to interaction design. By emphasising unity, mindfulness, inner experience, simplicity, and compassion, Sufism-infused design approaches advocate for technologies that support functional tasks and the holistic well-being and spiritual fulfilment of users. This synthesis of ancient wisdom with modern technology exemplifies how philosophical depth can inform and elevate design practices, leading to more meaningful and ethically grounded digital experiences.

Looking ahead, the future of HCI lies in its ability to continuously integrate emerging technologies with interdisciplinary and transdisciplinary insights. Bio-interactive technologies, quantum computing, and nanotechnology promise to revolutionise interface design, offering unprecedented levels of personalisation, adaptability, and cognitive augmentation. The ongoing integration of the 4E+ Cognition framework and Sufism-inspired principles will further enrich HCI, enabling the creation of technologies that are technologically sophisticated while also profoundly aligned with the complexities of human cognition, emotion, and spirituality.

In summary, the synthesis of HCI's historical trajectory, technological advancements, interdisciplinary foundations, and philosophical integrations presents a comprehensive and forward-looking vision for the field. By embracing a holistic, human-centric approach that honours the embodied, emotional, and ethical dimensions of human experience, HCI and IxD can continue to innovate in ways that enhance the quality of human life, foster meaningful interactions, and create technologies that are truly in harmony with the nuanced tapestry of human existence. It is important to acknowledge, however, that the philosophy and Hikmah underpinning this research encompass a far broader spectrum of philosophical, spiritual, and cognitive traditions than can be fully explored within the scope of this exegesis. While the dimensions I mentioned and will explore in the next chapter provide a foundational layer to the current study, their depth and implications offer avenues for future inquiry that lie beyond the boundaries of this work.

3.4. XR as a Medium: Expanding the Horizons of Interaction

In the exploration of eXtended Reality as a distinct medium, this research transcended the conventional boundaries of digital interaction, venturing into a realm where the fusion of the real environment with digital and virtual imagination can reshape our perception of the world and extend our mind.

Employing McLuhan's Media Tetrad (depicted later in Figure 3.21, section 3.4.4) as a critical framework, this study analyses the diverse impacts of XR on society, culture, and individual user experience and cognition. Through this lens, we delve into the essence of XR, not merely as a technological innovation but as a novel medium with the profound potential to redefine human experience in digital and immersive spaces (McLuhan, 1964/1994; McLuhan & Fiore, 1967).

In the quest to understand the essence and trajectory of XR as a medium, it becomes imperative to first grapple with the foundational question: What is a medium? This inquiry is not merely academic but serves as the cornerstone for appreciating the transformative potential of XR as a new and independent medium, endowed with its own unique rules, characteristics and language. A medium, in the broadest sense, is a conduit through which ideas, information, and experiences are communicated, interpreted, and understood (Couldry & Hepp, 2016; McLuhan 1964/1994, 2010). It shapes both the message and the process of engagement, influencing both the sender and the receiver in profound and often subtle ways (McLuhan & Fiore 1967; Meyrowitz, 1986; Peters, 2015).

Mediums as understood in HCI vary across visual, auditory, textual, and digital forms, each possessing unique affordances that dictate how messages are received and interpreted. This diversity underscores the mediums' active participation in the meaning-making process, highlighting their ability not just to transmit but also to transform the message. Understanding this dynamic is foundational to grasping the transformative potential of eXtended Reality (Bolter & Grusin, 2000; Manovich, 2002).

3.4.1. What is Medium?

In the scholarly exploration of communication and art, the concept of a medium plays a pivotal role, acting as the channel through which messages, narratives, and creative expressions reach an audience (McLuhan, 1964/1994). This inquiry into mediums underscores their role not as mere passive conduits but as active agents in shaping content, context, and reception. A medium, be it material or technological, is the tool through which artists, communicators, and creators express their visions, emotions, and ideas, endowing them with the power to influence, persuade, and evoke (Bolter & Grusin, 2000). McLuhan's seminal work, *Understanding Media: The Extensions of Man* (1964/1994), posits that a medium's impact extends far beyond the content it delivers, influencing cognitive processes, sensory perceptions, and social interactions.

In the field of communication and media studies, the classification of mediums is varied, covering visual (e.g., painting, photography), auditory (e.g., music, sound), textual (e.g., literature, poetry), and digital (e.g., virtual reality, augmented reality) forms. Each medium possesses inherent qualities and affordances that determine how audiences engage with and interpret them. These characteristics are not just technical but also deeply cultural, influencing and being influenced by the societal context in which they exist (Manovich, 2002). For example, traditional filmmaking combines visual and auditory elements to create narratives, using moving images, sound, and music to convey stories that resonate on multiple sensory levels. In contrast, virtual reality introduces a significant change, providing a fully immersive digital environment that encourages user interaction, thus moving beyond traditional narrative structures to offer a uniquely immersive experience. This contrast underscores the evolving nature of mediums, from linear and constrained to interactive and limitless (Ryan, 2001).

Humans, as creators, design and develop tools and media to extend their capabilities and facilitate various tasks. For example, the invention of the printing press in the 15th century by Johannes Gutenberg was a significant technological advancement aimed at making the production of books more efficient and accessible. This innovation was a direct result of human ingenuity and the desire to disseminate knowledge widely. Once a new medium or technology is integrated into society, it begins to influence and reshape human behaviour, thought processes, and social structures. In a sense, we shape our tools, and thereafter our tools shape us. McLuhan (1964/1994) argued that each medium engenders specific ways of thinking and interacting with the world. The printing press, for instance, led to the widespread availability of books, which in turn promoted literacy, individualism, and a linear, analytical mode of thinking characteristic of the print culture.

The reciprocal influence between humans and their tools is central to McLuhan's theory. This dynamic relationship can be illustrated through various historical examples; the telephone, initially invented to facilitate voice communication over long distances, fundamentally altered social interactions, making real-time, personal communication possible regardless of physical distance. In a similar way, television, as a medium, transformed how people received news and entertainment, shifting from a print-dominated culture to one where visual and auditory stimuli play a central role. This change has had profound effects on people's attention spans, cognitive processes, and social dynamics. McLuhan's concept of the global village further elucidates the transformative power of media. McLuhan (1962) discussed how electronic media collapse time and space, creating a world where information is instantly shared, fostering a sense of global interconnectedness. This shift has significant implications for cultural homogenisation and the formation of a global consciousness.

This research positions XR not merely as a technological breakthrough but as a profound medium for exploring consciousness, spirituality, and human experience in the digital era. Therefore, the critical examination of XR as a medium in this research provides a nuanced perspective on its role as a transformative element in communication, art, and human cognition. It calls for a reassessment of the relationship between medium and message, advocating for a reflective approach to the design and use of digital spaces that aligns technological progress with philosophical insight and cultural understanding.

3.4.2. McLuhan's View on Media

McLuhan's seminal concept 'the medium is the message' (1968) revolutionised the understanding of how media technologies shape human cognition and societal structures. McLuhan posited that the characteristics of each medium influence our ways of thinking, communicating, and perceiving the world, thus asserting the medium's role in our cultural and cognitive evolution. His exploration into the effects of print and electronic media demonstrated how these technologies foster distinct modes of thought and social organisation, from the linear, individualistic tendencies of print culture to the collective, immersive nature of electronic media (McLuhan, 1964/1994).

McLuhan famously conceptualised media as extensions of human faculties. He illustrated this idea by suggesting that the wheel extends the foot, the book extends the eye, and electronic media extend the central nervous system. The telephone, as an extension of the voice, enhances human communication, enabling real-time conversation across great distances, thus altering social interactions and relationships (McLuhan, 1964/1994). This extension idea underscores how media amplify or intensify certain aspects of human experience, altering the way we perceive and interact with the world. McLuhan's dictum on the medium emphasises that the medium itself, not the content it carries, should be the focal point of study. He argued that the characteristics of a medium simultaneously influence and control the scope and form of human association and action at the same time. (McLuhan, 1964/1994).

The relevance of McLuhan's theories extends into contemporary discussions on digital media, where scholars like Jean Baudrillard have further explored the symbiotic relationship between media technologies and societal dynamics. Baudrillard (1994), in particular, delved into the concept of hyperreality, where the distinction between the real and the mediated becomes blurred; a phenomenon that is becoming increasingly relevant in the context of XR.

Additionally, McLuhan's (1964/1994) exploration of media and its influence on society offers a profound framework for understanding the dynamics between technology, culture, and human perception. His seminal assertion that “the medium is the message” highlights the intrinsic power of media technologies not merely as conduits of content but as pivotal forces shaping human cognition, social interactions, and cultural evolution. This perspective underscores the need to scrutinise the inherent characteristics of media and their potential to reconfigure societal norms, values, and structures.

McLuhan's analysis of print and electronic media exemplifies his theory's applicability across different historical periods. He argued that print media, such as books and newspapers, fostered a linear, individualistic mode of thinking, emblematic of the Enlightenment and modern scientific discourse (McLuhan, 1962). Conversely, electronic media, like television and radio, promote a more participatory and immersive mode of information processing, encouraging patterns of thought and perception that are collective and holistic (McLuhan, 1964/1994). This dichotomy illustrates the medium's role in shaping not just the reception of content but also the broader cognitive and social frameworks within which individuals operate.

The enduring relevance of McLuhan's work is evident in the contemporary digital age, where new media technologies continue to redefine communication, identity, and community. His theoretical frameworks remain essential for analysing the multifaceted impacts of digital media, offering insights into the complex interplay between technology, culture, and human consciousness in the 21st century. In conclusion, McLuhan's contributions to media theory and communication studies provide invaluable insights into the role of media as transformative forces within society. His exploration of the medium's capacity to shape human perception, societal structures, and cultural practices underscores the importance of critically engaging with media technologies and their implications in shaping the contours of human experience.

3.4.3. The Medium of XR: A Unique Entity

Unlike cinema or games, which are primarily visual and auditory, XR integrates tactile feedback and spatial interaction, presenting new challenges and opportunities for creators and users alike (Ryan, 2001). This medium transcends traditional media by offering interactive environments that engage users in a multisensory dialogue, thereby establishing XR as a distinct medium with its own set of rules and language.

By recognising XR as a unique medium, I acknowledge its distinctiveness from traditional media, opening doors to novel forms of expression, interaction, and experience inherent to XR. Embracing XR’s intrinsic capabilities allows for the exploration of new dimensions of creativity and utility. The investigation of XR through the theoretical framework of McLuhan's Media Tetrad (Figure 3.13) provides a thorough insight into its revolutionary potential and its broad implications for society, culture, and individual perception. This analysis positions XR within the expansive domain of media ecology, highlighting its distinctive features as a medium that surpasses conventional methods of communication and interaction.

XR merges real and virtual environments, offering various levels of immersion and interaction within the digital realm. Acknowledging XR as an autonomous medium emphasises its uniqueness and its divergence from traditional media like cinema or video games. This acknowledgment is essential for unleashing XR's full capabilities, fostering new avenues for expression, interaction, and engagement that are specific to its nature.

Viewing XR solely through the lens of traditional media like cinema or video games can limit its potential for innovation, much like early comparisons of smartphones and tablets to books overlooked their unique affordances. While these established media have their own languages and aesthetics, applying them directly to XR risks obscuring its intrinsic qualities.

Recognising XR's inherent features allows developers to uncover new creative and practical possibilities, which could lead to a shift in how we interact. XR's immersive capabilities can transform education by facilitating experiential learning beyond conventional settings. This approach promotes engagement and retention through vivid simulations and hands-on experiences. XR introduces innovative methods for scientific exploration and data representation, allowing for immersive environments, three-dimensional data visualisation, and remote collaboration. XR's application in gamifying cultural heritage makes historical and cultural knowledge more interactive and accessible, offering new methods to explore and conserve cultural narratives.

3.4.4. Implications of XR-Medium through McLuhan's Tetrad

The unique characteristics and capabilities of XR can be understood through McLuhan's Media Tetrad (McLuhan & McLuhan, 1988), a framework that evaluates the effects of a medium on society. McLuhan’s Tetrad, illustrated in Figure 3.21, provides a systematic approach to dissecting the impact of media technologies by posing four key questions: What does the medium enhance? What does it make obsolete? What does it retrieve that had been obsolesced earlier? What does it flip into when pushed to extremes? This analytical model offers valuable insights into how XR, as a medium, transforms communication, interaction, and perception within various domains.

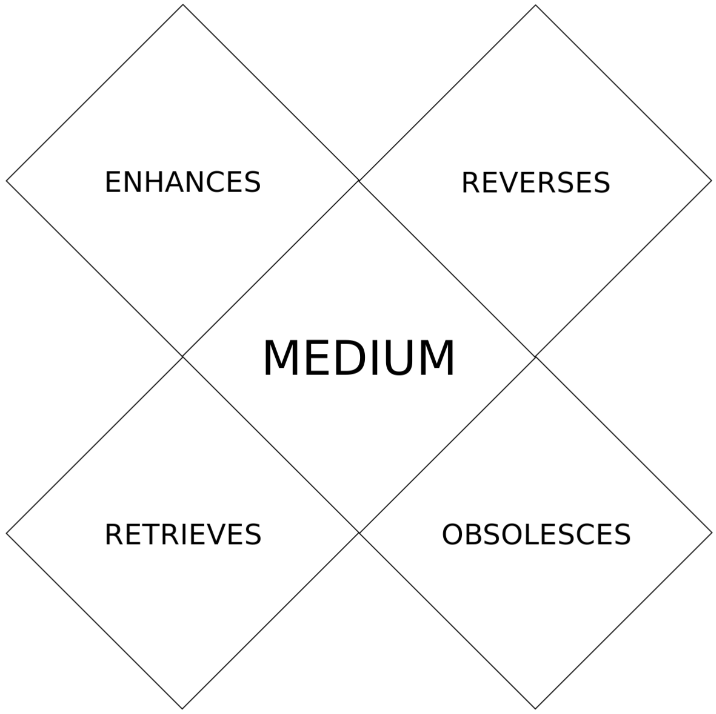


Figure 3.13 - McLuhan’s Tetrad.
Diagram illustrating multifaceted impacts of a medium on society and individual experience.
Note. This figure has been adopted from McLuhan & McLuhan 1988.

In applying McLuhan's Tetrad to XR, the following implications can be observed: the Tetrad reveals how any medium, here XR, enhances immersive interaction and multi-sensory engagement, makes obsolete traditional 2D interfaces, retrieves a sense of embodied experience previously diminished by screen-based media, and could potentially flip into an overly immersive experience that blurs the line between real and virtual.

Enhancement: XR enhances the sensory experience by merging digital and physical realities, creating immersive environments that can be interacted with in real-time. This technological advancement intensifies our capability to visualise and interact with complex data, simulate real-world scenarios for training or education, and foster new forms of entertainment and social interaction. XR's capacity to overlay information onto the physical world or to create entirely new, virtual worlds offers unprecedented opportunities for learning, design, and collaboration.

Obsolescence: With the rise of XR, traditional forms of media and communication might be rendered obsolete or significantly transformed. For example, conventional 2D screens and interfaces (such as smartphones, televisions, and computer monitors) may become less central as interfaces for interaction and consumption of content. Likewise, traditional methods of teaching and learning, which rely heavily on textbooks and static visual aids, may be supplanted by more interactive, immersive experiences that provide a greater understanding through simulation and virtual environments.

Retrieval: XR retrieves the ancient human tradition of experiential learning—learning by doing—by enabling simulations of real-world tasks and environments in a controlled, virtual setting. This harks back to the apprenticeship models of education, where learning was hands-on and deeply immersive. Furthermore, XR retrieves elements of pre-literate societies' reliance on spatial memory and storytelling, allowing users to navigate information in three-dimensional space and engage with narratives in a more embodied way.

Reversal: When pushed to its limits, XR could reverse into scenarios where virtual experiences become more valued or "real" than physical ones, leading to a preference for digital interaction over physical presence. This could potentially isolate individuals from their physical environments and communities, creating a disconnection from the tangible world. Moreover, the ubiquity and immersive nature of XR might lead to information overload or difficulty distinguishing between authentic and manipulated realities, challenging our perceptions of truth and authenticity.

These dimensions of McLuhan’s Tetrad clarify the transformative potential of XR as a medium, guiding both developers and users to consider balanced approaches that harness XR’s benefits while remaining vigilant of its challenges. This nuanced understanding, provided by the Tetrad, is crucial for advancing XR applications in a manner that aligns with both technological progress and societal well-being.

3.4.5. Bringing it All Together

By approaching XR with a mindset that embraces its unique potential and avoids confining it to existing paradigms, we foster innovation, creativity, and positive social impact in various domains, from education and research to art and culture. This critical perspective contributes to the ongoing dialogue about the nature of media and communication, creating a space for XR to develop its own language, rules, and contributions to human understanding and interaction. It is a bold step towards the future, acknowledging the complexity and potential of XR as a medium that can redefine how we learn, communicate, and experience the world around us. The examination of XR through the media tetrad unveils its potential to significantly alter sensory experiences, learning methods, and social interactions. Nonetheless, it also brings to light critical issues regarding traditional media's obsolescence, the risk of isolation, and challenges to understanding reality. As XR progresses, stakeholders must thoughtfully navigate these changes, aiming for XR to enhance human abilities and promote connections. Continuous dialogue, innovative design, and ethical implementation are crucial to harnessing XR's potential as a medium that could redefine human experiences in the digital era.

3.5. Chapter Summary

This chapter provided a comprehensive exploration of the interrelated fields that underpin the development and application of eXtended Reality. It started by detailing the technological explorations in XR, emphasising its transformative potential within the Fourth Industrial Revolution and its impact across various industries. The discourse then shifted to the integration of cinematic and video game techniques, highlighting how these mediums enrich XR environments through enhanced narrative depth, emotional engagement, and interactivity. It explored how affect and related concepts play a critical role in the design and interaction of XR interfaces, enhancing the emotional and sensory engagement of users.

The narrative then explored the contributions of Human-Computer Interaction (HCI), which deepen the understanding of user experience design in XR through cognitive science and philosophical insights. Further, the chapter discussed HCI's contributions, particularly its theoretical underpinnings, which improve user experience design in XR by integrating cognitive science such as 4E+, philosophical insights such as phenomenology, and spiritual wisdom such as Neoplatonism and Sufism. It also contemplated XR as a new medium, analysed through the lens of media theory, most notably in terms of McLuhan's ideas on media's influence on human perception and societal interactions. The section concluded by synthesising these insights to provide a holistic view of the transdisciplinary approaches informing the practical applications of XR in enhancing user experience and interaction design.

This comprehensive review serves as a foundation for the subsequent chapter on research design, demonstrating the application of these transdisciplinary insights to devise innovative XR interactions. This setup acts as a signpost for examiners, illustrating the seamless integration of theoretical frameworks into practical applications, in order to prepare the ground for a detailed exploration of specific XR design implementations. The holistic perspective adopted here justifies the research design and reflects the complexity and potential of XR as a transformative medium in enhancing Human-Computer Interaction.

Note. Illustration created by Zohreh Shirazi (2024) based on concepts by Ali Taheri.

Chapter 4: Design of the Study

This chapter explores the intricacies of the research design, outlining the foundational elements that structure the entire investigation. It begins by establishing the research paradigm, which forms the philosophical and epistemological basis for the study, shaping how the research questions are framed and addressed. Following this, the chapter delves into the chosen methodology, detailing the systematic approaches that underpin the research process and ensure its coherence and rigour. By providing a comprehensive overview of the philosophical and theoretical frameworks guiding the study, as well as the practical approaches used, this chapter sets the stage for a thorough and nuanced exploration of the subject matter, ensuring that the research is both deeply informed and methodologically sound.

4.1. Introduction

Research design is shaped by the researcher's worldview, where the nature of reality and knowledge is central to the research paradigm. Once established, this paradigm guides the systematic inquiry by posing questions that shape the research methodology and determine the methods used (Choudhury et al., 2007; Gilbert & Pratt-Adams, 2022). In the following paragraphs, I will establish the research paradigm as a foundation for the methodological approach used in this study.

The foundation of a research design can be visualised as an iceberg (Figure 4.1, adapted from Stilwell & Harman, 2021). Above the waterline are the visible methods directly applied in the research process. Submerged below are the deeper layers: methodology, theoretical framework, epistemology, and ontology. These layers support and contextualise the methods, though they are less visible.

Mockler (2011) and Kawulich et al. (2012) argued that the nature of reality and ways of knowing are central to a research paradigm. Once established, this paradigm guides the inquiry by shaping the methodology and determining the methods used. Mockler (2011) asserted that the paradigm, methodology, and methods are deeply intertwined with the researcher’s ontology and epistemology (see Figure 4.2, which illustrates the key elements of my research design).

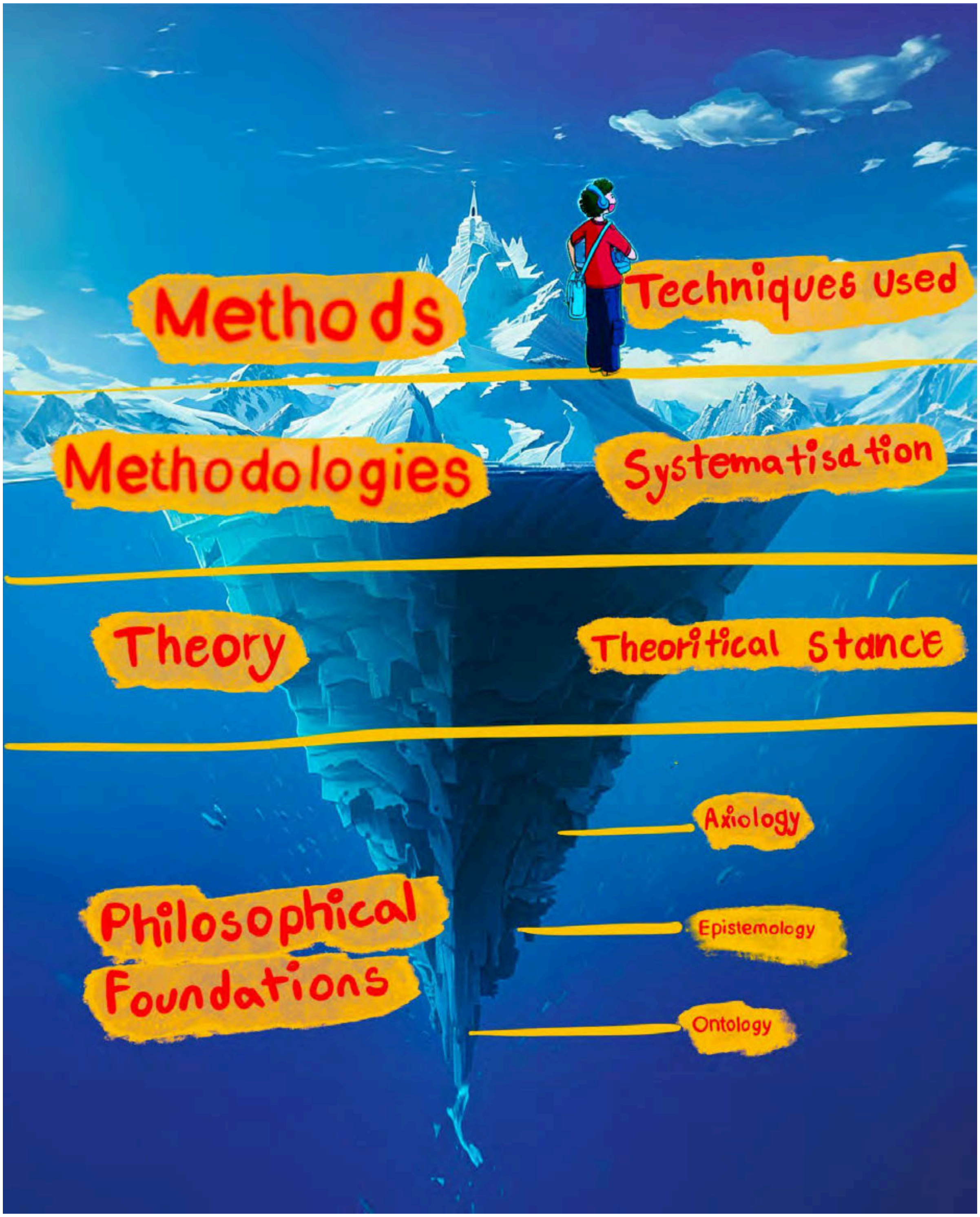


Figure 4.1 - The Iceberg Model of Research Design.

Note. This is depicting the key elements in my research design presented in this paper.

This figure is adapted from Stilwell & Harman (2021) idea.

Created by Zohreh Shirazi. No Copyright Claim.

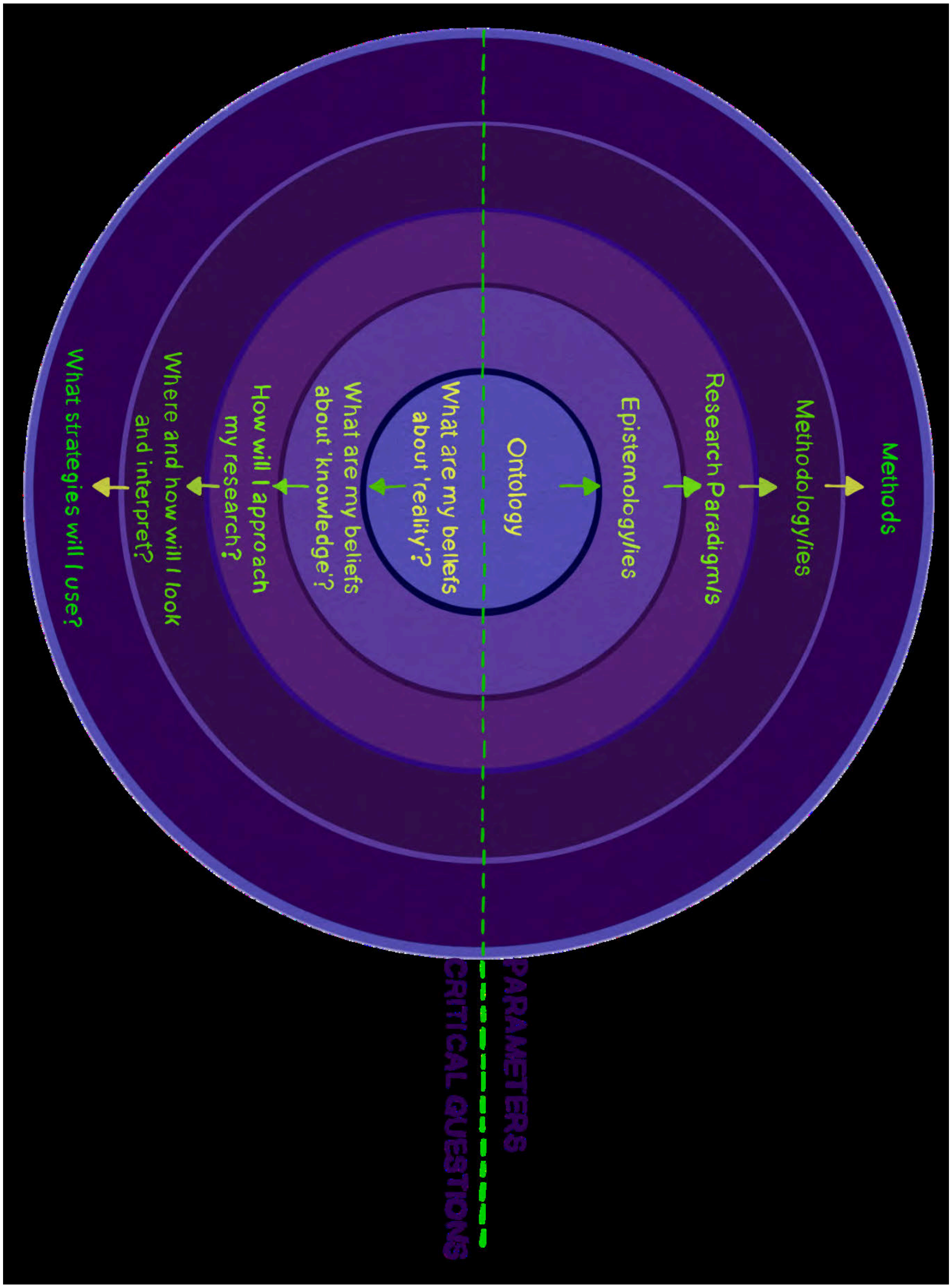


Figure 4.2 - The Interconnected Levels of the Research.

Note. This diagram has been adapted from Mockler's (2011) "Being Me: In Search of Authenticity" (p. 160). Copyright by Mockler.

The paradigm underpinning this research is practice-oriented with a transdisciplinary (more on TDR in Section 4.3.1) approach that harmonises technological innovation with cultural and philosophical wisdom. This study draws from the traditions of Neoplatonism and Ishraq (Illuminationism) philosophy, synthesising these with contemporary theories of cybernetics and 4E+ Cognition. The objective is to develop a holistic approach to Human-Computer Interaction (HCI) design that advances technological understanding and respects and incorporates philosophical depth. This approach is reflective of a broader movement within the field of HCI towards more inclusive, ethically grounded, and philosophically informed design practices (Sengers et al., 2006).

By situating the research within this paradigm, I emphasise its novelty and significance, highlighting a unique approach that integrates cognitive processes with the 4E+ dimensions. This perspective offers a deep understanding of human cognition, laying the foundation for a detailed exploration of the research design. This approach facilitates a comprehensive and innovative examination of cognitive interactions and experiences.

In this chapter, I explore the intricate tapestry of the research design—a journey that is as much about creative exploration in virtual environments as it is about a scholarly quest. At the heart of this endeavour lies a practice-oriented transdisciplinary approach which tries to fuse the realms of artistic innovation, technological advancement, and philosophical introspection. This research unites these landscapes, offering a novel perspective on creative design and interaction within the XR medium.

The uniqueness of this research lies in its methodological approach. Breaking away from traditional paradigms, it adopts a framework where practice is not merely an output, but a vital component of the research process itself. This approach is about creating or using XR technologies, as well as understanding and interpreting them through a lens shaped by the interweaving of cultural, philosophical, and scientific insights. The research design thus embodies a synergistic blend of creative practice, theory, and a deep reflection on the nature of knowledge and reality, as influenced by the mystical and philosophical traditions of Iranian culture.

According to Moustakas (1990), the essence of research design is deeply entwined with the researcher's personal experiences and intuitive insights, highlighting the importance of a committed, systematic approach to uncovering meaningful insights about the studied phenomenon. Scotland (2012) further emphasised that a research project's paradigm, methodology, and methods are fundamentally connected to the researcher's own ontological and epistemological beliefs. This chapter consists of five main sections that collectively build the foundation and framework of my research:

Section 4.2, Research Paradigm, will discuss an innovative and philosophically rich research framework that integrates Eastern and Western thought. It explores a practice-oriented, transdisciplinary approach, drawing on Islamic Ishraq Hikmah-philosophy (Illuminationism) and phenomenological interpretation of Neoplatonism. This paradigm leverages the principles of 4E+ Cognition as it emphasises the active role of the body, environment, and interaction with the environment in shaping cognitive processes. The section underscores the fusion of philosophical inquiry with artistic expression, advocating for XR designs that resonate cognitively and culturally.

Section 4.3, Research Methodology, articulates the transdisciplinary approach that seamlessly integrates artistic innovation, technological advancement, and philosophical introspection. This section breaks away from traditional paradigms, adopting a framework where practice is a vital component of the research process itself, influenced by Moustakas' (1990) emphasis on personal experiences and intuitive insights as essential elements of research design.

Section 4.4, The Practice, illustrates the role of the AppLab as a hub for practical projects, emphasising the significance of real-world projects in practice-oriented research. This section highlights the practical applications and contributions of the AUT AppLab research and learning lab and the projects we have been developing at AppLab, linking them to the research objectives and demonstrating their relevance in advancing XR interaction design.

Section 4.5, Methods, outlines the specific techniques and tools used in the research. The approach is divided into several distinct yet interconnected methods: Technological Framework, experimental visualisation, approaches, and reflective evaluation, each contributing to the comprehensive exploration of the research inquiry. Due to word count constraints, this section is provided in the appendix.

Section 4.6, Critique of the Research Design, marks the conclusion of the chapter. The section presents a detailed critique of the research design where I consider the strengths and challenges of the methodology.

Next, I will dive into the research paradigm itself, explaining the theoretical frameworks that underpin this research. This exploration will elucidate how these frameworks inform the methodology and shape the study's approach to understanding human interaction with immersive and interactive technologies.

4.2. The Research Paradigm

Bogdan and Biklen (1998) described a paradigm as a flexible assortment of interconnected assumptions, concepts, or propositions that guide and shape both thinking and research. In this research, I adopt a paradigm rooted in perennial wisdom, integrating diverse philosophical traditions with scientific knowledge. By transcending traditional disciplinary boundaries, the paradigm in this research facilitates a dialogue between technology, philosophy, and design. The research paradigm is characterised by a commitment to the following theoretical frameworks:

4.2.1. Levels of Intelligibility and 4E+ Cognition Theories: In this part I explore the intricate relationship between Neoplatonism and 4E+ cognitive science, focusing on how these two frameworks offer a profound understanding of human cognition. This discussion seeks to bridge ancient wisdom with modern scientific advancements, proposing a comprehensive model for understanding cognition. These theories are particularly relevant for HCI design in XR, as they offer insights into how users interact with the environment (real or virtual).

4.2.2. Unity of Intellect and Illuminationism: Here I delve into the Islamic Illuminationist philosophy, particularly Suhrawardi's concept of the Unity of Intellect. By merging ancient wisdom with modern scientific insights, this section provides a holistic paradigm to understanding human cognition. The discussion emphasises the importance of intuitive insight and the dynamic interplay between rational thought and spiritual illumination, offering practical guidelines for designing meaningful and transformative technological experiences.

4.2.3. Artistic Inquiry: This section explores the central role of artistic research in a practice-oriented inquiry. It discusses how artistic inquiry bridges theoretical constructs and practical exploration. This approach values the processes and outcomes of artistic practice as legitimate forms of research. This approach recognises the inherent value of creativity and intuition in the research process.

4.2.4. Practice-Led Research and Research-Led Practice: This dual approach, as discussed by Smith and Dean (2009), emphasises the reciprocal relationship between creative practice and research. Practice-led research involves using creative practice as a method of inquiry, where both the process and outcomes of the practice inform the research. Conversely, research-led practice uses theoretical and empirical research to inform and enhance creative practice. This approach allows for a dynamic interplay between theory and practice, fostering innovation in XR design.

Above, theoretical frameworks are suitable for my research because together they provide a comprehensive paradigm that integrates philosophical, cultural, and technological dimensions. Illuminationism, which emphasises intuition and imagination, allows for a holistic understanding of HCI that transcends traditional purely rationalist methodologies. Complementing this, the 4E+ cognition approach grounds the inquiry in a rational, scientific framework, balancing out the intuitive aspects of Illuminationism. Together, these frameworks create a dynamic interplay between creative exploration and structured analysis, enabling a more nuanced investigation of HCI within immersive XR environments.

4.2.1. Levels of Intelligibility and Cognitive Science

Neoplatonism, originating with the philosophy of Plotinus and expanded by thinkers such as Proclus, and again later by Suhrawardi and Ibn Arabi in the Islamic tradition, forms one of the key branches of perennial wisdom—the philosophical tradition that posits a universal truth underlying all spiritual and religious teachings. Neoplatonism, as part of the broader perennial wisdom, highlights the shared metaphysical foundations found in diverse spiritual traditions (Versluis, 2017). Its emphasis on the unity of intellect and the pursuit of inner illumination resonates with the teachings of ancient wisdom traditions, which similarly hold that transcendent knowledge is accessible to those who seek to align themselves with the universal truth. This view establishes philosophy as a living tradition that shapes our understanding of consciousness and cognition. This approach views philosophy not merely as an academic discipline or a collection of argumentative techniques; it embraces philosophy as a transformative way of life and focuses on cultivating wisdom and virtue (Hadot, 1995/2016).

Central to the discourse of this research is the concept of the Imaginal Realm (Mundus Imaginalis), an intermediate realm between the sensory/sensible world (Mundus Sensibilis) and the purely intellectual/intelligible world (Mundus Intelligibilis) (Corbin, 1998; 1971/1994; Halligan, 2001; Manheim & Corbin, 1964/2014; Nasr, 2006). Henry Corbin introduced the term Mundus Imaginalis to describe a space where symbolic manifestations and spiritual experiences reside, bridging the sensible and the intelligible. In designing this research, I have drawn on the concept of the Imaginal as a space of symbolic interaction and transformation, which aligns with the principles of embodied and enactive cognition. This approach recognises that within the Imaginal realm, the embodied mind engages with symbols and archetypes, actively constructing meaning and enacting realities that transcend physical boundaries. This process has practical implications for how I approach the creation and interaction within XR environments, ensuring that they facilitate a deep, active engagement with symbolic content. In practice, this means designing XR experiences that draw from and at the same time contribute to the shared symbolic systems and collective unconscious, enriching the user's cognitive and cultural engagement.

Notably, the concept of Mundus Imaginalis exhibits parallels with findings in cognitive science, suggesting potential intersections between Corbin's philosophical framework and contemporary cognitive theories. While a comprehensive formal argument to substantiate this alignment extends beyond the scope of the present research, in this section, I aim to explore and illustrate these connections. By doing so, it seeks to provide preliminary insights into how Mundus Imaginalis may inform and enhance our understanding of cognitive processes within the context of 4E+ Cognition in XR design.

By examining Relevance Realisation, Opponent Processing, and the interplay between the Task-Positive Network (TPN) and the Default Mode Network (DMN), Vervaeke (2013, 2019) argued that the Imaginal Realm is an inherent component of cognitive processes, facilitating insight, creativity, and adaptive behaviour. The process of relevance realisation, as articulated by Vervaeke et al. (2012, 2013), is a central concept in cognitive science and the philosophy of mind that seeks to explain how humans and other intelligent systems determine what information is pertinent in a vast sea of stimuli and data. This process serves as a foundational mechanism underpinning cognition, perception, attention, and consciousness.

Attention simultaneously engages in bottom-up and top-down processes, utilising a strategy known as opponent processing (Vervaeke & Ferraro, 2013). This involves the interplay between two neural networks: the task-positive network (TPN) and the default mode network (DMN). The TPN is associated with focused attention on external tasks, while the DMN is linked to mind-wandering and introspective thought. Although these networks are functionally opposed, they are causally interrelated and interdependent. The concurrent activity of these networks causes our minds to oscillate between focused attention and mind-wandering. Mind-wandering introduces variations—novel stimuli and connections that can lead to new insights. When the TPN re-engages, many of these variations are filtered out, but some are retained, facilitating innovation, deeper understanding, and new perspectives.

Friston and Frith (2015) proposed that the brain does not attempt to predict the external world directly due to its inherent complexity and unpredictability. Rather, the brain predicts its own sensory states through hierarchical predictive coding. At the primary level, the sensory-motor loop interacts directly with the world (Friston, 2010; Friston et al., 2017). This level generates neural patterns of firing and wiring. The brain predicts these patterns, striving to complete them before they manifest in action. For instance, most of our movements, such as walking, are driven by top-down predictions, with bottom-up error corrections refining these predictions when discrepancies occur. The brain constructs multiple hierarchical levels wherein higher levels generate predictions and lower levels perform error correction (Clark, 2013; Friston and Frith, 2015).

Through this iterative process, the brain develops increasingly abstract capacities to anticipate events at the primary sensory-motor level. This enables the organism to navigate and interact with the environment in progressively more intelligent ways (Clark, 2013). Each layer of the mind operates at its respective level: lower levels process immediate patterns, while higher levels handle more abstract and long-term patterns. This hierarchical organisation aligns with Plato's tripartite theory of the soul. Similarly, Neoplatonism presents levels of intelligibility, reflecting a structured ascent from the sensory to the intellectual realms (Perl, 2015).

We engage in simultaneous bottom-up processing from sensory features and top-down processing from concepts—many of which are Imaginal in nature. This dual processing resembles the operations of neural networks and dynamical systems, where both data-driven and concept-driven processes are at play. Much of the real world is not directly detected by the mind; our visual system, for example, captures fragmentary samples, and the brain constructs predictions to fill in the gaps. This utilisation of imagery and imagination is essential for perception and for establishing our connection with reality. In essence, imagination plays a critical role in enabling us to engage meaningfully with the world. Consequently, incorporating imaginal processes is a key aspect of the study's design, ensuring that both data-driven and concept-driven mechanisms are thoroughly examined.

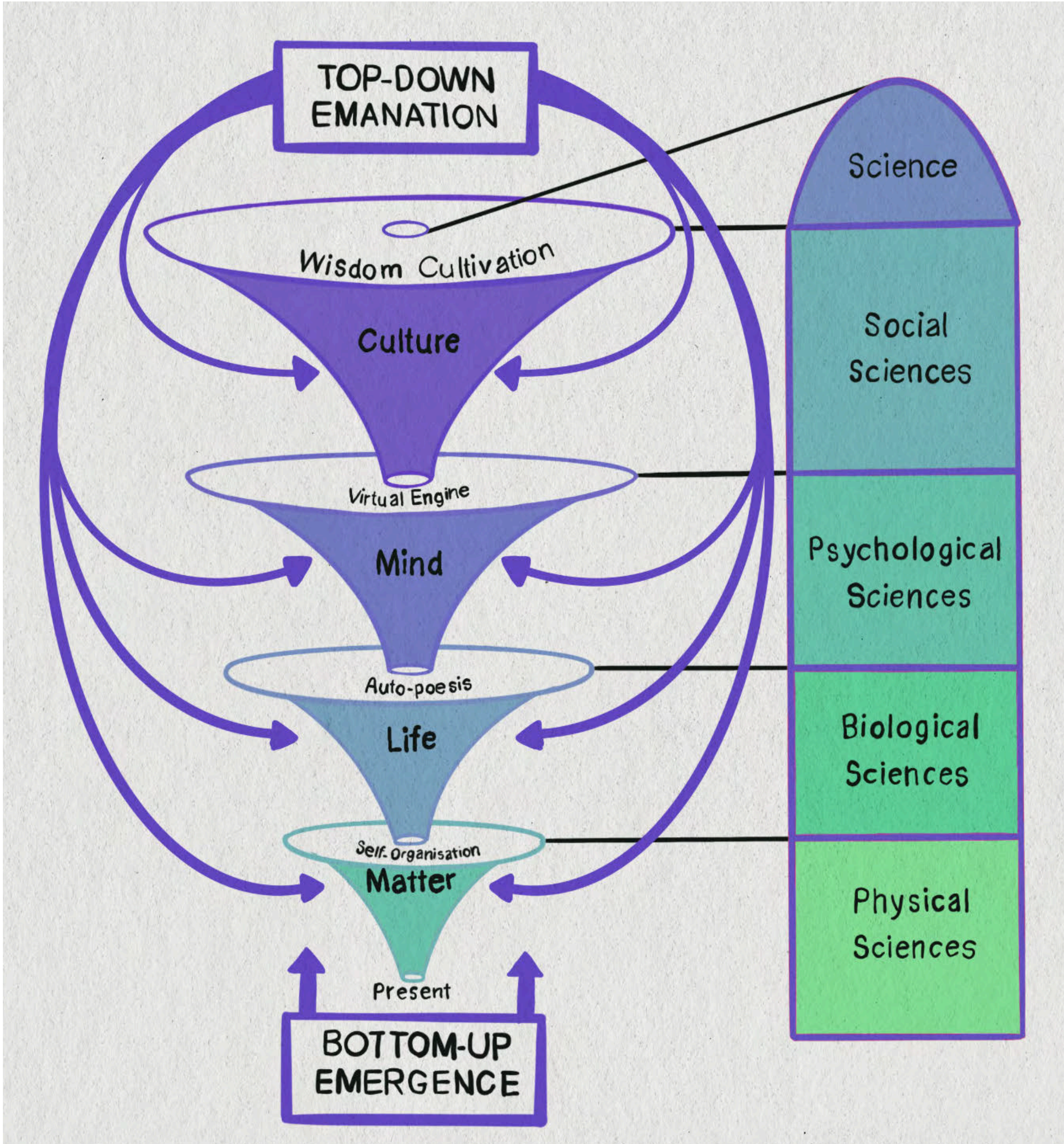


Figure 4.3 - Top-Down Emanation & Bottom-up Emergence.
Note. This visualisation combines insights from Vervaeke's cognitive science with the Greg Henriques big history model, Vervaeke, J. (2023, July 13). Transcendent Naturalism Ep. 1. Copyright by Greg Henriques (2003).

The concept of '*Top-Down Emanation & Bottom-Up Emergence*' (Figure 4.3 - adopted from Greg Henriques, 2003) encapsulates the intricate interplay between higher-order principles and grassroots interactions in the development and operation of complex systems and structures.

Rather than a linear cascade or mere aggregation, top-down emanation involves overarching principles that guide and shape the formation of lower-level phenomena, creating a synergistic influence akin to a river that shapes the landscape through which it flows. Conversely, bottom-up emergence highlights how complex patterns and systems arise from the dynamic interactions and relationships of foundational components, illustrating how various elements coalesce to form a coherent whole. This interplay acknowledges the fluid, reciprocal nature of complexity, where both higher-order influences and local interactions are continuously evolving and co-constructing the system (Clayton & Davies, 2006).

The 4E+ Cognitive framework is integral to my research design. At its core, it posits that cognitive processes are deeply rooted in the body's interactions with the world (Varela et al., 1991). In the context of the Imaginal Realm, embodied cognition underscores how physical experiences and sensory feedback influence imaginative and symbolic processing. For instance, when users engage with eXtended reality (XR) environments, their bodily movements and sensory inputs shape the navigational and imaginative tasks they perform, thereby grounding abstract concepts in tangible experiences. This embodiment facilitates relevance realisation by allowing the body to interact with and prioritise certain sensory inputs over others, thereby influencing which aspects of the Imaginal Realm become salient (Andersen et al., 2022).

Embedded cognition emphasises that cognitive processes are situated within and influenced by the socio-cultural and physical environment (Hutchins, 1996; Rietveld & Kiverstein, 2014). The Imaginal Realm, as an intermediate space between the sensory and intellectual worlds, is inherently embedded within cultural narratives, symbols, and social contexts. For example, cultural artefacts and societal norms shape the symbolic manifestations that reside in the Mundus Imaginalis. By recognising cognition as embedded, we acknowledge that relevance realisation is not merely an internal cognitive function but is also shaped by external socio-cultural factors, thereby aligning with Vervaeke et al.'s (2012) notion of relevance realisation as a participatory process.

Extended cognition suggests that cognitive processes extend beyond the individual's brain to include tools and external artefacts present in the medium that aid in thinking and experiencing the world (Clark & Chalmers, 1998). In relation to the Imaginal Realm, technologies such as head-mounted displays (HMDs), 360 Caves, and augmented reality (AR) serve as cognitive extensions that enhance and diversify the ways individuals interact with and navigate the Imaginal Realm (Aguayo, 2023). These tools facilitate opponent processing by providing additional sensory inputs and interactive possibilities that enrich the interplay between the TPN and DMN, thereby fostering more complex and nuanced insights and creative outputs.

Enacted cognition posits that cognition arises through dynamic interactions with the environment, emphasising active engagement and sense-making (Varela et al., 1991). The process of navigating the Imaginal Realm through XR technologies exemplifies enacted cognition, where users actively construct and interpret their experiences. This active engagement aligns with Vervaeke's (2012) concept of relevance realisation as a participatory process, where insights emerge from the continuous interaction between the individual and their environment. Enacted cognition also supports opponent processing by facilitating a constant feedback loop between focused attention (TPN) and imaginative exploration (DMN), leading to the self-organisation and evolution of cognitive patterns.

The affective dimension acknowledges the role of emotions and affective states in shaping cognitive processes and human experience overall. Emotions influence relevance realisation by prioritising certain experiences and insights over others, based on their emotional significance. In the Imaginal Realm, affective responses to symbolic and imaginative content can enhance or inhibit the emergence of insights and creative ideas. Emotional design in XR environments leverages affective processes to create immersive and impactful experiences that resonate with users on a deeper cognitive and emotional level, thereby enriching the interplay between the DMN and TPN.

Integrating the 4E+ Cognitive Framework with the earlier discussion on relevance realisation, opponent processing, and neural networks provides a multifaceted understanding of how the Imaginal Realm functions within cognitive architecture. Embodied interactions with XR environments shape which aspects of the Imaginal Realm are accessed and how they are interpreted, directly influencing relevance realisation by grounding abstract symbols in physical experiences. Embedded cognition ensures that the Imaginal Realm is continuously influenced by socio-cultural contexts, making relevance realisation a dynamic interplay between internal cognitive mechanisms and external environmental factors. Extended tools and technologies augment cognitive capabilities, facilitating more sophisticated opponent processing between the TPN and DMN by introducing new sensory and interactive dimensions that enhance imaginative and focused cognitive functions. Enacted engagement with the Imaginal Realm promotes active sense-making and co-shaping of insights, aligning with the self-organising principles of opponent processing and relevance realisation. Affective processes imbue the Imaginal Realm with emotional significance, prioritising certain cognitive pathways and enhancing the overall impact of insights and creative outputs.

By situating the Imaginal Realm within the 4E+ Cognitive Framework, we underscore its integral role in embodying, embedding, extending, enacting, and emotionally shaping cognitive processes. This holistic perspective bridges ancient philosophical concepts with contemporary cognitive science and also highlights the dynamic and interactive nature of human cognition as it navigates between the sensory, Imaginal, and intellectual realms.

4.2.2. Unity of Intellect and Illuminationism

The concept of the unity of intellect, rooted in Illuminationist philosophy, posits that true knowledge arises from the integration of direct, intuitive insight with rational, discursive thought (Corbin, 1993; Nasr, 1989). This philosophical stance aligns with the goals of transdisciplinary research, which emphasises merging multiple fields to achieve a holistic understanding of complex problems and to develop innovative solutions that transcend traditional disciplinary boundaries (Gibbons et al., 1994; Nicolescu, 2002).

Ishraq Hikmah, or Illuminationism, articulated by Suhrawardi in 1186, highlights the essential link between intellect and divine knowledge. According to this philosophy, true understanding emerges through an inner illumination where the intellect is bathed in divine light, leading to a profound grasp of reality (Nasr, 2006).

By embracing the principles of unity of intellect and Illuminationism, the research fosters a dialogue between ancient wisdom and modern technology, ensuring that the development of XR technologies and their applications is informed by a comprehensive understanding of human cognition and culture. Hence, the transdisciplinary research, as applied in this project, is not merely a methodological choice but a philosophical commitment to creating a more integrated and collaborative approach to problem-solving.

By drawing on the philosophical traditions of Islamic Ishraq Hikmah and fusing them with contemporary theories of knowledge and cognition, the research embodies a holistic, integrated approach to problem-solving. This synthesis bridges ancient philosophical wisdom with modern scientific insights and also provides practical guidelines for designing meaningful and transformative technological experiences. By embracing this holistic approach, we can enrich our engagement with technology and foster a connected understanding of ourselves and the world around us.

Suhrawardi Illuminationism posits that the highest form of knowledge is achieved through the harmonious synthesis of intuitive (mystical) knowledge and discursive (conceptual) learning. This approach contrasts with Peripatetic traditions, which prioritise empirical observation and rational deduction as the primary means of acquiring knowledge. By integrating both direct experiential insights and systematic analytical methods, Illuminationism offers a more comprehensive pathway to understanding metaphysical truths (Ziai, 1990). This non-dualistic perspective, which integrates rational inquiry with experiential and intuitive understanding, offers a nuanced framework for exploring the profound interconnectedness of self-knowledge and knowledge of the world. It highlights the dynamic interplay between intuitive insight (Kašf), experiential validation (Šohūd), and the existential presence ('Hudur) that characterises the deepest forms of knowing in the Illuminationist tradition (Aminrazavi, 2014; Deely, 2020).

While recognising the importance of reasoning, Suhrawardi emphasises that thought begins with intuition and praxis. This blend of Platonic intuitionism and Aristotelian rationalism fosters a dialogue between the Imaginal realm (Mundus Imaginalis) and the earthly self (Corbin, 1964; Walbridge, 2001). Integrating these illuminationist principles into my research design was essential for valuing creative practice and achieving a state of illumination, where abstract concepts and artistic works become tangible. This approach supported my goal of fostering innovative intellectual engagement through practice-led methodologies (Corbin, 1966; King, 1989; Ziai, 2001/2020).

4.2.3. Artistic Research

Artistic inquiry is not merely a component but a pivotal axis of the methodology employed in this practice-oriented, transdisciplinary research. Artistic research, in this context, serves as a bridge between theoretical constructs and practical exploration. In the exploration of a practice-oriented, transdisciplinary research paradigm, artistic research emerges as a pivotal methodology, bridging the theoretical and practical realms with a unique depth. This approach is particularly salient in the study of XR environments, where the integration of Islamic Ishraq hikmah-philosophy, cybernetics, and 4E+ cognition demands a nuanced understanding that transcends conventional research methodologies (Borgdorff, 2012). Artistic research, in this context, is not merely an adjunct to theoretical inquiry but a fundamental component of the research design, offering an immersive avenue for exploring, in this case, the transformative potential of XR.

Central to this research is the premise that artistic processes and outputs are integral to the generation of knowledge. Through the design and interaction within XR projects, these practical endeavours become a crucible for inquiry, allowing for the exploration of complex concepts and the embodiment of theoretical ideas in tangible forms (Frayling, 1993;

Scrivener, 2002). This methodology underscores the value of artistic intuition and creativity as potent tools for scholarly investigation, enabling a deeper engagement with the research questions. By leveraging the unique capabilities of artistic research to navigate the realms of subjectivity, ambiguity, and emotional resonance, this approach facilitates a holistic understanding of XR's potential, particularly in the context of HCI design informed by a rich tapestry of cultural and philosophical insights.

Furthermore, artistic research transcends the traditional boundaries of academic disciplines, fostering a dynamic interplay between creative exploration and theoretical analysis. This fluidity is especially pertinent in the context of this research, where the aim is to harmonise technological innovation with philosophical wisdom, thereby enriching the HCI design process within the 4IR landscape (Biggs & Karlsson, 2011). The insights derived from this approach contribute to the academic discourse while at the same time, resonate on a personal and human level, offering perspectives that are deeply embedded in experiential and existential dimensions. In sum, the incorporation of artistic research within this practice-oriented, transdisciplinary paradigm offers a comprehensive framework for understanding and innovating within the complex interstices of technology, culture, and design.

One key aspect was the use of observational and documentary practices, including photography, videography, and audio recording. These methods captured the workflow and the work done on the projects, providing a dataset for subsequent analysis and reflection. This documentation was essential in understanding how users engage with and perceive XR technologies, offering insights into the sensory and cognitive dimensions of these interactions. Personal insight approaches played a crucial role in this research, enabling the researcher to incorporate personal experiences and reflections into the study. Diaristic entries, combined with photography, provided a narrative framework that enriched the understanding of the subjective and emotional aspects of engaging with XR. This introspective method allowed for a deeper exploration of how XR environments can influence and transform human cognition and perception.

4.2.4. Practice-Led Research and Research-Led Practice

The interplay between practice-led research and research-led practice formed the cornerstone of the methodological framework for this PhD project. This dual approach served to underscore a dynamic, reciprocal relationship between theoretical inquiry and creative practice (Figure 4.4), challenging traditional boundaries and fostering a rich dialogue between creation and analysis. As Schön (1992/2017) has articulated, the synergy between theory and practice is not static but is characterised by a continuous flow of influence and transformation, a principle that is vividly embodied in this research endeavour.

In the context of this thesis, the practice-oriented research approach should not merely be considered a methodology but also a philosophical stance that regards the creative process as a fundamental mode of inquiry. This stance was manifested in two distinct yet interconnected modes: practice-led research, where the act of creation drives theoretical exploration, and research-led practice, where theoretical insights and inquiry inform and shape the creative output (Smith & Dean, 2009). By adopting a stance that aligns more closely with that of an artist or practitioner, the research emphasised the value of creative practice as a critical component of scholarly investigation, viewing the research process as an integral aspect of the practical work itself.

This practice-oriented approach deepened the understanding of theoretical concepts while fostering the emergence of new questions and insights that traditional methodologies might overlook. By evaluating outcomes through the lens of practice, this research could advance both the intellectual understanding of XR and the development of innovative interactions and experiences, effectively integrating practice-led and research-led approaches in a cohesive and impactful way.

To achieve this practice-oriented approach, I utilised some real-world projects that my supervisor and I were involved with at the AUT AppLab as a testing ground. These projects provided a practical environment to apply and evaluate theoretical insights, allowing for hands-on experimentation with emerging technologies and facilitating the exploration of user interactions and experience design principles in real-world scenarios. The AppLab, led by Dr. Claudio Aguayo, is a multidisciplinary and transdisciplinary hub dedicated to pioneering educational technology innovations. By leveraging emerging technologies, the AppLab redefines learning and teaching (Aguayo, 2021; also refer to AppLab website: https://www.applab.ac.nz/).

In this study, the AppLab served as a technological playground with resources for practical exploration and experimentation. This enabled me to explore and experience firsthand the application of theoretical insights from traditional wisdom and 4E+ Cognition to real-world projects, as elaborated in section 4.4. Additionally, the AppLab's focus on autopoiesis and 4E+ Cognition in digital learning design (Aguayo, 2023) aligns with this study's aim to explore how XR technologies facilitate cognitive processes that are embodied, embedded, enactive, and extended, with an emphasis on affective and emotional dimensions. By translating these theoretical principles into practical applications, the AppLab provided a critical foundation for this research, contributing to the broader discourse on educational pedagogy and technology design while supporting the development of the author's practical projects over the past seven years.

Figure 4.4 - Model of Creative Arts and Research Processes.
Note. This illustrates an iterative and cyclical framework that interconnects practice-led research with research-led practice. Copyright: Smith & Dean, 2009.

4.2.5. Bringing it All Together

When combined, the diverse perspectives mentioned created a guiding paradigm and cohesive framework for XR design, one that is technologically advanced while also profoundly human. The paradigm is a celebration of the complex, the emergent, and the personal, ensuring that every interaction within XR is a harmonious blend of intellect, emotion, and experience. Through this symphony of minds and worlds, I crafted XR environments that, as we will see in Chapter 5 and later in the exhibition, are as dynamic and evolving as the users themselves, fostering more meaningful engagement with the digital realm.

In embracing this transdisciplinary paradigm, I endeavoured to create XR interactions that are innovative, adaptive, and profoundly human-centred, capturing the essence of our shared journey through fluid realities. By recognising the emergent properties of these systems, this research aims to create XR experiences that remain engaging and relevant, reflecting the dynamic interplay between users and their environments. The unity of intellect and the philosophical tradition of Illuminationism emphasise the interconnectedness of all knowledge and the role of inner illumination in attaining true understanding, aligning with the transdisciplinary and holistic approach of the study. This cohesive framework integrates diverse fields and perspectives, ensuring that XR designs are technologically advanced while also culturally meaningful and intellectually profound.

The research framework integrates artistic creativity, cultural philosophy, and scientific investigation, establishing a foundational pillar for the study. Artistic research acts as a bridge, connecting theoretical frameworks with practical application, particularly in examining XR. The integration of Unity of Intellect and Illuminationism within Islamic Ishraq philosophy proposed by this study fosters a dialogue between ancient wisdom and modern technology, ensuring that XR technologies are developed with a comprehensive understanding of human cognition, culture, and ethics. This synthesis not only has the potential to bridge ancient wisdom with contemporary scientific insights but also to deepen our understanding of ourselves and the world.

Transitioning from the comprehensive research paradigm, next I will delve into the specifics of the research methodology that operationalises this innovative framework. The following section outlines the methodological approaches employed in this study, detailing the practical steps taken to integrate philosophical insights with cutting-edge technological exploration.

4.3. Research Methodology

In the context of this research, methodology pertains to the structured approach taken to investigate eXtended Reality and its intersection with 4IR, the concept of the medium, cognitive processes, culture, and traditional wisdom. My research methodology encompassed transdisciplinary research, cybernetics, 4E+ Cognition, and illuminative heuristic inquiry. This section details the methodologies employed in this research, providing a comprehensive exploration of the multifaceted approaches underpinning my practice-oriented transdisciplinary study. In this transdisciplinary research a robust multifaceted methodology ensured that the research remained grounded in systematic inquiry while allowing for flexibility and innovation. This methodology enabled me to freely explore new design principles emerging from my practice-oriented endeavours. It also facilitated the application of these principles within XR environments to create immersive experiences.

This methodology provided me with a clear and structured approach to inquiry, ensuring that the research was systematic, comprehensive, and verifiable. It allowed me to align my methods with my research questions, objectives, and theoretical frameworks. Specifically, this discussion of the methodology addresses how the integration of 4E+ Cognition and ancient wisdom can enhance embodied interaction experience design, immersion, and presence in virtual environments and XR experiences. This involves a detailed examination of design principles and the potential impacts on the evolution of Human-Computer Interaction in XR technologies. The transdisciplinary nature of this research brought diverse intellectual traditions and practical insights together, ensuring a comprehensive understanding of the research subject. Cybernetics and 4E+ Cognition offered complementary perspectives on the dynamic and interactive nature of XR environments, emphasising the role of feedback loops and environmental interactions. Illuminative heuristic inquiry added a profound philosophical dimension, encouraging deep reflection and personal engagement with the research subject. The integration of these methodologies formed a holistic approach that guided the investigation and systematically addressed the central research questions.

4.3.1. Transdisciplinary Nature of this Research

The Transdisciplinary Research (TDR) approach combines academic research with non-academic knowledge systems, fostering a collaborative effort to address real-world issues (Pohl & Hirsch Hadorn, 2007). The inclusive process of TDR ensures that diverse perspectives are considered, leading to more comprehensive and applicable outcomes (Lang et al., 2012). Moreover, TDR emphasises the iterative nature of research, where findings are continuously refined through stakeholder feedback and practical application, enhancing the relevance and impact of the research (Bergmann et al., 2012). Unlike multidisciplinary research, which merely juxtaposes multiple disciplines, transdisciplinary research strives to create a holistic synthesis that generates new knowledge and insights (Nicolescu, 2002; Lang et al., 2012).

Transdisciplinary methodology in practice-oriented research involves integrating theoretical knowledge with practical application to address real-world problems. This approach is characterised by its emphasis on collaborative and participatory methods, where practitioners and researchers work together throughout the research process. In this research, I played the role of both practitioner and researcher, ensuring that the research is theoretically sound while also practically relevant and applicable to real-world scenarios.

The transdisciplinary approach is at the heart of my research methodology, an approach that transcends traditional disciplinary boundaries to foster a holistic understanding of the research subject and practice (Nicolescu, 2002). The power of transdisciplinary research lies in its ability to provide holistic insights and innovative solutions that may not be achievable within a single disciplinary framework. By embracing a transdisciplinary approach, this research is able to address the technological aspects of XR and could also delve into its philosophical, ethical, and cultural dimensions, reflecting my commitment to understanding the XR medium in all its complexity. In the context of this study, transdisciplinary research encouraged me to draw insights and methodologies from diverse disciplines, including technology, traditional wisdom, philosophy, art, and cognitive science.

The convergence of knowledge from multiple fields is a fundamental aspect of transdisciplinary research, allowing for a synthesis of diverse forms of knowledge. This convergence is crucial for understanding how XR blurs the lines between the physical and digital realms and facilitates the investigation of the potential of transforming Human-Computer Interaction (HCI). In my study, I observed the convergence of knowledge from fields such as technology, philosophy, art, and cognitive science. Through the convergence of knowledge, I was able to explore how XR blurs the lines between the physical and digital realms, leading to new insights into embodied cognition and enactive experiences.

My approach to transdisciplinary methodology is characterised by a strong emphasis on collaboration among various stakeholders, including academics, practitioners, and community members. This collaboration involved myself, my supervisors, including my primary supervisor as the leader of AppLab, other academics as needed for each project, the AppLab team, and sometimes practitioners from other universities or companies. This methodology effectively bridged the gap between theoretical research and practical application by involving practitioners throughout the research process, thereby making the findings more applicable and beneficial in real-world settings (Richardson, 1994).

Based on the synthesis of insights from technology, philosophy, art, and cognitive science, the transdisciplinary approach provides a comprehensive framework for exploring the complex interplay between cognitive processes and human experience. This methodology supported the development of design principles through transdisciplinary practices, ensuring that theoretical frameworks were tested and refined in real-world contexts. Moreover, the collaborative nature of transdisciplinary research ensured that cultural and philosophical considerations were woven into the fabric of experience design, leading to outcomes that were both innovative and contextually relevant. Ultimately, this transdisciplinary methodology fostered the creation of more immersive, intuitive, and meaningful user experiences within the context of this study.

4.3.2. Cybernetics, the Art of Steering

> How does one become a cybernetician? Or, perhaps you want me to tell you how I became a cybernetician…we all are metaphysicians, whether we call ourselves such, whenever we decide upon in-principle undecidable questions. To answer the question, I could also say we are all cyberneticians (whether or not we call ourselves such) whenever we justify our actions without using the words 'because of . . . ,' or 'à cause de . . . ,' — Heinz von Foerster (1991)

Often described as *the art of steering* (Dubberly & Pangaro, 2019; Henriksen et al., 2018), cybernetics provides a comprehensive framework for understanding and managing complex systems, making it highly pertinent to transdisciplinary research. Deriving from the Greek word "kybernetes," meaning steersman or governor, cybernetics investigates the principles of regulation and control within systems (Wiener, 1948/2019). This section explores cybernetics' applications in shaping the methodological approaches of my research, detailing how its principles are seamlessly integrated into both the research process and artefact creation.

The research integrated cybernetic principles with cognitive theories to explore how interactions within XR environments can influence cognitive processes. This involved modelling cognitive interactions as feedback systems where actions and perceptions continuously informed and modified each other. Using this approach, simulations and interactive environments could be developed that facilitated cognitive feedback loops, allowing users to engage in adaptive learning processes.

The concept of steering and course correction is essential for managing complex research projects, especially in rapidly evolving fields like immersive media. Steering involves continuously incorporating feedback, self-regulation, and adaptation to ensure progress remains aligned with project goals (von Foerster, 1952). In this research, feedback loops were deliberately built into the iterative design and development processes. These loops allowed for regular reflection and adjustment, ensuring that the project remained focused and responsive to emerging insights. The steering process specifically involved critically evaluating my analysis and thinking in relation to the research questions, allowing for necessary adjustments to keep the work on track and aligned with the overall objectives.

In the context of this research, cybernetics informed the design and analysis of XR environments by emphasising the importance of feedback loops, self-organisation, and emergent behaviours. This methodology aligns with the dynamic and interactive nature of XR, where user interactions continuously shape and are shaped by the system, leading to emergent cognitive and experiential phenomena. Cybernetics extends its principles to the realm of cognition, providing insights into how cognitive processes can be modelled and understood as self-regulated and adaptive dynamic systems. This perspective aligns with the 4E+ framework, which views cognition as an embodied, embedded, enactive, and extended process.

In addressing the research questions, cybernetics was found to provide a comprehensive framework for understanding and enhancing embodied interaction experience design within XR environments. Cybernetics supports the integration of ethical, cultural, and philosophical considerations by fostering adaptive control mechanisms that respond to diverse user needs and preferences. Thus, cybernetics enhances our existing understanding of the potential impacts and future implications of these integrated design approaches on Human-Computer Interaction, facilitating the creation of more immersive, intuitive, and meaningful XR experiences.

4.3.3. Holistic Understanding

Holistic understanding highlights the integration of various dimensions of experience and knowledge to achieve a comprehensive and global view of the phenomena under study. This approach aligns with Maturana and Varela's (1987) insights on cognition as a biological phenomenon intrinsic to all living organisms, suggesting that every action of a living being is an act of knowing. Their work highlighted the interconnectedness of life and knowledge, proposing that cognition is a universal feature of life and living beings, not limited to humans. This methodology is particularly pertinent in fields such as experienced-based media like eXtended Reality, where it allows for the consideration of cognitive, emotional, and spiritual dimensions of human interaction. By embracing a holistic perspective, researchers can explore XR's potential to facilitate transformative experiences that resonate with both the individual's inner life and their external world.

Moreover, scholars like Moustakas (1990) and Root-Bernstein (2003) advocated for methodologies that encompass the totality of human experience—emotional, physical, intellectual, and spiritual. These approaches promote transdisciplinary learning and the integration of arts and sciences, fostering innovation and creative problem-solving. For example, Moustakas's heuristic research emphasised the importance of personal experience and intuition, while Root-Bernstein highlighted the cognitive benefits of polymathy, where individuals leverage diverse expertise to make connections across various fields.

The holistic methodology employed in this research facilitated the integration of cognitive, emotional, and spiritual dimensions, thus allowing for a deeper exploration of how the principles of 4E+ Cognition and Spiritual Wisdom can enhance embodied interaction experience design within XR environments. The holistic perspective is thus designed to ensure that the developed XR experiences would resonate with users; however, this was not tested in the current study. It is worth mentioning here that the methodology to study the final designs is significantly influenced by my individual experience and self-reflection, which may introduce biases in how the results are interpreted and analysed. Even though I applied reflexivity and maintained transparency to reduce these influences, the results are still presented from a subjective standpoint.

4.3.4. Heuristic Inquiry

Heuristic inquiry, as a research methodology, invites the practitioner researcher into an intimate dance with the phenomena under study, emphasising a deeply personal and transformative journey of discovery. Rooted in the works of Moustakas (1990) in the field of humanistic psychology, this approach transcends mere observation, urging the researcher to engage in a profound and introspective exploration of the self in relation to the subject matter.

In heuristic research, the researcher or practitioner seeks to fully immerse themselves in the lived experiences connected to the phenomenon under research, often resulting in new insights and self-awareness. The process consists of six distinct phases: initial engagement, immersion, incubation, illumination, explication, and creative synthesis. These phases guide the researcher through the dynamic interaction between subjective reality and objective knowledge, fostering a deeper understanding through reflection, intuition, and personal connection.

This approach aligns with philosophical traditions that value introspection and the inner journey as pathways to deeper understanding. It resonates with the notion that knowledge is not static but is a living, evolving process that unfolds through continuous engagement and reflection (Douglass & Moustakas, 1985). Heuristic inquiry is a call to embrace the full spectrum of human experience—its light and shadow, its clarity and ambiguity. It is a methodology that celebrates the richness of personal narrative and the transformative power of self-inquiry, offering a nuanced and human perspective on the phenomena we seek to understand.

At its core, heuristic inquiry is an immersive process that weaves together the threads of personal experience and scholarly investigation. It is a method that honours the subjective and the emotional, recognising that true understanding emerges not just from intellectual rigour but from the heartfelt engagement and intuitive insights of the researcher. As Moustakas (1990) eloquently put it, this methodology aims to “discover the nature and meaning of experience” (p. 9) and to uncover the “essence of the phenomenon" (p. 44).

Heuristic inquiry's emphasis on personal experience and introspection is instrumental in addressing the central research questions of this study. This approach ensures that the insights gained are academically rigorous and also personally resonant and reflective of the user's subjective experience. Through the process of self-inquiry and reflection, heuristic inquiry facilitates the discovery of new design principles that emerge from practice-based exploration. This methodology supports the integration of cultural and philosophical considerations into experience design by allowing the practitioner to connect with these dimensions on a personal level. This approach was particularly poignant in exploring virtually interactive experiences, where subjective user experiences form the crux of technological interaction. In the realm of heuristic inquiry, the practitioner's own experiences, reflections, and insights are not merely supplementary but are central to the process of knowledge creation.

4.3.5. Illumination and Presence: An Ishraqi-Heuristic Methodology

Suhrawardi's Illumination is a philosophical framework in which knowledge and being are deeply intertwined, illuminated by the light of divine truth. His Ishraqi philosophy shares significant connections with Neoplatonism, particularly in its emphasis on the hierarchical structure of existence and the soul's ascent toward higher states of awareness. Similar to the Neoplatonic tradition, Suhrawardi envisions reality as a series of descending and ascending levels of light. The ultimate goal is the soul's reunion with the divine source, which is akin to the Neoplatonic concept of the One (Chittick, 2000; 2001). The ascent is not merely intellectual but an experiential journey, where the seeker moves through various degrees of illumination, gradually attaining direct knowledge of the metaphysical realities beyond the physical world.

The integration of these Neoplatonic ideas into Suhrawardi's Ishraqi framework informs his unique epistemology, where both rational inquiry and mystical insight guide the soul towards ultimate truth (Corbin, 1998; Ziai, 2005). Henry Corbin emphasised that the Ishraqi epistemology and methodology are inherently experiential, Intuitive, and require the practitioner to transcend the confines of rational thought and embrace the inner light of intuition (Landolt, 1999).

That being said, Suhrawardi Illuminationism posits that the highest form of knowledge is achieved through the harmonious synthesis of intuitive (mystical, tasted, direct, or *Hudhuri*) knowledge and discursive (conceptual and based on rational deduction) learning. By integrating both direct experiential insights and systematic analytical methods, Illuminationism offers a more comprehensive pathway to understanding metaphysical truths (Ziai, 1990; Ihsan et al., 2022). Moreover, Ziai (1990) highlighted that for Suhrawardi, the act of knowing is an illumination that enlightens the intellect and purifies the soul, leading to a harmonious integration of knowledge and existence. In this context, *Hudhuri* knowledge (which interestingly enough means *Presence*!) plays a central role as it emphasises direct, unmediated awareness rather than inferential reasoning.

In artistic practice, this concept can be seen in the importance of being fully present and immersed in the creative process. The artist-researcher is encouraged to engage with their work on an intuitive level, drawing from immediate, lived experience rather than solely relying on intellectual frameworks. This aligns with phenomenological approaches to artistic research, where embodied experience and direct engagement with the creative process take precedence over detached analysis (Chittick, 1989/2010). Consequently, Suhrawardi illuminationist philosophy offers a robust methodology for artistic practice that emphasises the synthesis of intuition, experience, and reflection.

Hudhuri (Presence) Epistemology focuses on direct, immediate knowledge, advocating for an intuitive and experiential approach to creativity, while the integration of Mysticism and Rationality encourages alternating between intuitive creation and critical reflection. The Ontology of Light positions light as both a literal and metaphorical symbol of knowledge, guiding the artist’s exploration of visibility and insight.

Table 4.1 highlights the methodological intersections between heuristic inquiry and Ishraqi philosophy, emphasising their shared focus on lived experience, intuition, and transformation.

Both methodologies prioritise lived experience as the foundation of knowledge—heuristic inquiry through the researcher's personal journey and Ishraq through the direct, experiential reception of divine light (Throne, 2019; Ziai, 1990). Intuitive knowledge is central, as both methods value insights that transcend rational analysis, though rational thought is also integrated to refine these intuitive understandings (Moustakas, 1990; Ziai, 1990). The balance between rational and intuitive thought is crucial, as the interplay of intuitive creation and critical reflection guides artistic practice (Moustakas, 1990; T. Zhang, 2022).

Both approaches also emphasise active engagement and praxis, advocating for a dynamic process of discovery where action and reflection coalesce to reveal deeper truths (Najafi, 2022). The metaphor of a journey and transformation resonates in both, as knowledge is viewed as an evolving process, whether through the researcher's personal growth or the seeker's spiritual illumination (Corbin, 1964; Moustakas, 1990). Finally, both frameworks support the union of the knower and the known, where true understanding arises from a deep immersion in the phenomenon being studied, merging the seeker with the object of inquiry (Corbin, 1964).

Table 4.1 - The Ishraqi Heuristic Methodology

Methodological Concept	**Description and Application in Artistic Research**
Emphasis on Lived Experience - Hudhuri (Presence) Epistemology	Both heuristic inquiry and Ishraq prioritise the individual's lived experience as a fundamental component of understanding. In heuristic research, the researcher's personal experience is the main focus, used as an instrument for comprehending a phenomenon. Similarly, in Ishraq, knowledge is rooted in the individual's direct and immediate experience of the divine light. Emphasises being present in the creative process, prioritising intuitive, experiential knowledge.
Intuitive Knowledge	Intuition plays a crucial role in both methodologies. Heuristic inquiry begins with intuitive introspection, recognising that profound understanding often arises from an inner sense of knowing. Ishraqi philosophy also places a high value on intuitive knowledge, viewing it as a form of direct perception that transcends rational analysis.

Integration of Rational and Intuitive Thought	While intuition is central, neither methodology dismisses the value of rational thinking. In heuristic inquiry, rational processes such as explication and creative synthesis are employed to deepen intuitive insights. Ishraq similarly acknowledges the role of reason in illuminating the path to higher understanding, suggesting that rational thought can enhance and clarify intuitive insights. Alternating between intuitive creation and critical reflection, allowing both modes to guide practice.
Active Engagement and Praxis	Both approaches advocate for an active, engaged process of discovery. In heuristic inquiry, the researcher is dynamically involved in the exploration, reflecting and acting upon their insights. Ishraqi methodology requires the seeker to engage in spiritual practices and exercises that facilitate the reception of divine illumination, emphasising the importance of praxis in achieving true knowledge.
Journey and Transformation	The metaphor of a journey is prevalent in both heuristic and Ishraqi methodologies. Heuristic inquiry is described as a path of self-discovery and transformation, where the researcher's understanding evolves through continuous exploration. Ishraqi philosophy also portrays the search for knowledge as a transformative journey, where the seeker is progressively illuminated and transformed by their encounters with the divine light. Conceptualising creative phases as stages of growth, moving through levels of understanding and insight.
Union of the Knower and the Known	In both methodologies, there is a concept of merging the researcher with the object of inquiry. Heuristic inquiry involves a deep immersion where the researcher becomes one with the phenomenon being studied, leading to a profound internalisation of knowledge. Ishraq holds that true knowledge arises when the seeker's of light unites with the object of inquiry, creating an intimate, immediate understanding.

By synthesising these shared principles, the Ishraqi heuristic methodology offers a robust framework for research that is both deeply personal and universally resonant. This combined approach acknowledges the significance of the researcher's lived experience while also integrating intuitive and rational insights, fostering a holistic understanding that is actively engaged and transformative. In this way, the methodology aligns with the principles of both heuristic inquiry and Ishraqi philosophy, creating a path toward knowledge that is enriched by the illumination of both the intellect and the heart.

This methodology emphasises the journey of self-discovery and the pursuit of wisdom through direct, intuitive insight, aligning with the concept of the unity of intellect. By integrating the Ishraqi methodology with heuristic methodology, the research was able to thoroughly explore the cognitive and technological aspects of XR, and at the same time, was able to examine deeper philosophical and spiritual questions that these technologies evoke. The goal of this study is to bridge the gap between human cognition, technology, and transcendent knowledge, offering a comprehensive understanding of XR's potential to transform human experience.

4.3.6. The Sufi Journey of Self

The Sufi journey of self, or the mystical path towards divine union, is a profound spiritual undertaking in Islamic mysticism that seeks to transcend the ego (nafs) and achieve unity with the Divine (Tawhid). This journey involves self-purification, devotion, and spiritual practices, enabling the seeker to experience the Divine presence directly. Additionally, the 'Journey' as a metaphor for artistic growth frames the creative process as a personal, evolving journey through stages of awareness, paralleling spiritual ascent. Embodiment of Divine Light highlights the act of creation as a reflection of divine inspiration, positioning artistic practice as inherently spiritual. The integration of personal narrative and heritage encourages using philosophical insight approaches to incorporate personal experiences and cultural heritage into the creative process, embedding individual transformation within the artwork.

Notable Islamic mystics and philosophers such as Ibn Arabi, Al-Ghazali, and Rumi have contributed to the understanding of this journey through their allegories, philosophical discourses, and personal narratives. Incorporating the Sufi journey of self, rooted in the works of figures like Ibn Arabi, Suhrawardi, and Avicenna, this research emphasises a transformative spiritual path to divine union. This concept is mirrored in immersive experiences within XR, where symbolic representation and allegory enhance cognitive and spiritual engagement. Suhrawardi Illuminationism, with its focus on inner light and experiential knowledge, aligns with XR's capacity to create immersive environments that bridge empirical and spiritual exploration.

Figures like Ibn Tufail and Attar of Nishapur further provide allegorical frameworks that illustrate the potential for self-discovery and intellectual growth through XR, offering a unique lens for understanding Human-Computer Interaction in a transformative and embodied context. Ibn Arabi's concept of the Perfect Man (Insan al-Kamil) illustrates the culmination of the Sufi journey, where the individual becomes a reflection of divine attributes, representing a state of unity with the Divine. Al-Ghazali's works offer practical spiritual guidance, while Rumi's poetry emphasises the emotional and experiential aspects of the Sufi path, often using metaphors of love and union to convey the transformative journey towards divine realisation.

The Sufi journey is also captured in philosophical works such as Ibn Sina's (Avicenna, ca. 970–1037) Ḥayy ibn Yaqẓān (meaning *Alive, Son of Awake*), which is written in early the 11th century. The story of *Ḥ*ayy represents the human intellect, striving to reach a state of pure knowledge and unity with the divine. Avicenna uses the story as an allegory to explore his metaphysical ideas, particularly the relationship between the soul and the intellect. In the story, Hayy, isolated on an island, attains knowledge of the divine through reason and contemplation, illustrates the human soul's quest for meaning and truth.

Suhrawardi (1154–1191), founder of the Illuminationist school, presents the mystical journey as one of inner illumination, where true knowledge is obtained through divine light. In his work *The Occidental Exile* (written in the late 12th century), Suhrawardi depicted the soul's ascent from ignorance to knowledge, blending metaphysical insights with cognitive processes to foster spiritual growth.

Ibn Tufayl's (1105-1185) version of *Ḥayy ibn Yaqẓān* (Arabic: حي بن يقظان, Latin: Philosophus Autodidactus "The Self-Taught Philosopher"; English: "The Improvement of Human Reason: Exhibited in the Life of Hai Ebn Yokdhan", written in the early 12th century) explored the journey of self-discovery through direct experience, reflecting on the acquisition of knowledge outside conventional frameworks. This allegory underscores the potential of experiential platforms, such as XR, to facilitate transformative learning and intellectual enlightenment, similar to the mystical journey of self-exploration found in Sufi thought (Tufayl, 2015, L. E. Goodman, Trans).

In the context of XR and HCI, this journey can be translated into a process of design and research that emphasises holistic, embodied, and experiential learning (Table 3.2). This framework effectively bridges the philosophical traditions of these Islamic thinkers with modern XR technologies. By drawing on Sufi's insights and narratives, XR can be developed to offer profound, immersive experiences that facilitate intellectual and spiritual growth.

Table 4.2 - Design Principles for Experience Design (Influenced by the Sufi Journey)

Principle	**Description**	**Influence**	**Example**
Intuitive Experiences	Facilitate intuitive, immersive interactions, avoiding complex interpretations.	Inspired by Avicenna's "Ḥayy ibn Yaqẓān".	Interactive environments that allow users to explore without explicit instructions, focusing on self-guided discovery.
Personal and Spiritual Growth	The Sufi journey is inherently personal and transformative. Experience designs should create personalised paths for users, enabling them to explore their own spiritual or individual journeys.	Based on Suhrawardi's allegories of ascent and illumination.	Open-World design that allows users to walk their own journey.
Symbolism and Allegory	Sufi literature often uses symbols and allegories to convey complex concepts. Similarly, an interactive experience can employ visual symbols and narrative structures to represent philosophical and spiritual ideas, making them accessible and engaging for users.	Influenced by Ibn Arabi's Imaginal World and Attar's Conference of the Birds. Influenced by the use of metaphors in Ibn Arabi's exploration of the Imaginal World.	Metaphorical elements in storytelling and the design of environments that reflect philosophical and spiritual ideas.

Holistic Problem Solving	Employ systemic, cybernetic approaches that consider the interconnectedness of all design elements.	Aligns with the non-duality of Sufi thought and the 4E+ Cognition framework.	Adaptive systems in XR that respond to user behaviour and environmental factors dynamically.
XR as an Independent Medium	Recognise XR as a unique medium with distinct affordances for interaction and engagement.	Focus on XR as a standalone medium beyond traditional interfaces.	Immersive experiences that are unique to XR and offer new forms of engagement not present in other media.
Emphasis on Qualia[18] and Affect	Prioritise emotional and qualitative user experiences in design.	Inspired by Sufi emphasis on inner experiences and emotions.	Emotional feedback loops that are incorporated in XR to enhance user engagement and connection.
Cultural and Philosophical Considerations	Integrate cultural and philosophical insights from Islamic philosophy and Ishraq Hikmah into XR design.	Draws from the researcher's background in Ishraq Hikmah and Islamic philosophy.	Creating culturally rich XR experiences that reflect philosophical traditions and ethical considerations.
Physical Interaction and Embodied Feedback	Design for physical interaction and embodied experiences that emphasise the role of the body in cognition.	Based on 4E+ Cognition, particularly the embodied and enactive components.	Full-body tracking and haptic feedback in XR that reflect physical movements and interactions.
Sensory Experience and Immersion	Develop multi-sensory, immersive experiences that unify sensory input with intellectual and emotional engagement.	Informed by the Sufi principle of the unity of sensory and spiritual experience.	XR environments with audio-visual-tactile integration that foster a deep sense of immersion.
Contextual Awareness and Physical Affordances	Incorporate the user's physical and environmental context into the design of affordances.	In line with 4E+ Cognition's emphasis on environmental embeddedness.	XR interactions that adapt based on the user's real-world surroundings and thereby enhance intuitiveness and usability.

[18] It refers to the internal, subjective qualities of experiences, a key concept in the philosophy of mind and consciousness. In academic terms, "qualia" are defined as the subjective, individual experiences of perception and sensation, like the redness of a rose or the taste of coffee. They represent the qualitative, phenomenological aspects of consciousness, often discussed in philosophy of mind and consciousness studies. Qualia are considered ineffable and intrinsic to personal experiences, making them difficult to objectively measure or describe. (Dennett, 1998)

The Table 4.2 above summarises the proposed key design principles for XR in Human-Computer Interaction (HCI), developed for this study. These principles blend philosophical foundations from Sufi mysticism and Neoplatonism with contemporary theories of 4E+ Cognition. Each principle embodies the research's transdisciplinary and holistic methodology, underscoring the importance of creating XR environments that engage users on intellectual, emotional, and spiritual levels. By integrating intuitive user experiences, symbolism, and culturally informed design, these principles push technological boundaries while prioritising the user's connection with the content. This approach positions XR as a tool for immersive, transformative learning and self-exploration, allowing users to transcend the purely functional aspects of technology and engage in meaningful interactions. The combination of ancient wisdom and modern cognition within this framework enables XR environments to foster a more comprehensive understanding of human experiences and interaction.

4.3.7. Bringing it All Together

The 'Research Methodology' section outlined an integrative framework that combines transdisciplinary research, cybernetics, 4E+ Cognition, and illuminative heuristic inquiry, all underpinned by the philosophical depth of Islamic Ishraq Hikmah-philosophy. This approach facilitates a comprehensive understanding of XR, its implications for human cognition and experience. This also opens up new avenues for exploring the ethical, cultural, and spiritual dimensions of technology, guided by the principles of unity of intellect and the transformative potential of illuminative heuristic inquiry.

Building on the philosophical insights of Islamic Ishraq Hikmah-philosophy, the research employs illuminative heuristic inquiry as a method to explore the subjective, experiential dimensions of interacting with XR. This approach allows for a deep engagement with the phenomenological aspects of XR, facilitating a nuanced understanding of how these technologies can shape human perception, consciousness, and spiritual experience. As discussed in this section, the research aims to use illuminative heuristic inquiry to uncover the transformative potential of XR, guided by the principles of Ishraqi philosophy and the quest for intellectual and spiritual illumination.

The study seeks to highlight the potential for XR to facilitate a deeper connection between the inner self and the physical environment in HCI design. By promoting holistic and embodied experiences, the chosen approach counters the trend of disembodiment and alienation in contemporary HCI. The research also aims to demonstrate the potential for synthesising oriental and occidental philosophical viewpoints, providing a more comprehensive understanding of cognitive processes. This synthesis can enhance problem-solving and decision-making in design, offering valuable contributions to the field of creative technology.

Furthermore, the study explores the gamification of cultural heritage, creating interactive experiences that engage younger generations with cultural and philosophical perspectives. This approach underscores the potential of XR to preserve and promote cultural heritage in meaningful ways. The Sufi journey of self, with its emphasis on personal transformation and spiritual enlightenment, provides a deep methodological framework for practice-oriented research in XR and HCI design. By integrating the principles of Ishraq Hikmah, cybernetics, and 4E+ Cognition, this study offers a comprehensive approach to designing immersive and holistic user experiences. The outcomes of this research hold significant implications for the future of HCI, contributing to the development of technologies that foster deeper connections between users and their environments, ultimately enhancing the human experience.

At the end, I like to mention that these philosophical narratives, intertwined with my own academic journey, illustrate the universal quest for knowledge and self-awareness. The ascent out of the cave, as envisioned by Plato, Suhrawardi, Ibn Sina, Ibn Arabi, Attar, and Ibn Tufail, represents the transformative journey of the soul from ignorance to enlightenment. Through this process, I have advanced academically while undergoing a profound personal transformation, gaining a deeper understanding of myself and the world around me. This journey, illuminated by the wisdom of the ancients and the insights of contemporary scholars like John Vervaeke, has shaped my PhD experience into a path of true anagoge (anagogy), a continuous ascent toward the light of knowledge and self-realisation.

4.4. The Practice

This research extends into real-world projects through the AUT AppLab[19], a hub of digital innovation in education exploration and development. This section elucidates the role of the AppLab in this study, emphasising the significance of real-world projects in the development of practice-oriented research artefacts.

The AppLab at Auckland University of Technology (AUT) stands as a beacon of innovation in the realm of educational technology. This multidisciplinary hub harnesses the power of emerging technologies to redefine the landscape of learning and teaching across various educational sectors. This learning lab represents a coalition of imaginative, creative, and digitally capable staff and students from Auckland University of Technology, alongside a range of external institutional and industry partners. By integrating a diverse array of technologies—including Real Environment (RE), interactive media, web applications, mobile applications, Virtual Reality (VR), Augmented Reality (AR), Mixed and eXtended Realities (MR/XR), and other digital media—the AppLab actively explores and crafts pedagogical transformations that align with cutting-edge educational strategies and technological advancements. Furthermore, AppLab employs an iterative approach characterised by constant loops between problem identification, theory-driven solution-seeking, and context-specific prototyping. This methodology ensures adaptability to emerging technological advancements and evolving practical knowledge, allowing the lab to stay at the forefront of digital education innovations. Such a dynamic process is essential for addressing the complex challenges inherent in developing effective immersive learning environments.

This research intricately aligns with the AppLab's mission, especially in terms of the research’s exploration of immersive learning within eXtended Reality and its intersection with cognitive processes through the lens of 4E+ Cognition and philosophical and spiritual wisdom. The AppLab's commitment to creating meaningful learning outcomes,

[19] AppLab is a cross-disciplinary group of academics, researchers, students, designers, and developers exploring new ways of learning through technology and new media. see https://www.applab.ac.nz/ and https://www.researchgate.net/lab/The-AppLab-Claudio-Aguayo.

through innovative digital and multimedia design and development, serves as a critical foundation for my study and research journey. The lab's projects, ranging from environmental education enhancements via XR, developing immersive learning simulations in paramedicine, and STEAM education content, exemplify the potential of XR technologies to foster deep, impactful learning.

4.4.1. The Importance of Real-World Projects

In my view, real-world projects play a pivotal role in practice-oriented research as they serve as a crucial bridge between theoretical knowledge and practical application. These projects facilitate a deep engagement with the complexities and nuances of real-world scenarios, allowing researchers to test, refine, and validate theoretical constructs within authentic contexts (Barab & Squire, 2004/2016). This integration of theory and practice is essential for generating actionable insights that can directly inform and improve professional practice, educational methodologies, and technological innovations.

In the realm of educational technology and design, the significance of real-world projects is particularly pronounced. According to Herrington et al. (2010), authentic projects that mimic real-life tasks provide a great context for learners to apply theoretical knowledge, thereby fostering deeper learning and engagement. This strategy is consistent with the principles of situated learning, which view the acquisition of knowledge as fundamentally connected to the context in which it is applied (Lave & Wenger, 1991). Real-world projects in practice-oriented research embody this philosophy by situating theoretical exploration within the practical challenges and opportunities of real-world settings.

Moreover, real-world projects offer a unique opportunity for interdisciplinary and transdisciplinary collaboration, bringing together experts from various fields to address complex problems (Nowotny et al., 2001). This transdisciplinary approach is crucial for tackling the multifaceted challenges of contemporary society, including those related to sustainability, health, the environment, and education. By working on real-world projects, researchers can draw upon a diverse array of perspectives and methodologies that enrich the research process and outcomes.

The application of real-world projects in practice-oriented research also plays a critical role in technology development and innovation. As argued by Edelson (2002), design-based research, which often involves the creation and testing of technological interventions and solutions in real-world and practical settings, provides valuable feedback loops that inform both theory and design. This iterative process ensures that technological innovations are grounded in empirical evidence and are responsive to the needs and constraints of end-users. Furthermore, focusing on real-world problems ensures that the research is meaningful and societally relevant. By addressing actual problems and needs, research projects can lead to tangible benefits for communities and industries (Gibbons et al., 1994). This alignment with societal challenges enhances the applicability of research findings while strengthening the relationship between academia and industry.

The real-world projects undertaken by the AppLab are crucial for practice-oriented research as they offer concrete instances where theoretical insights can be explored, applied, evaluated, and refined. These projects bridge the gap between abstract academic concepts and their practical implications, allowing, in this case, for a deeper understanding of how XR technologies can be utilised to foster experienced-based teaching and learning. Engaging with current societal challenges grounds the research in reality, ensuring that the solutions and insights generated are both relevant and applicable to the educational and technological landscapes.

In summary, real-world projects are indispensable to practice-oriented research, offering a dynamic platform for the integration of theory and practice. Through these projects, researchers can navigate the complexities of real-world challenges, fostering transdisciplinary collaboration, technological innovation, and societal impact. The insights gained from such projects are invaluable, providing a solid foundation for advancing knowledge and practice in various fields.

4.4.2. The AppLab and its Place in this Research

The role of the AppLab in this research is multifaceted. Firstly, it provides a practical space and access to advanced equipment for applying the theoretical insights gleaned from 4E+ Cognition within real-world educational settings and initiatives. Projects like *Pipi's World* (2017-2019) and the *NIWA Airbox* (2019) initiative demonstrate how XR can be utilised to engage learners in complex scientific and environmental concepts in an intuitive and immersive manner.

In addition, the AppLab's focus on autopoiesis and 4E+ Cognition in the design of digital learning affordances offers a theoretical and methodological blueprint for this research (Aguayo, 2019, 2023). By considering how learning environments can be designed to be self-maintaining and adaptable while providing means for user engagement into emotional and affective dimensions in relation to learning processes, this study explores how XR technologies facilitate cognitive processes that are embodied, embedded, enactive, and extended, with a focus on user affection and emotions. Such an approach advances our understanding of how XR can enhance learning within immersive environments and at the same time contributes to the broader discourse on educational pedagogy and educational technology design principles.

As the CTO and Team Manager at AppLab, I have the responsibility of leading practical research and development (R&D) efforts across our diverse XR and digital media projects. My role extends beyond traditional technical leadership; it involves integrating a transdisciplinary approach that bridges the technical and artistic aspects of our work. This alignment is essential for fostering a holistic vision that supports both innovative technical execution and compelling creative expression in each project.

A unique part of my contribution at AppLab is serving as the glue, bridging the gap between technical rigour and artistic intention. This alignment is more than task management; it involves deeply understanding each aspect of a project, from its artistic objectives to its technical and technological requirements, translating these into a cohesive structure. With a polymath background, I move fluidly between disciplines, able to interpret complex requirements from clients, academic collaborators, or project leads and distil them into actionable, targeted tasks for each member of the team. This adaptability allows me to facilitate a dynamic exchange of ideas, ensuring that both creative and technical components are thoroughly addressed and well-integrated. In this capacity, I play the role of an interpreter, translating abstract goals into structured plans that are both creatively inspiring and technically feasible. I work closely with each team member, helping them understand the overarching project goals and their individual roles within them, while aligning our efforts with client expectations and research objectives. By facilitating this translation process, I enable the team to work cohesively, making certain that each project is conceptually strong, technically sound, and tailored to meet specific user needs.

Additionally, I support the team in balancing experimental R&D with practical applications, a crucial aspect in fields like XR, where innovation and usability must coexist. Through this integrative approach, I help foster an environment where ideas from diverse fields converge, leading to XR solutions that push the boundaries of technology while also resonating with end-users on a meaningful level.

The AppLab's innovative efforts in translating the theoretical principles into practical applications, coupled with its openness to indigenous worldviews and modes of knowledge in education, provide a crucial foundation for this research. By integrating the philosophical insights with the cutting-edge technological innovations in education explored at the AppLab, this study was able to uncover new pathways for enhancing human cognition and experience through XR. Thus, the AppLab, with its commitment to meaningful, sustainable, critical, and transformative learning experiences, plays an indispensable role in providing a platform and shaping the direction and outcomes of this research, as well as in supporting the development of practical projects by the researcher over the past seven years.

Each of the following AppLab projects contributed in unique ways to the research by providing practical examples of how XR technologies can be applied across various domains to enhance learning, cognition, and spiritual understanding. By drawing on the insights and outcomes from these AppLab projects, the research gains a rich source of empirical evidence and data as well as experiential knowledge to inform its exploration of XR's potential in education and beyond. Table 4.3 below provides an overview of several AppLab projects and highlights their contributions to my research journey. Additionally, four of these projects were selected during their early design and development stages for me to document and explore in greater depth as part of my doctoral research, which I will discuss in more detail later.

Table 4.3 - The Projects in AppLab and their Contributions to my Journey.

Projects	**Description**	**Contribution to My Research**
O-TŪ-KAPUA (What Clouds See) (2015-2017)	The O-TŪ-KAPUA (What Clouds See) project, led by UNITEC along with NIWA, F4 Collective, and Susan Jowsey and Claudio Aguayo at AUT, merges art, science, indigenous perspectives, and technology to offer an immersive educational experience on climate change. Using augmented reality markers, soundscapes, colouring crafts and 360 VR tours within an art gallery space, it enhances understanding of atmospheric science and ecological interdependence (Jowsey & Aguayo, 2017). This project makes scientific concepts accessible and fosters a personal connection to the environment, promoting environmental awareness among young learners. (Jowsey & Aguayo, 2017).	The O-TŪ-KAPUA project has informed my PhD research by demonstrating the potential of XR technologies to communicate complex global challenges. Although it was developed before I joined the AppLab, its success in merging cognitive and emotional learning was informative for my objective to explore 4E+ Cognition within XR. The project's methodologies, such as sensory and participatory learning, provide a framework for enhancing educational experiences through XR. The success story of this project development has guided my research from early days, especially in regards to creating immersive environments that foster cognitive and emotional engagement and integrate scientific inquiry with artistic expression.
Pipi's World - XR Marine Education (2017-2019) This project was selected for further	The *Pipi's World* project, led by Dr. Claudio Aguayo at AUT, showcases the use of XR to enhance marine conservation and education. In collaboration with The University of Waikato, Conical Studios and the Goat Island	*Pipi's World* has significantly informed my PhD research by demonstrating XR technologies' practical application in education. It aligns with my exploration of using XR to facilitate complex cognitive processes through embodied and embedded cognition within the AR

exploration in this research	Marine Discovery Centre (University of Auckland), this initiative is based on a BYOD (bring your own device) and experiential learning framework enacted within an XR environment at a marine educational centre. The project promoted marine conservation education among senior primary students using AR, VR, and other digital and non-digital interactive elements; it aimed to increase ecological literacy by providing a tangible understanding of marine conservation and human impact on marine environments (Aguayo & Eames, 2020). This project makes complex scientific concepts accessible and engaging, fostering deeper understanding through narrative-driven experiences like exploring the Goat Island Marine Reserve from Pipi's perspective (Videla et al., 2021).	app. Observing its focus on user engagement, self-determined learning and intuitive interaction has provided insights into designing effective, user-centric educational tools. The project's experiential learning approach and co-creation with students reflect an autopoietic approach in the self-organisation of educational systems such as *Pipis World*. This aligns with my research on evolving digital learning tools to meet diverse learner needs and foster meaningful experiences. Additionally, Pipi's World highlights the importance of integrating non-digital aspects of XR, supporting that MR and XR, merge real-world and digital affordances to create immersive educational experiences. The project included both digital elements, like an AR app and 360 VR videos, and non-digital experiences, such as snorkelling tours and haptic interactions themed around marine conservation. This holistic approach underscores the potential for XR to not only enhance cognitive learning but also engage learners through tactile and real-world experiences, offering a multi-dimensional educational framework that informs my own research on XR's role in facilitating comprehensive and meaningful learning environments.
NIWA Airbox (2019) This project was selected for further exploration in this research	This collaborative project between NIWA, AUT, Massey University, and Curious Minds educates New Zealand secondary school children about air science using Augmented Reality (AR) technology. The AR app visualises air quality data, making complex scientific information accessible and engaging. Users can conduct	The *NIWA Airbox* project has technically informed my PhD research by showcasing XR technologies in science education. Its approach aligns with my exploration of using XR to enhance understanding and interaction with abstract concepts through extended, embodied and embedded cognition. A key technical aspect of the project is the two-way reciprocal IoT

	experiments, record observations, and share findings, actively participating in the scientific process. The project showcases XR technologies' potential to transform environmental education by providing an interactive platform that enhances understanding of abstract concepts, making air quality data both perceptible and comprehensible and empowering students to address environmental issues.	communication between the physical airbox and the digital-virtual AR app. This enables real-time data exchange, allowing users to both send data to the physical device and receive immediate real-time feedback via the app, enhancing user interaction and engagement with scientific data. This dynamic exchange between the physical and digital realms strengthens the learner's sense of agency and interaction, providing a valuable framework for my research on developing impactful XR educational applications involving IoT and real-time visualisation.
Year of the Salps (2019-2020)	The *Year of the Salps* project, led by Dr. Claudio Aguayo at AUT's AppLab and Dr Moira Decima (NIWA), innovatively uses immersive technologies for marine and climate change education. In collaboration with AUT, the University of Auckland's Goat Island Marine Discovery Centre, NIWA, and Leigh School. This initiative engaged primary children and the public in marine conservation science. It involved students in monitoring salps—jelly-like planktonic invertebrates important for marine food webs and carbon cycling—through hands-on research and co-developing a mobile learning app for citizen science data collection and education (Aguayo & Décima, 2020, 2022). This project promotes STEM/STEAM careers and fosters understanding of ecological systems by making complex scientific concepts accessible and engaging through XR technologies. (Aguayo, 2020)	The *Year of the Salps* project has influenced my PhD research by demonstrating another case of combining XR technologies for marine education. It aligns with my exploration of how XR facilitates holistic understanding by integrating cognitive and emotional learning within younger primary school learners. The project's hands-on approach reflects embodied and embedded cognition principles, enhancing learners' perceptual and cognitive engagement. The project also informed my PhD by revealing how senior primary children use technology in practice, which led me to reflect on different strategies for designing VR and other XR elements for different age groups in the future.

MESH360 (2015-ongoing)	The *MESH360* project, led by Dr. Thom Cochrane from the University of Melbourne, Dr. Claudio Aguayo and his team at Auckland University of Technology (AUT), and AUT's Paramedicine lecturers, leverages XR technologies to enhance simulation training in critical healthcare education. By creating realistic, high-stress medical scenarios, *MESH360* enables healthcare students and professionals to practise skills in a safe yet authentic environment. The project improves preparedness and competency through simulations of high-risk situations, such as emergency call-outs and rescue operations, making a pivotal contribution to paramedicine and clinical education (Aguayo et al., 2021). Utilising VR headsets and interactive environments enables participants to enhance their critical thinking and decision-making abilities under pressure, while biometric feedback delivers real-time insights into physiological responses that enrich training evaluations. (Cochrane et al. 2020; Wilkinson et al., 2019).	The *MESH360* project has informed my PhD research by demonstrating how XR technologies can enhance learning through attention to embodied and emotional cognition in high-stress scenarios. This aligns with my exploration of XR's potential to extend cognitive processes. Additionally, *MESH360*'s adaptive learning environments provide a valuable framework for my research, showing how educational technologies can be designed aiming for high authenticity of learning scenarios. In the *MESH360* project, users engage in high-stress medical simulations that require realistic physical interactions, enhancing the learning experience through authentic embodied simulation. A key aspect of MESH360 was the integration of biometrics data, which enriches the study's outcome. By capturing physiological responses such as heart rate, the project offers insights into learners' emotional states and engagement levels. Furthermore, MESH360 employs a collaborative Design-Based Research (DBR) approach, involving iterative cycles of design, implementation, and evaluation with input from educators. This collaborative methodology ensures that the XR solutions are grounded in real-world needs and continuously refined based on user feedback.
AUT Marae 360 (2019, 2024)	The *AUT Marae 360* project, initially spearheaded by Hohepa Spooner, Ali Taheri, and Claudio Aguayo, and later led by Taituwha King and Erana Louise Foster, stands as a groundbreaking initiative in the preservation and promotion of Māori culture through immersive technology. By employing 360-degree	The project proved particularly valuable during the COVID-19 lockdown when physical visits to AUT and the Marae were not possible, offering a virtual space to experience the marae. Its impact on my PhD research is profound, as it illustrates how even a simple 360° virtual tour can enhance teaching and learning of protocols and knowledge, especially in

	photography in an Augmented Virtuality (AV) format, the project creates an interactive and immersive digital representation of AUT's Marae (traditional Māori meeting house). Users could embark on a virtual 360° guided tour of the marae, enriched with cultural narratives, protocols, and interactive elements, fostering a deeper understanding and appreciation of Māori culture among diverse audiences.	cultural contexts. It underscores that XR is not solely about high-end technology or advanced devices; rather, its effectiveness lies in how thoughtfully it is applied to create meaningful, accessible educational experiences.
Explora - Chile Es Mar (2019-2020) This project was selected for further exploration in this research	The *Explora Chile* project, led by Dr. Claudio Aguayo at AUT in collaboration with ECIM UC Chile, utilises XR technologies to enhance marine education. By employing AR, VR, and MR, the project creates immersive experiences that promote ecological literacy and marine conservation awareness in relation to sustainable fishing practices in Central Chile. *Explora Chile* makes complex marine science concepts, cultural use of local marine resources, accessible and engaging for all learners, allowing them to explore underwater habitats and observe marine life interactively. This innovative approach fosters a deep understanding of marine ecosystems, highlights human impact, and induces a cultural and local sense of responsibility towards marine conservation. (Aguayo, 2022)	The *Explora Chile* project has informed my PhD research by showcasing how XR technologies foster a holistic understanding of environmental issues, when providing a combined narrative across different technological affordances. The project's attention on socio-cultural factors also provided some inspiration on the importance of culturally responsive design. This aligns with my investigation into using XR to embody complex scientific processes and enhance connection with ecological and cultural concepts. *Explora Chile*'s immersive learning experiences exemplify XR's potential to boost cognitive and emotional engagement in relation to local natural and cultural heritage. The project's design reflects an autopoietic approach, emphasising adaptability, user engagement, and the provision of an integrated narrative across diverse digital and XR affordances. This project provides a practical model for sustained, meaningful learning outcomes based on situated design and innovation.
Mahia Ecological Map (2021)	The *Mahia Ecological Map* project, led by Hohepa Spooner, Claudio Aguayo, and Stanley Frielick at	The significance of this project for the current research lies in its ability to bridge personal narrative with broader

	Auckland University of Technology (AUT), represents an introspective and holistic exploration of identity, culture, and environment, deeply rooted in the diverse landscapes and Māori communities of New Zealand. This project seeked to reflect on the individual's (a group of Māori participants living in the areas) formative years spent in both urban and rural settings, emphasising the profound impact these experiences have on their sense of belonging and connection to nature. By advocating for a future that harmonises community ties, spiritual well-being, and ecological health, the *Mahia Ecological Map* project promotes educational self-sovereignty and a unified human family for at-risk communities.	cultural, indigenous and environmental themes. Through detailed recounting of personal experiences and their influence on identity, the *Mahia Ecological Map* project highlights the importance of cultural heritage and environmental stewardship. By combining cultural heritage with ecological understanding, the project fosters a holistic advocacy for a balanced lifestyle that values community, nature, and well-being. Importantly, the focus of this project was on storytelling rather than the technology used. The strength of the project lies in its narrative-driven approach, demonstrating how cultural stories can be used to promote ecological awareness and deepen connections with the environment.
AUT Virtual Marae (2017-2024) This project was selected for further exploration in this research	The *AUT Virtual Marae 3D* project, led by Hohepa Spooner, Taituwha King, Ali Taheri, Dr. Claudio Aguayo, and the AppLab team at AUT, uses advanced digital technologies to capture, preserve, document, and promote Māori culture. This initiative has created a fully digital representation of the AUT Marae and a detailed reconstruction of Auckland's natural landscape before urbanisation. By utilising 3D modelling and VR, it offers an immersive experience that bridges past and present, enhancing cultural and environmental education.	Philosophically, the project aligns with ancient philosophia, focusing on enlightenment through experiential knowledge. The VR experiences help users understand Māori culture and Auckland’s natural heritage, The project's design emphasises cultural attention and user immersive engagement, and the integration of digital and physical learning environments, promoting sustained and meaningful learning experiences on Māori culture. This aligns with my research on XR technologies enhancing embodied and embedded cognition.
General R&D (ongoing)	Research and Development (R&D) at AppLab focuses on grounding emerging digital tools and	Overall, the breadth of AppLab's R&D projects has equipped me with the necessary technical skills and inspired

	philosophies into practical applications. For example, during the 2019 Summer Research Scholarship, we explore Web XR and Photogrammetry. Later we shift focus towards machine learning within interactive media. The lab’s goal is to transform education through innovation and user-centric design, making learning more engaging and effective. By integrating VR, AR, MR, AI, photogrammetry, digital storytelling, and new digital tools in education AppLab creates adaptive, interactive and user-centred educational environments that meet diverse learning needs across sectors.	innovative approaches to integrating the philosophy, art, and technology together. The dynamic R&D environment at AppLab, equipped with advanced tools has been pivotal in establishing the technical foundation for my PhD research. Engaging in diverse projects that explore Web XR, Photogrammetry, machine learning within interactive media, and the integration of VR, AR, MR, and AI has provided me with comprehensive hands-on experience in cutting-edge technologies essential for developing complex virtual experiences. This exposure to both the technical and methodological aspects of emerging digital technologies at AppLab has empowered me to push the boundaries in my own research.

These projects enhance ecological literacy and science education while also embody the principles of experienced-oriented learning by promoting learning experiences that are engaging, memorable, and rooted in real-world contexts.

Throughout my doctoral research, I have employed various AppLab projects and collaborative initiatives as artefacts and instances of practice. These projects have provided practical contexts for applying and testing theoretical frameworks, serving as tangible examples of innovative digital education solutions. While my work primarily involves the application of design principles to project development, it is pertinent to address the ethical dimensions associated with these projects and their outcomes. Acknowledging these considerations is essential to ensure the integrity and cultural sensitivity of my research, even though traditional ethical concerns may not directly apply to my role.

Collaborative projects with paying clients involved both formal and informal agreements. These partnerships were instrumental in identifying project needs and effectively applying AppLab's design principles. In many instances, clients were informed of the study's objectives and consented to the integration of research-based design methodologies into their project development. While my primary role was to apply various design principles grounded in my tacit knowledge and research, these collaborations offered invaluable practical insights and facilitated the implementation of user-centred, culturally responsive design strategies.

Since no human participants were involved in the aspects of these projects related to my practice-oriented PhD explorations, standard academic ethical considerations do not apply. Nonetheless, it is noteworthy that some AppLab-led projects, such as Pipi's World and NIWA Airbox, were developed for paying clients and necessitated careful ethical consideration regarding consent and collaboration. The ethical management processes for these projects were conducted outside the scope of this PhD study by the relevant parties and external collaborators; they also obtained ethics approval from the Auckland University of Technology's Ethics Committee (AUTEC). However, and in relation to my PhD study, as some of the projects were collaborative, in the spirit of Te Tiriti it is important to point out that the partnership approach was based on both Māori community and the counterpart engaging in good faith, mutually respecting each other's authority, and working collaboratively to achieve outcomes that were beneficial to all parties involved.

The Te Tiriti spirit is particularly applicable to projects related to Māori communities, such as *Rapua te Mārama* and the *AUT Virtual Marae*, to ensure that Māori individual and collective rights are respected and protected. Although my study did not directly involve Māori communities, it is essential to acknowledge and incorporate these ethical frameworks to ensure respectful and equitable research practices. I want to emphasise that I do not claim any outcomes from the *Rapua te Mārama* and *AUT Virtual Marae* projects and will fully attribute all rights and recognitions to the Māori communities involved. This commitment reflects my dedication to honouring Te Tiriti principles and fostering inclusive research environments that respect the sovereignty and cultural integrity of Māori participants and stakeholders.

The principles of respect, control, and reciprocity were central to my approach, aligning with both Māori and broader indigenous ethics. By recognising Māori groups as partners and granting them control over their involvement in the research, I ensured that the benefits of the research were equitably realised within Māori communities. Integrating these ethical considerations into my research practice has been important in maintaining the trust and respect of all stakeholders involved. By adhering to the principles of the Te Tiriti and ensuring transparent and consensual collaboration with clients, my research upholds ethical standards and also contributes to the broader discourse on culturally sensitive and responsible research practices.

4.4.3. The Practice-Oriented Artefacts (The PhD Projects)

The central theme of my PhD research revolves around the innovative application of XR (eXtended Reality) technologies to enhance educational experiences across various domains. This research examines different facets of XR technologies in a diverse range of projects conducted both independently and in collaboration with AppLab at Auckland University of Technology (AUT). These projects are categorised into four distinct areas, and each category represents a unique facet of XR's potential. For more information, refer to Tables 4.4 to 4.6 below for further descriptions; the tables provide a summary; more detailed explanations will be covered in Chapter 5.

Experience-Based Education is the first category, focusing on how XR can enhance learning through direct engagement with educational content. *Pipi's World* and *Explora Chile* projects will be explored. These projects leverage AR, VR, AV, and more to create immersive experiences that promote ecological literacy and environmental awareness. The effectiveness of XR in making complex scientific concepts accessible and engaging will be explored in this section.

The second category, **Atoms and Bits - Mixed-Reality Interaction**, examines the intersection of physical and digital worlds. Projects like *NIWA Airbox* and *Digital Twin Robot* demonstrate how XR can be used to visualise and interact with real-time data and real-world objects in or through mixed-reality settings. These initiatives highlight the potential of XR technologies to create dynamic, responsive interactive environments that integrate real-world data and making the invisible, visible.

The third category, **Abstract Ideas for Interaction Design**, delves into the integration of embodied, enacted, embedded, and extended cognition within XR environments. Inspired by projects like Jeffrey Ventrella's "Clusters," this research investigates how XR can facilitate complex cognitive processes and enhance user interaction with abstract ideas. By applying theories such as Lynn Margulis's endosymbiosis theory, these projects explore innovative ways to create lifelike digital environments (*Conscious Particles*) that promote deep cognitive engagement.

Finally, **Cultural Wisdom in Interactive Spaces**, explores how XR can be used as a tool to preserve and disseminate cultural heritage. Projects like *Rapua Te Mārama* and *AUT Virtual Marae* illustrate the power of immersive technologies to bring cultural narratives to life, fostering a deeper connection with and appreciation for Māori traditions and histories. By creating interactive digital environments, these projects protect cultural knowledge while making it accessible to a broader audience, ensuring its continuity for future generations.

Table 4.4 - The PhD Artefacts

Domain	**Name**	**Description**
Experience-based Education	*Pipi's World* (This is an AppLab Project done collaboratively with third-party)	An AR mobile app, a VR experience, and an AV 360 virtual tour, designed to increase ecological literacy by providing interactive learning experiences centred around marine conservation.
	Explora (This is an AppLab Project	Utilises AR, VR, and AV to create engaging educational experiences that promote marine conservation and

	done for a third-party client)	ecological literacy.
Atoms and Bits - Mixed-Reality Interaction	*NIWA Airbox* (This is an AppLab Project done for a third-party client with an additional side version developed solely by myself)	An AR app that visualises air quality data, making complex scientific information accessible and engaging for young learners.
	Robot IoT Digital Twin (This is a personal endeavour solely by myself)	Combines robotics and IoT to create digital twins, enabling interactive and real-time data interaction in mixed-reality environments.
Abstract Ideas Interaction Design	*Conscious Particles* (This is a personal endeavour solely by myself)	This is about applying life-like behaviours to particle systems, drawing on Endosymbiosis theory of Lynn Margulis.
Cultural Wisdom in Interactive Spaces	*Rapua Te Mārama* (This is done outside of AppLab by myself in collaboration with staff of UoA)	Showcases the use of XR to preserve and communicate Māori cultural heritage, immersing users in narratives about life and death during the COVID-19 lockdown.
	AUT Virtual Marae (This is an AppLab Project	Virtual recreation of the AUT Marae using web interactive and VR to make Māori cultural education accessible,

	done for AUT with an additional side version developed solely by myself)	fostering a deeper understanding and connection with Māori traditions. This project has informed my PhD research by demonstrating how XR technologies can create comprehensive educational experiences that connect cultural and ecological narratives.

Through these practical projects, my PhD research explored the transformative potential of XR technologies, providing insights into how immersive digital tools can be designed and implemented to create meaningful and impactful experiences. Each category and project contributes to a comprehensive understanding of how XR can bridge the gap between abstract concepts and tangible experiences, fostering both cognitive and emotional engagement. Table 4.5 outlines the various AppLab-PhD projects I have been involved in, highlighting my specific roles and the extent of my original contributions to each initiative. This table provides an overview of my responsibilities, the proportion of original work I independently conducted, the collaborative efforts within each project, and the overlaps between AppLab and PhD artefacts.

Table 4.5 - The AppLab-PhD Projects and My Role

Projects	**My Individual Contribution**
Pipi's World (2017-2019) https://www.fablesofnaranj.com/portfolio/xr-Marine-education-pipi-world	As I joined AppLab when this project was already in progress, my contribution focused on technical consultation and hands-on implementation. I provided guidance on how to approach the virtual tour component and the production of 360-degree photos and videos for the project. Specifically, I was responsible for taking the 360-degree photos of the Goat Island marine reserve and creating the Augmented Virtuality (AV) experience as part of the XR spectrum for this project. In

	addition, I documented the project process through photos and videos, later editing them into a cohesive narrative. These final documents served as research data, which I analysed to produce insights into XR educational design and contributed to research papers. My independent PhD exploration from this project included analysing the effectiveness of theAV experience in facilitating ecological literacy and assessing how embodied interactions could enhance educational engagement in virtual environments.
NIWA Airbox (2019) https://www.fablesofnaranj.com/portfolio/NIWA-Air-Box	I was working side by side with Dr Aguayo in this project and was involved in all the meetings with the clients and with the Massey team. My individual contribution was from coming up with ideas for the visualisation to managing the AppLab team through the development. Early in the project based on my knowledge of digital twins and the use of IoT devices to gather data and communicate those data to digital devices through Unity game engine. I quickly came up with the idea of having an augmented reality version of the box that, using sensor, data visualises the invisible. I managed the AppLab team throughout the development process, ensuring alignment with the project's goals and technical requirements. The AR visualisation framework developed during this project became a core artefact for my PhD research. I independently explored how real-time sensor data could enhance user engagement and environmental awareness by leveraging extended cognition principles. This artefact provided a practical case study for my investigation into XR's potential to foster meaningful interactions between users and abstract environmental concepts.

	Additionally, As a side project directly connected to my PhD research, I independently developed a HoloLens version of the application, acting as the sole developer for this extension. This version added an immersive layer to the project, allowing users to engage with the airbox data in an immersive, spatially interactive manner. The HoloLens application became an artefact in my PhD research, providing a platform to investigate how MR could enhance environmental education by integrating digital and physical affordances.
Explora - Chile Es Mar (2019-2020) https://www.fablesofnaranj.com/portfolio/Explora	As the lead UX designer for the Explora Chile project, my primary responsibility was to shape the overall user experience and interaction design, ensuring an engaging and effective learning application. Collaborating with Dr. Claudio Aguayo as the project leader and the AUT AppLab team, I worked to create an immersive educational tool that would captivate young audiences and foster a deeper understanding of marine conservation and sustainable fishing practices. The application utilised XR technologies, including immersive 360-degree videos, augmented reality (AR), audio narratives, and gamified sustainable fishing experiences. These elements combined to make complex ecological concepts more accessible and relevant within the local Chilean context. My individual contributions involved designing intuitive interaction models and crafting dynamic virtual environments using advanced Unity software. I implemented features such as proximity-based shaders and motion controls to enhance interactivity, ensuring the application was engaging and user-friendly. Beyond technical implementation, I collaborated closely with the team to align the educational content with curricula and experiential learning goals. An iterative design

	process allowed us to test and refine features based on user feedback, ensuring the application effectively communicated its educational objectives. I enhanced the immersive and emotional engagement of the application by incorporating animated marine life, such as seagulls and fish, that responded dynamically to user actions. This interactive feature reinforced learning outcomes through immediate feedback, enriching the visual appeal and emotional resonance of the experience. Additionally, I pushed the boundaries of the 360-degree drone fly-over of the Chilean coastline by integrating visual effects and spatial audio, creating an immersive and realistic exploration of marine ecosystems. This element leveraged extended cognition by offering users a unique perspective that deepened their understanding of the content.
AUT Virtual Marae (2017-2024) https://www.fablesofnaranj.com/portfolio/aut-virtual-marae (Due to embargo, this website is password protected. You can find the password in Section 5.3.4.2.)	As a key member of the creative team of the project, I was entrusted with designing and producing the virtual interactive exhibition for this culturally significant project. Based on my previous successful experience with *Rapua Te Mārama*, I was appointed to manage the AppLab team in development of this project while also being the creative director for the project working with our Māori colleagues at TAP to find the best culturally appropriate approach to the design of the project. While the primary project focused on creating a WebGL interactive experience, I independently developed a high-fidelity desktop VR version of the experience as part of my own exploration. This version, created in my own time, was a significant extension of the original project, offering a more immersive and technically advanced experience. Although the two projects shared assets, I recreated most of

	the virtual models to meet the higher visual and interactive quality required for the desktop VR platform. Additionally, I redesigned the interaction mechanics specifically for the VR environment, focusing on creating intuitive and immersive user interactions that leveraged the strengths of the VR medium.

In addition to my involvement in the AppLab-PhD projects, I participated in an extra collaborative project outside of AppLab. I undertook an independent collaborative project as part of the Rapua te Mārama study at the University of Auckland (UoA). This endeavour is detailed in Table 4.6. Serving as the creative director, I was the main person responsible for designing and producing the virtual environment and interaction design aspects of the exhibition. This role required me to operate independently from AppLab, allowing me to lead the creative process and implement innovative solutions autonomously.

Table 4.6 - The UoA Project and My Role

Projects	**My Individual Contribution**
Rapua te Mārama (2021-2022) https://www.teipuaronui.co.nz/about-the-study https://www.teipuaronui.co.nz/about-the-study https://www.fablesofnaranj.com/portfolio/Rapua	As part of the creative team of the project, I designed and developed the virtual interactive exhibition. I was acting independent from AppLab for this project and was the creative director of the process. I led the project autonomously, while collaborating with cultural stakeholders to ensure the exhibition alignment with cultural values and objectives. My responsibilities included crafting the conceptual framework, designing the environment, designing the interactive elements, designing the overall experience, and overseeing the technical execution. Most of the creative and technical work for the

	project was executed independently, reflecting my personal exploration into how interactive and XR technologies can facilitate cultural engagement and preservation. As part of my reflective research methodology, I created a 'Making of' video that documents the design and development process of the project. This video not only serves as an educational resource but also provides a transparent account of the methods and creative processes employed. The video illustrates key aspects of collaboration, technical problem-solving, and iterative design that informed the project's success. Watch the video here: Rapua Te Mārama - Making of https://youtu.be/4Hq-WliXcSc

In the next chapter, Chapter 5 - The Practice and Critical Commentary, I get into the details of each project, offering a thorough examination and critical analysis of their contributions to my research. Chapter 5 focuses on a detailed examination of the practical dimensions of this research. The purpose is to analyse the projects identified in this section and relate them to the theoretical discussions previously addressed. The discussion presented in Chapter 5 covers the nuances of practice-led research, exploring how the practical elements of XR design are both informed by and contribute to the overarching theoretical framework of the study. The goal is to offer a reflective and comprehensive evaluation of the design processes, methodologies, and outcomes, highlighting the dynamic relationship between theory and practice in the evolving field of XR.

4.5. Methods

The methodology of this transdisciplinary exploration is bifurcated into multiple distinct yet interconnected sets of methods: technological framework, experimental visualisation, philosophical insight approaches, and reflective evaluation. In the context of the XR medium, this multifaceted approach facilitates the development of a comprehensive understanding of the medium and its sensory impacts.

Throughout my PhD journey, I faced numerous challenges, including self-doubt, isolation, and an overwhelming workload, exacerbated by the COVID-19 pandemic. These struggles often clouded my concentration and led me to question my capabilities and the value of pursuing a PhD. However, these very challenges became integral to my research methodology, shaping how I approached and developed my work. This journey of self-discovery mirrored Plato's allegory of the cave, as I moved from darkness to light, gaining intellectual and spiritual insight from philosophers like Avicenna, Aristotle, and Suhrawardi. By incorporating methods such as reflective journaling and self-dialogue, I documented my internal struggles and gradual growth. Each challenge I overcame felt like emerging from a cave, contributing to a broader worldview and deeper understanding of myself and my research. Though these experiences were difficult, they led to a transformation in how I viewed the world and my work, aligning with Suhrawardi's philosophy of illumination, which emphasises the journey from ignorance to enlightenment.

During the pandemic, I immersed myself in studying ancient wisdom, including the perennial wisdom, which advocates timeless, universal truths. This deep dive, coupled with the teachings of Dr. Vervaeke and his ecology of practice, helped me navigate my mental and emotional challenges. The synthesis of ancient and modern wisdom allowed me to view my academic and personal growth as a continuous ascent, much like Plato's Anagoge—the journey from shadows to light, from confusion to clarity. Ultimately, this journey reshaped my worldview, helping me better understand and align my research with both intellectual and spiritual dimensions.

As for the practical projects development at the AppLab or by myself, the methods normally spanned five key phases: pre-production, production, post-production, external feedback (if applicable), and final adjustments and evaluations. Each phase incorporates specific methods tailored to the objectives and challenges of that stage. The pre-production phase focused on conceptual framework development, journaling, and initial testing. Tools such as The Brain (see Figure 4.5), a software application designed for mind mapping and note-taking, were instrumental in organising thoughts and reflections. Additionally, photography, videography, voice recording, and screen recording documented the evolving visual and conceptual elements. The production phase involved strategic feedback mechanisms, interdisciplinary and transdisciplinary collaboration, and rigorous documentation. Despite the constraints of the pandemic, innovative approaches to feedback and collaboration ensured continuous progress. Strategic use of GitHub and Unity for version control facilitated efficient project management and collaboration. During the post-production phase, user testing, feedback collection, and collaborative refinement within the AppLab team and with clients (when applicable) ensured that the final product met the desired standards and objectives. AppLabs real-world project processes—including client meetings for third-party collaborations, brainstorming sessions, and iterative feedback loops—provided practical insights and enhanced the relevance of the research.

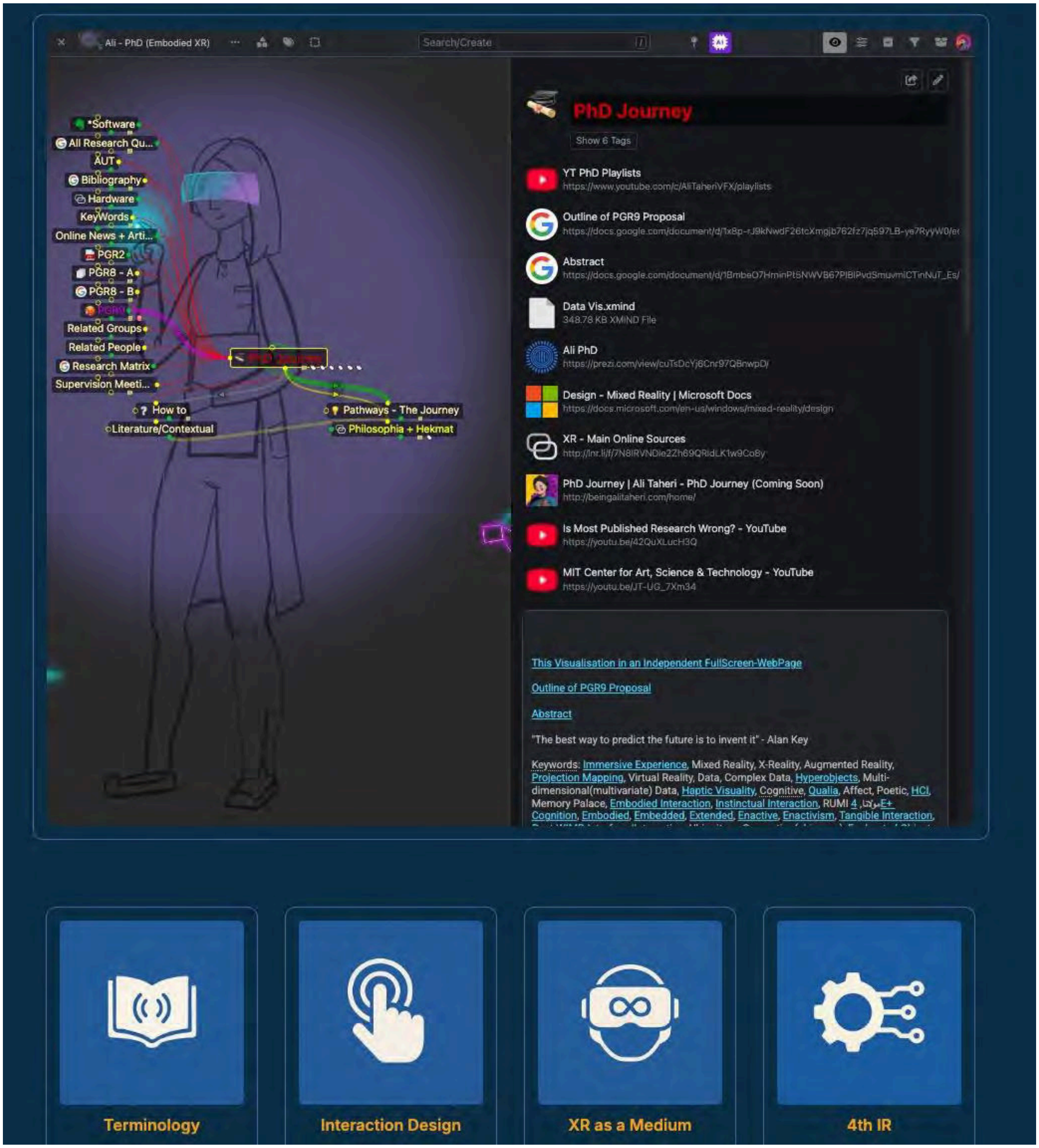


Figure 4.5 - The Brain MindMap Webpage in my PhD Dedicated Website.

Accessible via this link:

https://www.fablesofnaranj.com/knowledge-base/postgraduate-study

4.6. Critique of the Research Design

The research design for this thesis, grounded in a tapestry of cultural, philosophical, and cognitive theories, exhibits notable strengths in its holistic and transdisciplinary approach. By integrating Eastern philosophical insights from Illuminationism with advanced Western scientific principles such as 4E+ Cognition and cybernetics, the methodology has carved a novel niche within the field of Human-Computer Interaction (HCI) design, particularly within eXtended Reality technologies.

One of the primary strengths lies in its ability to bridge theoretical depth with practical application. The research paradigm effectively synthesises diverse elements—philosophical wisdom, technological innovation, and artistic creativity—creating a robust framework that enriches traditional HCI paradigms. The incorporation of Ishraq Hikmah-philosophy enhances the depth of cognitive engagement by fostering a comprehensive understanding of user experience that transcends mere functionality and enters the realm of intuitive and spiritual user interactions.

Moreover, the use of practice-oriented research methodologies, such as personal insight and associative hyper-textual mapping, has allowed for a nuanced exploration of subjective experiences within XR environments. These methodologies foreground the researcher's introspective journey, ensuring that the design process is continuously reflective and informed by both personal and collective human experiences.

The research design, rooted in a transdisciplinary methodology that incorporates elements of 4E+ Cognition and Neoplatonism, presents several notable strengths. One of the primary strengths is the comprehensive and holistic nature of the approach. By integrating cognitive, philosophical, and practical perspectives, this research design ensures a multifaceted exploration of XR environments. This integration fosters a deep understanding of how technological, cultural, and ethical dimensions interact, providing a richer context for the study of Human-Computer Interaction within XR.

The 4E+ Cognition framework provides a robust theoretical foundation that emphasises embodied, embedded, enactive, and extended cognitive processes. This approach aligns closely with my XR design objectives, ensuring that the environments created are both cognitively and emotionally resonant. By considering effective and emotional dimensions, the research design addresses the holistic nature of human cognition, leading to more engaging and meaningful XR experiences. Another strength lies in the incorporation of heuristic inquiry and phenomenology, which allow for an immersive and introspective examination of personal experiences within XR. This approach ensures that the findings are firmly anchored in the lived experiences of both the researcher and participants. Additionally, the iterative, feedback-driven nature of the cybernetic approach enhances the research design, allowing for ongoing refinement and adaptation.

Despite these strengths, the research design encounters several challenges that warrant reflection and careful consideration. The primary challenge arises from the ambitious scope of integrating highly diverse disciplinary perspectives. The synthesis of such varied fields—ranging from ancient philosophy to cutting-edge cognitive science—while innovative, posed complexities in maintaining methodological coherence and balance. The risk of diluting critical aspects of each disciplinary influence was significant without rigorous methodological checks and balances. The transdisciplinary approach, while enriching, also demanded a high level of expertise across multiple domains, which can be challenging to achieve within the confines of a single study. Ensuring that each disciplinary perspective is accurately represented and effectively applied to the research outcomes required meticulous planning, wide-ranging scholarly expertise, and extensive collaboration.

The subjective nature of heuristic inquiry and phenomenology, while enriching, can also introduce biases. The reliance on personal experiences and introspection of the researcher can affect the objectivity of the findings. Ensuring methodological precision and maintaining a balance between personal insights and scholarly analysis was therefore crucial to mitigate this challenge. Reflexivity and transparency in documenting the research process were essential to address potential biases and enhance the credibility of the findings.

Furthermore, the practice-oriented nature of the research, which leverages real-world applications in XR, brought with it the challenge of translating complex theoretical concepts into practical implementations. The iterative nature of design-based research necessitated continuous refinement and adaptation, which can be resource-intensive and time-consuming. Balancing the creative demands of XR development with the rigorous requirements of academic research posed a significant challenge in terms of time management, resource allocation, and maintaining scientific rigour.

In conclusion, the research design's strengths lie in its holistic, transdisciplinary approach, which provides a deep and multifaceted understanding of XR environments. However, the complexity and potential biases inherent in this approach required careful management to ensure methodological diligence and coherence. Addressing these challenges effectively enhances the validity and reliability of the research findings, contributing valuable insights to the fields of HCI, XR, and cognitive philosophy.

Note. Illustration created by Zohreh Shirazi (2024).

Chapter 5: The Practice and Critical Commentary

5.1. Introduction

The focus of this chapter is to provide a detailed examination of the practical dimensions of my research. The purpose of this section is to critically analyse the practical projects that were considered in this research and explain how they intertwine with the theoretical discussions previously addressed. It acts as an essential link between abstract theories and their real-world applications. This analysis bridges the gap between the conceptual and the tangible, providing a comprehensive understanding of how theoretical frameworks can be effectively applied in practical contexts.

Practice-oriented research is characterised by a cyclical process where practice informs theory and theory informs practice, creating a dynamic interplay that enriches both. The scope of this practice-oriented research encompasses the design, development, and evaluation of XR experiences aimed at enhancing educational, cultural, and technological interactions. By focusing on these diverse domains, the chapter illustrates the multifaceted dimensions and applications of XR, highlighting its unique contribution to human-computer interaction. It explores how the practical elements of XR design are both informed by and contribute to the overarching theoretical framework of the study.

The primary purpose of this chapter is to explain the results by telling engaging stories that balance subjectivity and objectivity. The stories provide a reflective evaluation of the design processes, methodologies, and outcomes of these projects. Through this lens, the results are explained not just as outcomes but as part of a narrative that illustrates the effectiveness and relevance of the research process.

Central to this discussion is the main research question: "How can integrating 4E+ Cognition and spiritual wisdom in eXtended Reality inform holistic experience and interaction design for enhanced cognitive, emotional, and spiritual engagement?" This overarching inquiry is supported by three sub-questions:

- What kind of design principles might emerge from a practice-oriented exploration of 4E+ interaction in XR artefacts?

- How can interaction in XR be designed to effectively reflect and incorporate ethical, cultural, and philosophical considerations?
- What are the potential impacts and future implications of these integrated design approaches on the evolution of human-computer interaction in XR technologies?

Throughout this chapter, I explore these questions by presenting and analysing practical XR projects that embody the integration of 4E+ Cognition and spiritual wisdom. Each project serves as a case study that demonstrates how theoretical frameworks can inform and enhance the design and implementation of XR experiences. By doing so, the chapter highlights the dynamic interplay between theory and practice, and emphasises the importance of a transdisciplinary approach that blends technological innovation with philosophical insights and cognitive theories. By addressing the challenges and opportunities of XR, this section directly contributes to answering the main research question and its sub-questions. The discussion of practical examples and design principles provides insights into effective strategies for leveraging XR in technological, cultural, and educational settings.

Overall, this chapter plays a pivotal role in connecting the theoretical insights discussed in previous chapters with their practical applications in real-world contexts. By engaging in thorough analysis and introspection, the discussion highlights how XR technologies can be harnessed to translate abstract ideas into concrete, experiential realities, showcasing their potential to revolutionise the way we engage with knowledge and experience.

5.2. The Journey

The journey of this PhD research has been one of continuous exploration, oscillating between the technical and the philosophical as I sought to merge these dimensions within the realm of eXtended Reality. Initially, my focus was largely on the technical aspects of XR, guided by a Cartesian analytical mindset that emphasised precision, structure, and mechanistic understanding. This technical inclination directed my early research efforts towards the intricate details of programming, visual effects, and virtual reality development, primarily within the frameworks of Unity game engine, IoT, and artificial intelligence. My approach was deeply rooted in the rational and the quantifiable, exploring how advanced tools and technologies could be harnessed to create immersive experiences.

The first significant turning point in my journey came when I found myself away from my cultural roots. This separation prompted a subtle shift in my perspective, igniting a curiosity about the philosophical and spiritual dimensions inherent in my heritage. Changing supervisors and departments further amplified this introspection, exposing me to diverse ideas and philosophies that contrasted with my technical focus. Later, the onset of the COVID-19 pandemic added another layer to this transformation. The global lockdown provided a unique opportunity for introspection, prompting me to revisit the philosophical dimensions that had long been an undercurrent in my intellectual pursuits. The enforced solitude and the subsequent shift to remote, digital interactions highlighted the limitations of a purely technical approach. This period of reflection rekindled my engagement with perennial wisdom and philosophical traditions, particularly the teachings of Suhrawardi and the School of Illumination. This reawakening brought a renewed focus on the interplay between the spiritual and the technological, pushing my research beyond the confines of analytical thinking.

Integrating Perennial Wisdom and 4E+ Cognition

Perennial wisdom, a philosophical and spiritual perspective, suggests that the recurrence of common themes across world religions and spiritual traditions points to universal truths about reality, humanity, ethics, and consciousness. A fundamental notion within perennial wisdom is that diverse cultures throughout human history share many common themes. From a 4E+ Cognition perspective—where the environment and the body significantly shape human cognition—this sharedness becomes even more apparent. Since all humans, regardless of geographical or cultural background, generally interact with similar environmental and bodily conditions, there exists a universal dimension to human cognition. For me, these two perspectives suggest that human cognition, cultures, and even ontological thinking across time and space are intertwined, meaning that a deep understanding of one's own culture could potentially facilitate a profound understanding of others.

The interconnectedness implies that by delving deeply into my own cultural and philosophical traditions—illuminating their core truths about reality, ethics, and consciousness—I could transcend surface characteristics. By understanding the universal aspects within my own heritage, I can facilitate a profound appreciation of other cultures, revealing the shared human experiences and truths that bind us across diverse backgrounds. This process enabled me to recognise and resonate with the essential aspects of other cultures, fostering an integrative and empathetic understanding. By first connecting with the depths of my own cultural heritage, I found it easier to engage with other worldviews, enriching my ability to collaborate creatively with those from different cultures than mine and together create a culturally meaningful experience.

Synthesis of Technical and Philosophical Insights

This PhD journey has been a dynamic interplay between practice and theory, where each project undertaken acted as a microcosm for testing and refining the integration of technical expertise with philosophical inquiry. The evolution of my research from a techno-centric approach to one that embraces a holistic understanding of human-computer interaction has been marked by this synthesis. It is within this context that my practice-oriented research finds its narrative, as I aim to contribute to a more nuanced understanding of how XR can be designed to engage, to enlighten, and to foster a deeper connection between the digital and the human experience. By embracing perennial wisdom and the 4E+ Cognition framework, I have sought to create XR environments that are deeply resonant with human cognitive, emotional, and spiritual processes. This holistic approach ensures that XR serves as a medium for profound human experiences, bridging the gap between abstract ideas and concrete, experiential realities.

5.3. The Practice

Immersing myself in the world of interactive mediums and immersive technologies has been a pivotal aspect of my PhD research, enabling me to explore and harness the potential of eXtended Reality in innovative ways. This deep immersion served as a deliberate methodological approach to gain nuanced insights into the virtual world and the capabilities of immersive technologies. One of the foremost insights, previously discussed in Chapter 3, was the imperative to approach XR with an open mind, free from the constraints of established media frameworks. The rapidly evolving landscape of XR presents challenges as our understanding of optimal interaction paradigms is still developing. Therefore, it is essential to recognise XR as a distinct medium and to embrace its unique affordances without attempting to mimic other forms of media.

From a media theory perspective, XR signifies a paradigmatic shift in the structuring of narratives and interactions. It offers a multimodal and highly interactive platform that transcends the linear storytelling typical of traditional media like cinema (Manovich, 2002). Unlike cinema, which engages viewers through passive observation, XR fosters active participation, redefining users from passive recipients to active co-creators of their experiences. This transformation aligns with the Extended Mind Theory (Clark & Chalmers, 1998), which posits that cognitive processes extend beyond the individual to include tools and technologies that enhance mental capabilities. In XR environments, cognitive tasks are distributed across both digital and physical realms, enabling users to engage in complex problem-solving and creative endeavours that are seamlessly integrated with their surroundings.

Based on this theoretical foundation, I endeavoured to grant XR its independent identity, drawing inspiration from the 4E+ Cognition framework and perennial wisdom. The illuminationist tradition, rooted in Neoplatonic philosophy, offers a holistic worldview that contrasts sharply with the reductionist and mechanistic paradigms often prevalent in technology design. This tradition emphasises an integrated approach that considers the emotional, spiritual, and cognitive dimensions of human experience. Inspired by these philosophies, my aim was to design XR environments that enable interaction while also foster moments of reflection and enlightenment, thereby facilitating meaningful connections and personal growth.

By harmonising bottom-up emergence with top-down emanation, XR environments can achieve a balance between user autonomy and guided experiences, ensuring that interactions remain both meaningful and aligned with the desired educational and spiritual outcomes. This synthesis would be able to facilitate the creation of dynamic and adaptive environments that respond to individual user needs while maintaining a coherent and purposeful narrative structure. In my research work, this perspective has driven a commitment to developing XR interactions that go beyond technical innovation. XR's most significant feature is its ability to engage humans in immersive and meaningful interactions.

In creating the practical projects that are part of this research, one of my goals was to develop experiences that are cutting-edge in their design and use of technology while also spiritually and philosophically enriching, providing users with moments of reflection, deeper understanding, and ultimately, a sense of illumination. Such an approach would ensure that technology serves as a conduit for more profound human experiences. This involved considering XR as a new medium and designing XR environments that allow users to experience something unique throughout the virtual world. This approach also enables the XR medium to establish a more meaningful connection with the user, thus enacting the experience. This reciprocal relationship was designed to influence the user's enactive cognition processes and experiences, creating a feedback loop that enhances both the user and the XR environment.

By leveraging the principles of the Extended Mind and 4E+ Cognition, the XR environments developed were able to facilitate a symbiotic interaction where the environment could adapt to the user, and the user's actions, in turn, shaped the environment. This dynamic interplay fostered a continuous evolution of both the technology and the user's cognitive and emotional states, leading to increasingly immersive and enriching experiences. As I moved forward, these theoretical insights became the foundation for developing practical XR projects that embody this holistic and integrative approach, paving the way for experiences that are spiritually and philosophically satisfying.

This section is structured to provide a systematic exploration of the practical projects undertaken during the research. Each project is analysed in terms of its design process, implementation, and outcomes, with a particular focus on how it exemplifies the integration of theoretical and practical elements. The projects are categorised into four main areas or domains:

Section 5.3.1**, Experience-based Education**: Projects like *Pipi's World* and *Explora* fall into this category. They highlight the potential of XR to enhance experiential learning. By providing interactive and immersive environments, these projects foster a deeper understanding of complex scientific and environmental concepts.

Section 5.3.2**, Atoms and Bits - Reciprocal Interaction**: This category focuses on projects that integrate real-world data and environments with virtual experiences. Examples include the *NIWA Airbox* and *Robot Car IoT Digital Twin* projects, which demonstrate how XR can enhance interaction and engagement with digital content.

Section 5.3.3**, Abstract Ideas for Interaction Design - Conscious Particles**: This section explores the design and implementation of interactions inspired by autopoiesis and affective computing, where virtual particles behave like conscious, living entities. It includes an examination of various abstract interaction designs (IxD) and their theoretical underpinnings.

Section 5.3.4**, Cultural Heritage in Interactive Space**: This category includes projects such as *Rapua te Mārama* and *AUT Virtual Marae*, which leverage XR technologies to preserve and disseminate cultural heritage. These projects illustrate how XR can be used to create immersive educational experiences that engage users with cultural narratives in a meaningful way.

Next, I present the practices that fall under experience-based educational projects as a key domain where the 4E+ Cognition is actively implemented. By focusing on educational environments, these projects demonstrate how XR can facilitate innovative interactions while also fostering meaningful and enriching learning experiences. Through these experience-based initiatives, we can observe how integrated XR environments create immersive educational settings that resonate deeply with users, encouraging active engagement, reflection, and a deeper understanding of complex concepts.

5.3.1. Experience-based Educational

Experience-based education emphasises the importance of active engagement and experiential learning in fostering deep understanding and long-term retention of knowledge. In the context of eXtended Reality, experience-based education leverages the immersive and interactive capabilities of XR technologies to transform traditional learning environments. By creating simulated environments that closely mimic real-world scenarios, XR facilitates a hands-on approach to learning that engages multiple senses and cognitive processes, thereby enhancing the overall educational experience (Aguayo, 2023; Aguayo & Eames, 2020).

Central to the effectiveness of XR in experience-based education are the theoretical frameworks of 4E+ cognition and autopoiesis. The integration of these theoretical frameworks into XR design can address many of the challenges associated with immersive learning. In the realm of XR, autopoiesis informs the design of educational environments that ought to be dynamic and responsive, capable of evolving based on user interactions and feedback. This adaptability ensures that XR learning experiences remain relevant and personalised, catering to the diverse needs and preferences of individual learners (Aguayo, 2023; Macrine & Fugate, 2021). By designing XR systems that adapt to users' needs and preferences, educators can create more personalised and effective learning experiences.

XR technologies play a pivotal role in enhancing cognitive engagement in educational settings. Cognitive engagement is deepened through immersive simulations that allow learners to explore complex concepts in a tangible and interactive manner. For instance, XR can simulate intricate scientific phenomena or ecological systems, enabling learners to visualise and manipulate these concepts in ways that traditional teaching methods cannot achieve. This hands-on approach promotes learning, critical thinking, and problem-solving skills by giving learners agency within the simulated environments (Aguayo & Eames, 2020).

Building upon these theoretical foundations, the subsequent sections present detailed case studies of XR projects that embody experience-based education in practice. Two projects that I was involved in, *Pipi's World* and *Explora*, demonstrate how the integration of 4E+ Cognition and autopoiesis principles can guide the creation of immersive and interactive learning environments which enhance ecological literacy and foster deep understanding. These projects serve as exemplary models of how theoretical insights are translated into practical applications, showcasing the transformative potential of XR in educational contexts.

5.3.1.1. Pipi's World

The *Pipi's World* project (2017-2019), led by Dr Chris Eames from the University of Waikato, and Dr. Claudio Aguayo from the Auckland University of Technology (AUT), exemplifies the potential of using XR technologies to enhance environmental education (Aguayo & Eames, 2023). This initiative, developed at AppLab (back then, AppLab was part of AUT's Centre for Learning and Teaching) in collaboration with *Conical Studios* and integrated into the educational activities at the *Goat Island Marine Discovery Centre*. This project utilises a set of non-digital to digital installations, including an Augmented Reality (AR) mobile app, low-end (360 videos) and high-end (CGI– computer-generated interface) VR experiences to create engaging and immersive learning experiences centred around the character Pipi the snapper. Through AR, VR, and a range of other interactive elements (see Figure 5.1), *Pipi's World* aims to increase ecological literacy by providing users with a tangible understanding of marine conservation and the impact of human activities on marine environments. By allowing users to interact with digital representations of marine ecosystems, this project makes scientific concepts more accessible and fosters a deeper understanding of environmental issues (Aguayo & Eames, 2020, 2023).

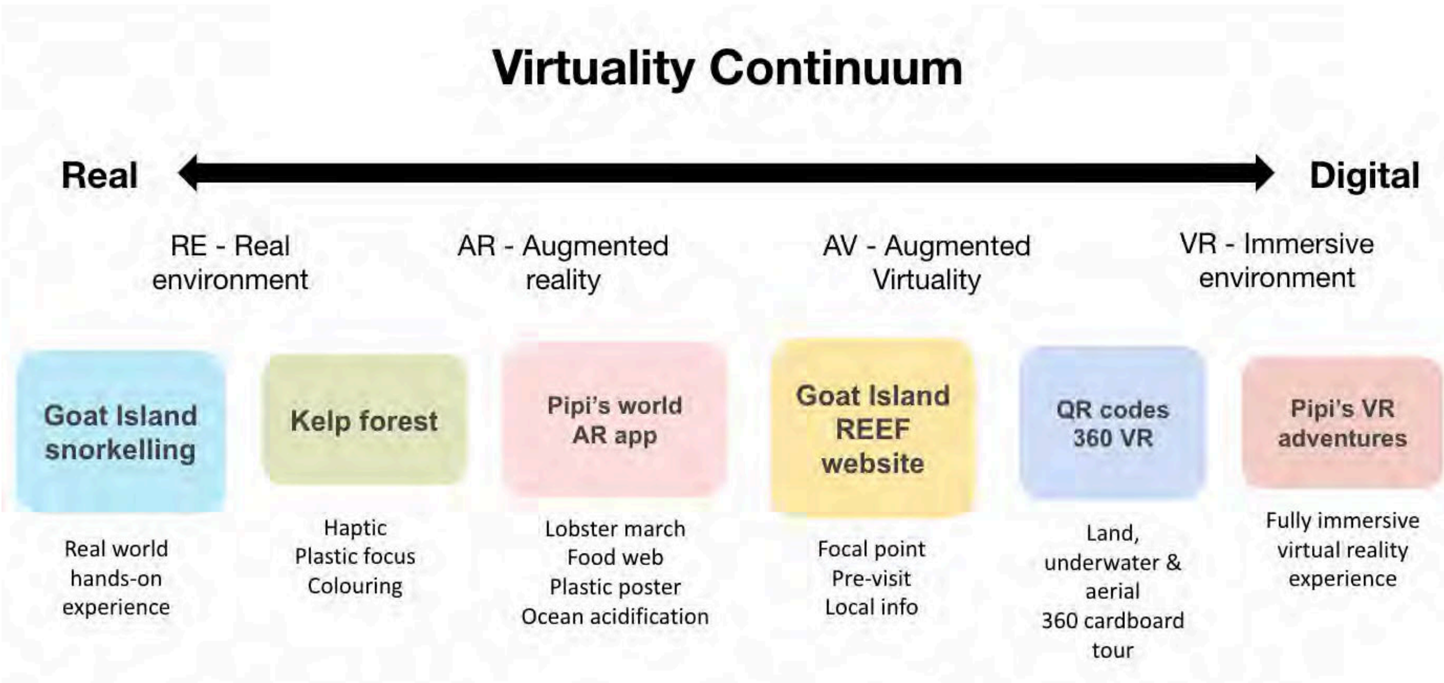


Figure 5.1 - The XR Approach Developed for *Pipi's Project*.
The Pipi's World project uses XR and other digital and non-digital experiences along the reality-virtuality continuum to create engaging learning experiences centred around marine conservation in a marine visitor centre in Aotearoa New Zealand.
*Note. T*his figure is taken from Eames & Aguayo, 2020b.
Copyright AppLab 2018, reprinted with permission.

This experience-based educational project was initiated shortly after my arrival in New Zealand in November 2017 and marks my introduction to working at AppLab. Figure 5.2 illustrates the idea board for Pipi's World, showcasing the initial concepts and collaborative brainstorming that shaped the project's direction. Working on this project taught me how to manage a project from start to finish and helped me understand the philosophy behind the work. While I was only employed in a technical support role, I was able to incorporate my unique perspective. In this sense, Pipi's World laid the foundation for my PhD. One of the significant events during this experience was meeting and working with Dr. Aguayo, soon to be my supervisor, and getting to know his view on the place of XR technology in educational settings as well as his 4E+ perspective on the nature of human experience.

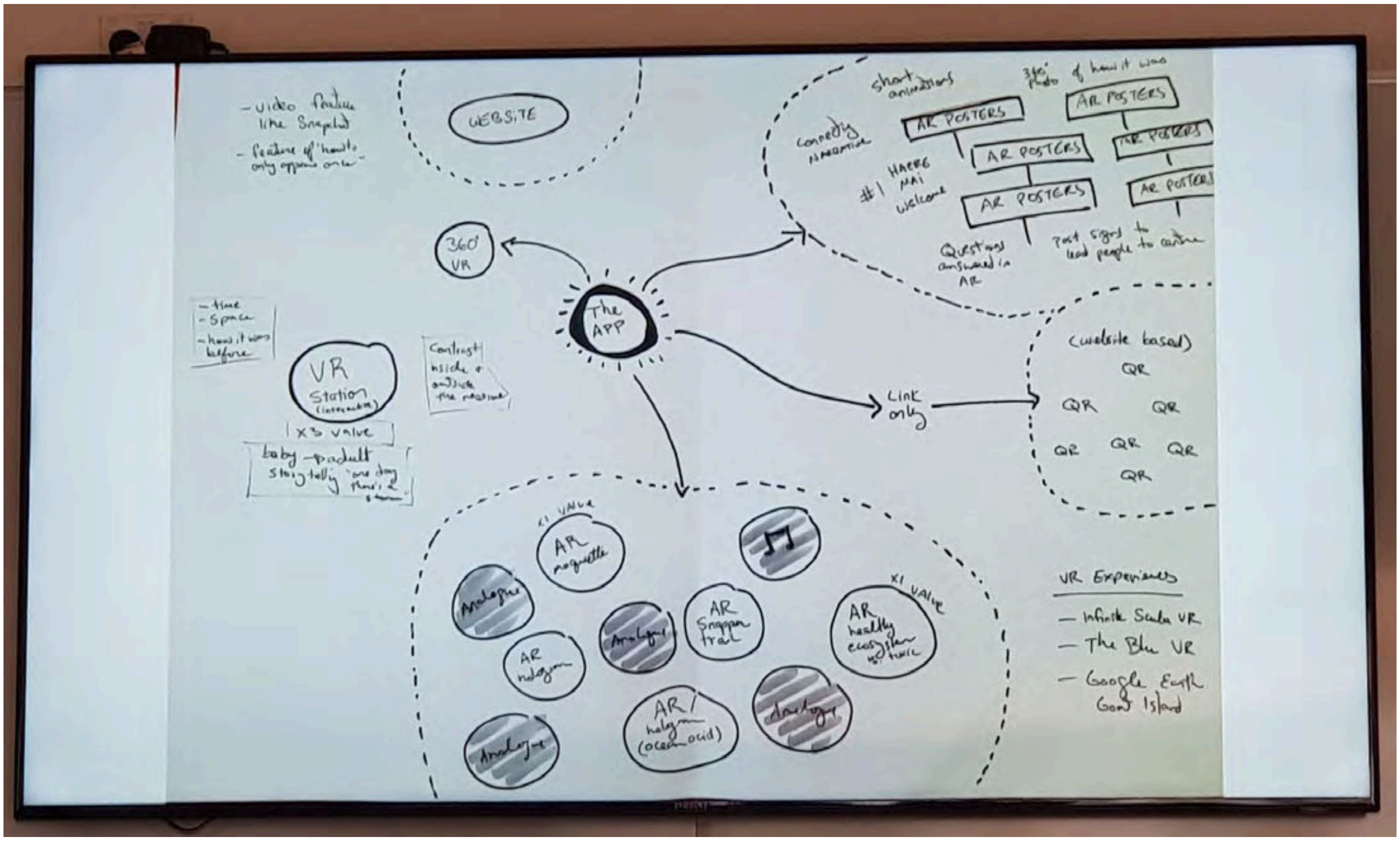


Figure 5.2 - The Idea Board for *Pipi's World*.
Note. The image depicts the brainstorming board for *Pipi's World*, capturing the early stages of ideation and the collaborative efforts that guided the project's creative development. Copyright 2018 by AUT AppLab, reprinted with permission.

Figure 5.3 presents a reconceptualisation of the linear reality-virtuality immersive XR continuum from Figure 5.1 as a "global reality"—a juxtaposed, circular XR continuum that forms a unified and behaviourally inseparable learning substrate. This continuum is intricately connected to human cognition, leading to unique learning processes and distinct learning outcomes for each individual learner or user. At this global reality level, and following principles from quantum physics, all potential states are possible, even those that may appear contradictory. However, once an observation is made, the observer actively enacts the experience, thereby defining the properties of the environment being observed (Aguayo & Eames, 2023; Aguayo, Videla-Reyes, & Veloz, 2023).

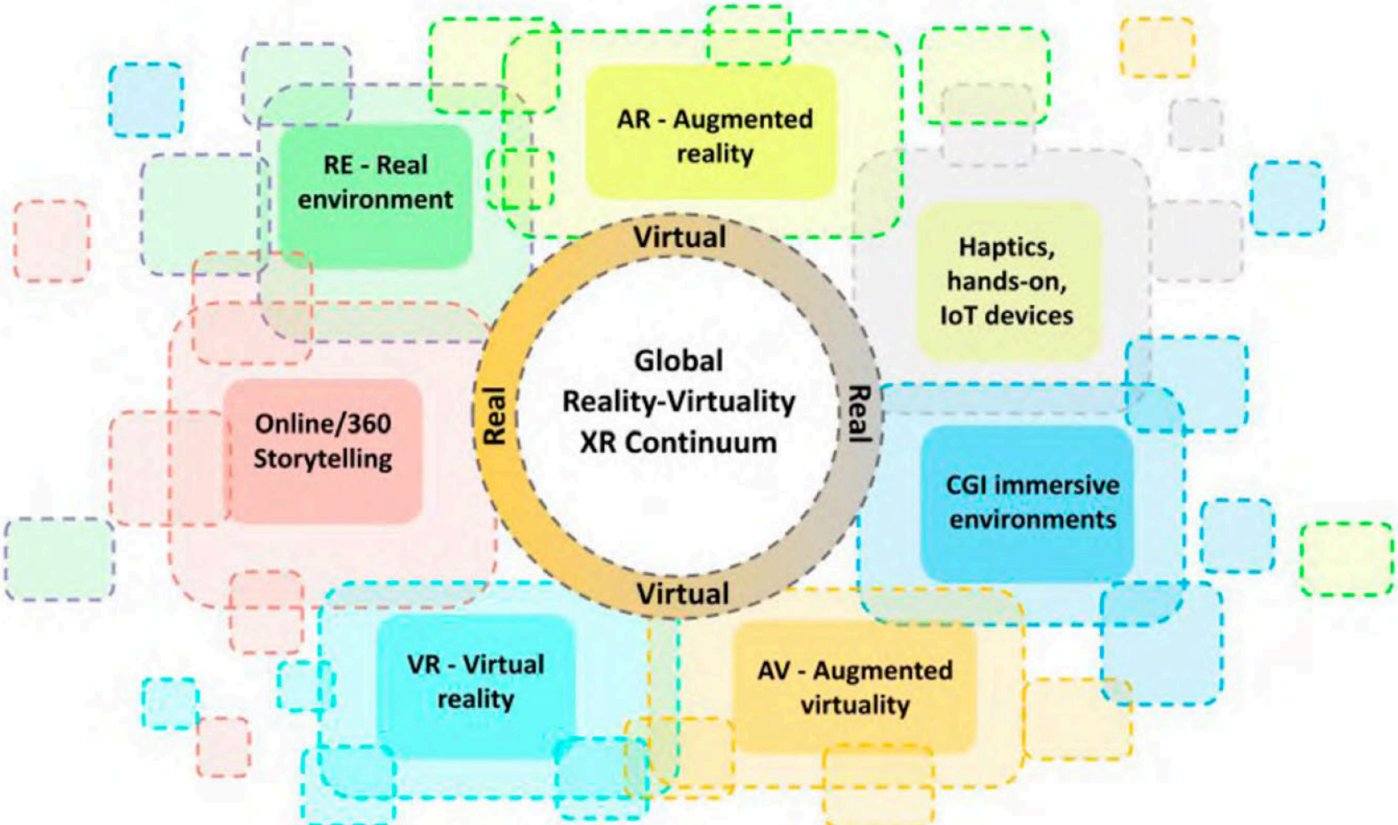


Figure 5.3 - Global Reality-Virtuality XR Continuum.

Note. The diagram reimagines the linear reality-virtuality XR continuum from Figure 5.1, as a circular model, integrating the immersive experience into a unified global reality. This new framework functions as a cohesive learning environment, deeply interconnected with human cognition and consciousness. It allows each learner or observer to generate distinct learning experiences. In this global reality, all potential states, including contradictory ones, exist simultaneously. However, when the observer engages with the system, their interaction shapes the observed environment, influencing the outcome of their experience. This is taken from Aguayo, Videla-Reyes, & Veloz, 2023, p. 13. Copyright 2023 by AUT AppLab.

Figure 5.4 - The Author with a 360 Camera

Note. On Location of Goat Island Marine Reserve (2018).

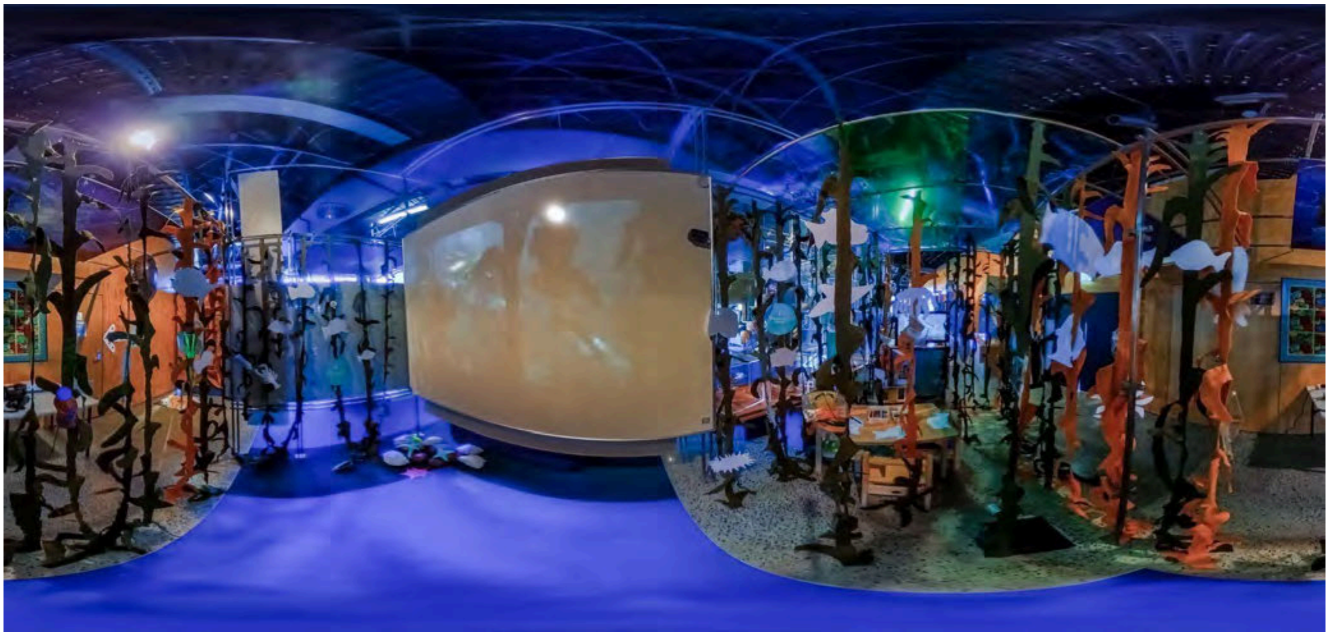


Figure 5.5 - The Kelp Forest Experience.

Note. Part of *Pipi's World* XR project (Smith, 2018).

This shows the stretched 360 Panorama of the Kelp Forest Experience.

Photo taken and developed by Taheri. Copyright by AppLab, 2018.

Figure 5.6 - One of 360 Augmented Virtuality of Goat Island.
Note. One of the many 360s that contributed to the AV aspect of the *Pipi's World* project. Photo taken and developed by Taheri. Copyright by AppLab, 2018.

The importance of this project lies in its innovative approach to making complex scientific concepts accessible and engaging for learners. By allowing users to interact with digital representations of marine ecosystems and conservation issues, the project fosters a deeper, more intuitive understanding of these critical topics. The narrative-driven experiences, such as exploring the Goat Island Marine Reserve through Pipi's perspective, help to contextualise scientific data within real-world scenarios, making the learning process both memorable and impactful.

Pipi's World has informed my PhD research by demonstrating the practical application of XR technologies in educational settings. This project aligns closely with my exploration of how XR can be utilised to embody and facilitate complex cognitive processes, as seen in the integration of embodied and embedded cognition principles within these immersive experiences. By observing the project's emphasis on the socio-cultural context, user engagement, and intuitive interaction with digital content, I gained valuable insights into designing educational tools that are both effective and user-centric while prioritising culturally embedded pedagogical processes and learning outcomes.

Moreover, the philosophical underpinnings of *Pipi's World*, which draw on concepts of experiential, self-determined, and situated learning, resonate with the theoretical frameworks in my research. The project's use of co-creation with students and educators to inform the process of designing the app reflects an autopoietic and organic approach to educational technology that emphasises adaptability and self-organisation within learning environments. This aligns with my research focus on how digital learning tools can evolve to meet the diverse needs of learners while fostering deep, meaningful learning experiences (Aguayo et al., 2020).

Reflecting on *Pipi's World* from my current perspective of a more developed and theorised approach to XR in educational settings, there are several areas where improvements could be made to enhance both the educational impact and user engagement. Firstly, integrating more robust feedback mechanisms would allow for the real-time assessment of user understanding and engagement. For example, implementing interactive quizzes or reflection prompts within the XR environment could provide immediate insights into the effectiveness of the educational content and allow for iterative improvements based on user performance and feedback.

Another area for enhancement is the inclusion of collaborative features that enable multiple users to interact within the same virtual environment at once. This could foster a sense of community and shared learning, allowing users to discuss and explore marine conservation topics together, thereby deepening their collective understanding and commitment to environmental stewardship. By integrating these reflections and proposed improvements, the *Pipi's World* project could evolve to offer even more impactful and engaging educational experiences. Embracing advanced technologies and user-centred design principles would ensure that the project remains at the forefront of XR-based environmental education and continues to inspire and educate users about marine conservation in increasingly meaningful ways.

The project's various stages were documented through photographs and videography. This visual archive highlights the technical progress achieved and weaves a narrative of the project's evolution from a philosophical perspective. I invite you to explore additional videos and photographs of the *Pipi's World* project available on the AppLab website. By following this URL from my website https://www.fablesofnaranj.com/portfolio/xr-Marine-education-pipi-world, you can explore a comprehensive collection of visual materials that showcase the project's innovative XR environments and the engaging learning experiences they facilitate.

As part of my work on *Pipi's World*, I contributed to enhancing its immersive and educational impact. By providing technical consultation on developing the virtual tour and capturing 360-degree photos and videos, I created the augmented virtuality components that enriched the XR spectrum of the project. These interactive 360 experiences allow users to virtually explore marine environments, making complex ecological concepts more accessible and engaging. Additionally, my documentation of the project's development through photos and videos captured the creative process and served as valuable resources for research and further educational content development.

In summary, my work on *Pipi's World* has allowed me to gain practical and theoretical knowledge on creating immersive experiences and enriched my understanding of XR's role in education. It exemplifies how immersive technologies can be harnessed to create engaging, effective learning experiences that bridge the gap between abstract scientific concepts and tangible real-world applications.

5.3.1.2. Explora Chile Es Mar

The *Explora* project (2019-2020), led by the Pontificia Universidad Católica de Chile (PUC) in collaboration with AUT AppLab, represents a significant advancement in leveraging XR technologies with mobile devices for environmental education. Building upon the insights and design principles derived from Pipi's World (Aguayo et al., 2020), this project aimed to transfer and adapt these principles to the Chilean context (see Figure 5.6), focusing on educating young audiences about the effects of human activities on the marine ecosystems of central Chile (Aguayo, 2022). Figures 5.7 to 5.14 illustrate various aspects of the project, highlighting its immersive and interactive nature.

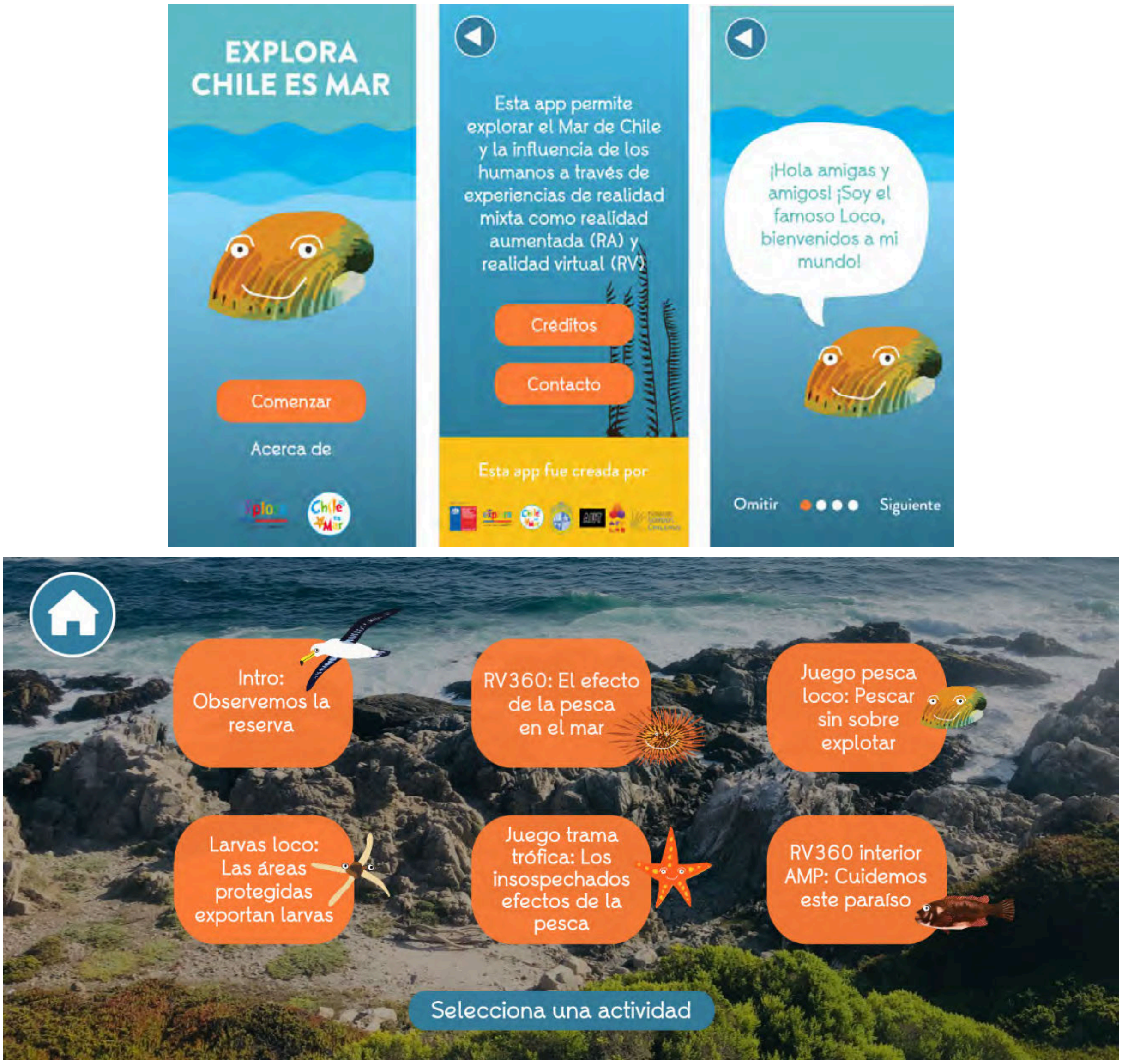
Figure 5.7 - The Pontificia Universidad Católica de Chile.
Note. Copyright by AppLab, 2020.

This project was undertaken by AppLab after the NIWA project (2019 - see later in section 5.3.2.1) and represents a pivotal phase in my academic and professional journey. This project marked the conclusion of a period in which my focus was predominantly on technological sophistication and innovation. Additionally, the alignment of this project with my primary supervisor's intellectual background played a crucial role in shaping this project's philosophy, coinciding with a significant shift in my own mindset.

As the lead UX designer, one of my responsibilities was to oversee the overall feel and interaction design of the application. Collaborating closely with Dr. Claudio Aguayo as project leader and the design and programming team at AUT AppLab, we sought to create an immersive learning experience that would captivate young audiences and foster a deeper understanding of marine conservation and sustainable fishing practices. The application utilises XR, incorporating immersive 360-degree videos, AR, audio narratives, and two sustainable fishing interactive experiences. This multifaceted approach provides interactive gamified exercises that engage users and make complex ecological concepts relevant to the local context more accessible.

My role in the *Explora* project involved shaping the user experience and ensuring that the application effectively communicated its educational objectives. Leveraging my background in visual effects and cinema, I utilised advanced tools and methodologies within Unity software to create a dynamic and responsive virtual environment. This involved designing intuitive interaction models, implementing proximity shaders and motion controllers to enhance interactivity, and ensuring high-quality visuals that would engage the target audience. My contributions extended beyond technical implementation; I actively participated in collaborative discussions with the team to align the application's content with educational curricula and experiential design contexts. By adopting an iterative design process, we were able to test and refine features based on clients' interactions and responses, demonstrating that the chosen methodologies were effective in addressing the project's educational goals.

Images in Figures 5.8 illustrate the introductory screen and main menu of the *Explora Chile Es Mar* application, both of which are pivotal in shaping the user's first impressions and facilitating seamless navigation within the app. Created by our talented designer, James Harvey Smith, these interfaces embody a user-centred design approach that aligns with the educational objectives and philosophical frameworks underpinning the project.



Figures 5.8 - The *Explora's* Intro and Menu.

Note. Created by James Harvey Smith. Copyright by AppLab, 2020.

The use of AR (Figures 5.9 and 5.10) and 360-degree VR videos (Figures 5.11 and 5.12) requires users to physically interact with the application, promoting kinesthetic learning. For example, users have to move their devices to explore virtual marine environments, simulating the physical experience of navigating through coastal ecosystems. This physical engagement enhances the learning experience by aligning cognitive processes with bodily movements, making the educational content more memorable and engaging.

Figure 5.9 - User Scanning the AR QR Code on Location.

Note. Copyright by AppLab, 2020.

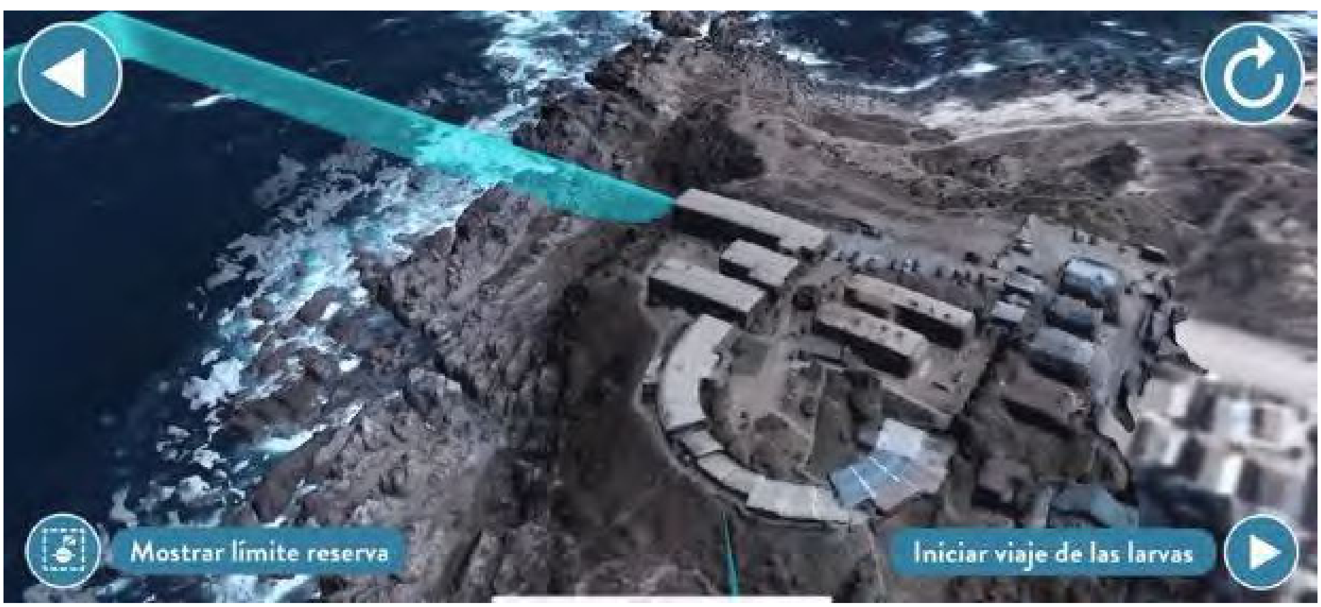


Figure 5.10 - 3D AR Visualisation of the Marine Research Station (PUC) in Central Chile.

Note. Created by Aguayo, Wagstaff, and Taheri. Copyright by AppLab, 2020.

Figure 5.11 - *Explora* Arial 360 AV.

Note. Created by Aguayo, Wagstaff, and Taheri. Copyright, AppLab, 2020.

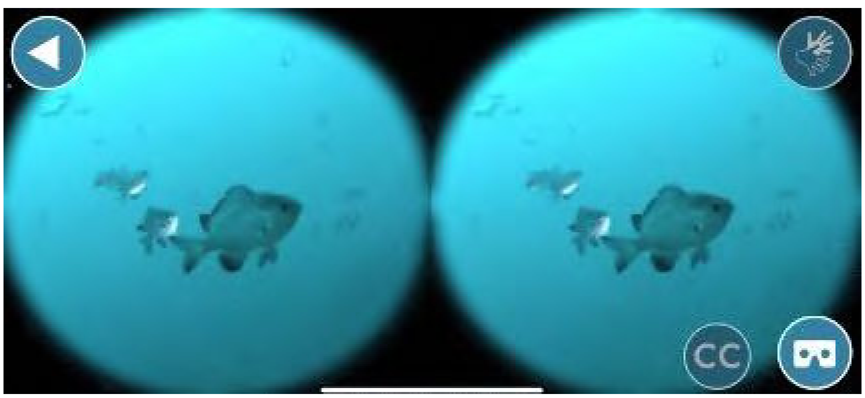


Figure 5.12 - *Explora* 360 AV in VR Mode.

Note. Created by Aguayo, Wagstaff, and Taheri. Copyright, AppLab, 2020.

The application was designed to reflect the specific environmental context of central Chile. By incorporating local marine species, ecosystems, and conservation issues, the content was directly relevant to the users' real-world experiences. Embedding the learning within the users' socio-cultural contexts increases relevance and facilitates a deeper connection to the material, fostering a sense of stewardship for their natural heritage. Interactive tasks, such as sustainable fishing games (see Figures 5.13 and 5.14), allow users to enact decision-making processes and observe the consequences of their actions within the virtual environment. This active participation promotes experiential learning, enabling users to construct knowledge through direct engagement and reflection on their actions.

The mobile application serves as a cognitive tool that extends users' mental capacities, providing access to information and experiences beyond their immediate environment. By utilising the mobile device as an extension of the mind, users can explore complex ecological concepts and visualise data in ways not possible through traditional learning methods. Audio narratives and immersive visuals are employed to evoke emotional responses and foster empathy towards marine life and conservation efforts. Engaging the users emotionally enhances motivation and interest, reinforcing the educational messages and encouraging positive attitudes towards environmental stewardship.

By encouraging users to reflect on the interconnectedness of various life forms and the ethical implications of human activities on the environment, the application transcends mere information dissemination. This approach aimed to foster a sense of unity and responsibility, inspiring users to contemplate their role in preserving the natural world. The methodologies employed in the Explora project were selected to address the specific needs and challenges of marine education within the Chilean context.

By combining advanced XR technologies with culturally relevant content and the 4E+ Cognition framework, the project effectively engaged users on multiple levels. The iterative design process, including collaborating with an audio and soundscape design team based in Chile, grounded in user feedback and collaborative input from educators and scientists, ensured that the application was both pedagogically sound and appealing to the target audience.

The *Explora* project, while part of my professional work at AUT AppLab, directly contributed to my PhD research by providing a practical platform to apply and test the theoretical frameworks explored in my studies. The overlap between AppLab and my PhD artefacts is characterised by the application of the 4E+ Cognition framework into XR design.

To enhance the immersive quality and emotional engagement (affective dimension), I incorporated animated seagulls and fish that responded dynamically to the user's actions. (See Figures 5.13 and 5.14). This generated a visual appeal and provided immediate feedback, reinforcing learning outcomes through direct interaction. Another significant contribution was pushing the limits of the 360-degree drone fly-over experience of the Chilean coastline. I integrated visual effects and sound effects to create an immersive and emotionally resonant experience. By utilising post-processing techniques and spatial audio design, I enhanced the realism and presence within the XR environment. This element leveraged extended cognition by allowing users to perceive and understand the marine ecosystem from an otherwise inaccessible perspective, deepening their connection to the content.

Figures 5.13 and 5.14 - Animated Interactive Games.

Note. Created by Aguayo, Smith, Wagstaff, and Taheri. Copyright AppLab, 2020.

This project allowed me to refine my design principles and methodologies, which are central to my research objectives. This project stands as a testament to the transformative potential of XR technologies in education. It successfully demonstrated how technological innovation, when harmonised with cultural, philosophical, and cognitive frameworks, can create a holistic and impactful learning experience.

The project's success underscores the importance of a transdisciplinary approach in XR development, one that values the integration of technology with human experience and cultural contexts. This project also marked a pivotal moment in my academic journey, prompting a re-evaluation of my approach to XR design and reinforcing the value of balancing subjectivity and objectivity.

I encourage you to discover more about the Pipi's World project through additional videos and photographs featured on the AppLab website. By visiting my website at https://www.fablesofnaranj.com/portfolio/Explora, you can access an extensive collection of visual content that highlights the project's XR environments.

5.3.2. Atoms and Bits - Reciprocal Interaction

The convergence of physical and digital realms has been a central theme in my research journey. This intersection, which I refer to as "Atoms and Bits," explores the reciprocal interaction between the tangible physical environment (atoms) and the abstract virtual domain (bits). Rather than viewing the MR aspect of XR as merely associated with specific devices or headsets, I perceive it as an ecosystem where the physical and digital worlds seamlessly blend, enabling a dynamic interplay that enhances user experience.

As I closely examined this intersection, especially considering the expanded definitions of XR provided by the Fourth Industrial Revolution (4IR), I became increasingly interested in designing a hybrid approach that effectively bridges the physical and virtual realms. The driving question behind my inquiry was: How can we create a seamless connection between the virtual and physical worlds in a way that enhances user experience?

This question guided my exploration of embodied and extended cognition principles as key connectors between the real and virtual environments. The realisation that technology alone could not fully encapsulate the depth and complexity of the human experience was a turning point in my research. It led me to acknowledge the necessity of a more integrated approach that harmonises technological innovation with philosophical inquiry. This change in approach marked both an academic shift and a profound personal transformation. This inquiry led me to focus on embodied and extended design principles as the key connectors between the real and virtual environment.

By leveraging the concepts of embodied cognition and 4E Cognition (the emotional aspects had not yet fully emerged at this stage), I aimed to develop interactions that integrate reality into the virtual environment while at the same time extend the user's physical and cognitive presence into the digital space. The goal was to create an experience that felt instinctual and intuitive, blurring the boundaries between the physical and virtual worlds, enabling the user to engage in reciprocal interactions with both.

When considering mixed and extended reality, I do not focus on a particular headset or device. From my view, mixing realities encompasses a system, or even an ecosystem, that seamlessly blends the physical world with the digital or virtual world, a system that combines the atoms[20] of the real world with the bits of the digital-virtual world! In such an ecosystem, there should be a reciprocal connection and interaction between the two realms so that they can seamlessly blend and interact with each other.

As I go deeper into this hybrid approach, the next logical step was to explore how these concepts could be practically implemented in the design process. This exploration led to the development of various strategies aimed at operationalising the integration of real and virtual worlds, each focusing on different dimensions of this intersection. The following concepts emerged out of my theoretical research and practical tests:

Augmented Virtual Spaces: One of the initial steps involved incorporating real-world elements into the virtual space. This was achieved by using sensors that allow real-time

[20] For the sake of the conversation, assume atoms are the smallest building blocks of the physical world.

data from the physical world to be transferred into the virtual environment. This was done to enhance the user's sense of immersion by creating a more dynamic and responsive virtual environment that reflects the conditions and events of the physical world. By synchronising real-world data with virtual interactions, the user could now experience a seamless integration between both realms, making the virtual environment feel more tangible and connected to their immediate reality.

Virtual Augmentation in Real Environments: Another approach was to overlay virtual elements onto real-world settings. Utilising AR technologies, virtual objects and information were superimposed onto the user's view of the physical world. This method aimed to enhance the user's interaction with their environment by providing additional layers of digital information and interactive features.

Dynamic Environment Adaptation: In my inquiry, I also explored how virtual environments could dynamically adapt based on real-world changes. For example, using real-time environment data to influence the conditions in the virtual world. This adaptive approach was implemented to ensure that the virtual world remains relevant and responsive to the user's real-world context.

What follows is a detailed discussion of how the above concepts were translated into actionable design principles in real-world projects in order to provide a foundation for creating a more fluid and interconnected user experience that aligns with the principles of embodied and extended cognition. By leveraging the strengths of both realms, the goal was to push the boundaries of what is possible in human-computer interaction and to pave the way for new forms of digital engagement and understanding.

5.3.2.1. NIWA Air Box

The *NIWA Airbox* project (2019), led by the National Institute of Water and Atmospheric Research (NIWA) in New Zealand, was a collaborative initiative involving NIWA, AUT AppLab, Massey University's engineering students, and the Curious Minds programme. Undertaken in 2019, the project aimed to educate New Zealand school students about air quality and atmospheric science, particularly in relation to climate change. By leveraging AR technology, the project sought to visualise complex air quality data, making it accessible and engaging for young learners.

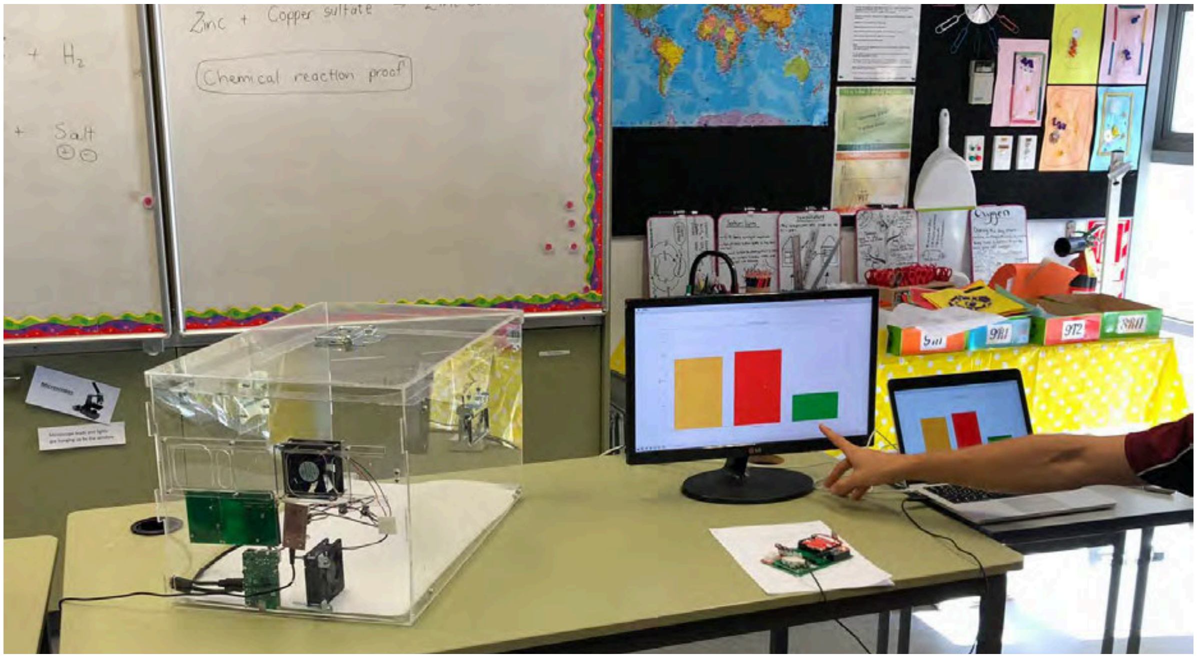


Figure 5.15 - Early Prototypes of AirBox by the Team at Massey.
Note. Copyright by NIWA & AppLab, 2019.

The *NIWA Airbox* project exemplifies the transformative potential of XR technologies and IoT integration in science education by providing an interactive platform that enhances students' understanding and engagement with abstract environmental concepts. By deploying a network of sensors and IoT devices to monitor environmental data (see Figure 5.15), the project makes invisible air quality data visible and comprehensible through real-time collection, analysis, and visualisation in augmented reality (see Figures 5.16 and 5.17). The purpose of this hands-on, data-driven learning experience was to educate students about climate and environmental changes, in addition to empowering them to become informed and proactive about ecological issues. Despite significant technical challenges in ensuring data accuracy and reliability, the project successfully created an intuitive interface that made the data accessible and engaging, allowing students to interact meaningfully with the information and facilitating a deeper understanding of ecological systems and their dynamics.

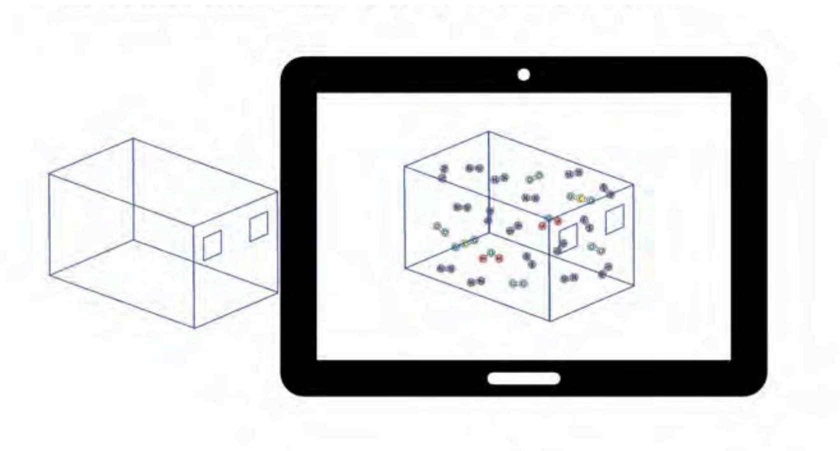


Figure 5.16 - Early AR Ideas by AppLab.
Note. Created by Taheri, Copyright by NIWA & AppLab, 2019.

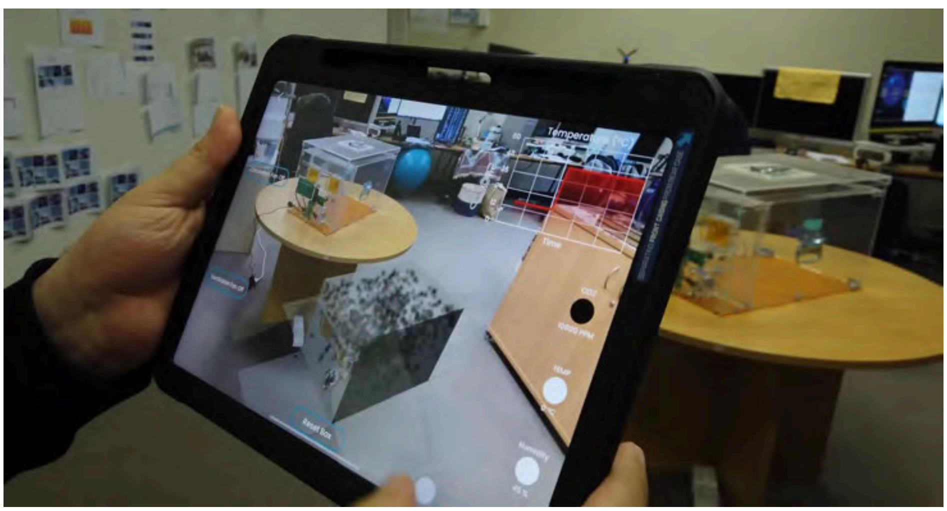


Figure 5.17 - The *NIWA Airbox* AR Visualisation Running on an iPad.
Note. Copyright by Taheri, 2019.

This project has provided technical insights for my PhD research by demonstrating the application of XR technologies in science education and science visualisation. Its methodology aligns with my exploration of using XR to deepen users' understanding and interaction with abstract concepts through extended, embodied, and embedded cognition. By making invisible air quality data perceptible and comprehensible, it brings enlightenment through knowledge—transforming the unseen into the seen and fostering a deeper understanding of our environment. A significant technical feature of the project was the bidirectional IoT communication between the physical airbox and the digital AR app. This enabled real-time data exchanges, allowing users to send data to the physical device and receive immediate feedback via the app, thereby enhancing user interaction with scientific data. This dynamic interplay between the physical and digital realms strengthens the learner's sense of agency and engagement, offering a valuable framework for my research on developing impactful XR educational applications that involve IoT and real-time visualisation.

As a key member of the AppLab team, my role in the *NIWA Airbox* project was multifaceted. I was primarily responsible for the design and development of the AR application interface, ensuring that complex scientific data was presented in an intuitive and user-friendly manner. This involved working closely with atmospheric scientists to understand the intricacies of air quality scientific data, translating complex information into interactive AR visualisations that could be easily understood by secondary school children. I developed the system to integrate real-time environmental data from IoT sensors into the AR app, allowing users to access up-to-date air quality information. I also designed interactive elements that encouraged users to explore and engage with the data, such as virtual experiments and simulations. By taking on these responsibilities, I had full control over how the theoretical frameworks explored in my PhD research were applied in real-world practice.

An essential component of the *NIWA Airbox* project was the development of user-friendly data visualisation tools. Recognising the high demand for accessible platforms that require no coding skills and can interface with various types of sensors, we focused on creating visualisations that allowed students to intuitively explore and understand the air quality data collected (Figure 5.18). The AR app enabled users to visualise the result of their own interaction with the box environment, which generated the data. By providing this comparative capability, we aimed to enhance students' comprehension of environmental dynamics and foster a more holistic understanding of air quality issues.

Figure 5.18 - Data Visualisation Presented in AR.
Note. Copyright Taheri, 2019.

The *NIWA AirBox* project provided a practical platform to apply and test the 4E cognition framework in an educational context. The AR application encouraged physical interaction (embodied cognition) by requiring users to move their devices to explore different layers of air quality data overlaid onto their real-world environment, grounding abstract scientific concepts in tangible experiences.

By using location-specific data (embedded cognition in contextual environment), the application made information more relevant and meaningful, fostering a personal connection to environmental issues as users gained insights into their immediate surroundings. Through virtual experiments where users could manipulate variables and observe real-time outcomes (enactive cognition), the app promoted learning through doing, enabling knowledge construction via direct interaction and experience. The AR technology served as a cognitive tool that extended users' mental capacities (extended cognition), augmenting their perception with additional layers of information; by overlaying digital data onto the physical world, it provided insights inaccessible through unaided observation, enhancing understanding of complex concepts.

I focused on principles of extended cognition and embodied interaction to create more immersive and cognitively engaging experiences for users. By engaging with the AR app, learners could experience a form of cognitive extension where digital information becomes an integrated part of their perceptual world, mirroring natural processes and enhancing the learning experience. The project's success in using XR to create meaningful and engaging educational experiences provides a valuable framework for future research aiming to develop similar XR applications that facilitate deep, impactful learning.

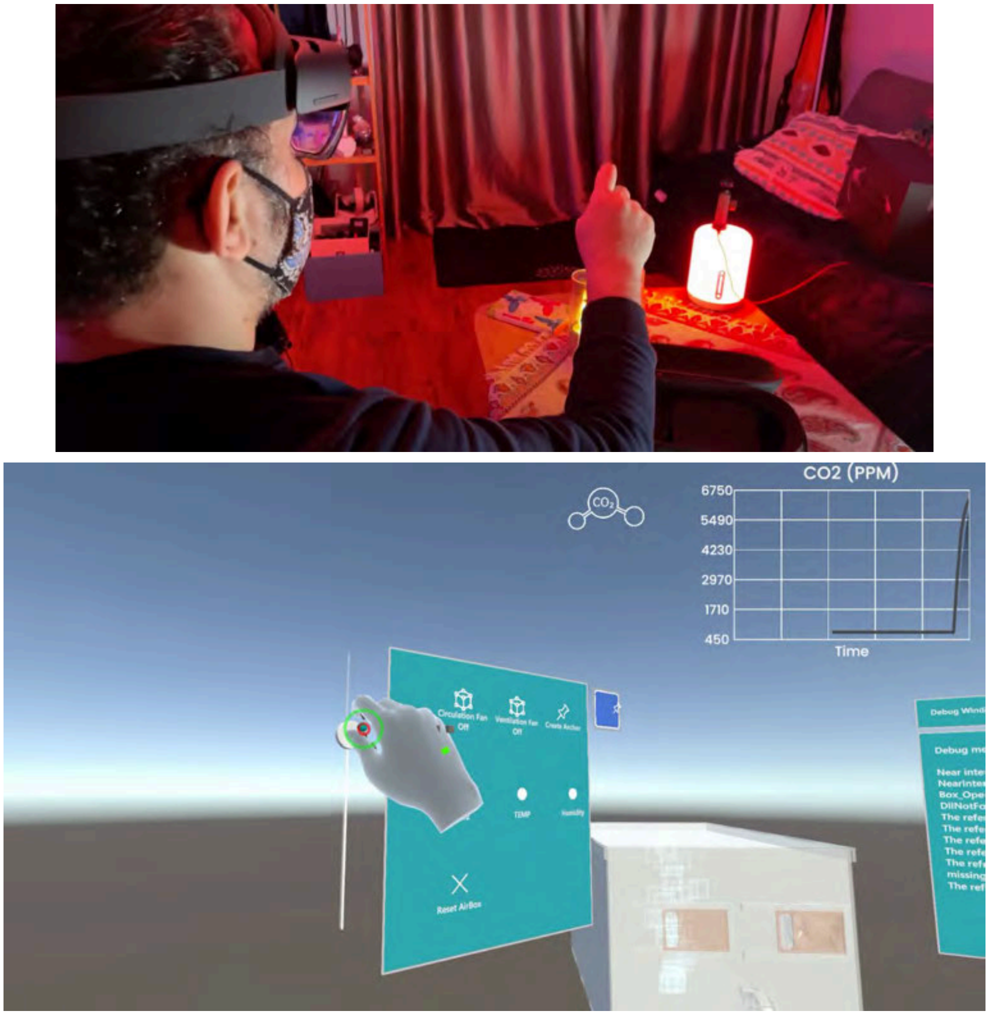
Reflecting on the execution of the *NIWA Airbox* project, I realised a critical oversight. Despite the project's technical robustness and innovative use of XR technologies in science education, it lacked an engaging artistic and emotional component—a regrettable shortcoming, especially given its focus on students. This deficiency marked a pivotal moment in my professional journey, highlighting the need for a more holistic approach that integrates technical precision with creative, artistic, and emotional elements. At the time, I was deeply immersed in perfecting the technical aspects of projects, striving to enhance them using the latest techniques and achieving high-quality execution. However, I began to notice the absence of an emotional connection within the NIWA AirBox project, especially given its aim to engage students. This realisation highlighted an opportunity to incorporate the emotional dimension—leading me to expand my focus from the 4E cognition framework to the 4E+ framework. Consequently, I recognised the necessity to expand my focus to include emotions. This extension incorporates emotions as an essential dimension of human experience and cognition, ensuring that future projects engage users cognitively and physically while also resonating with them emotionally and artistically.

This experience underscored the necessity of balancing the rational and analytical with the existential, artistic, and emotional dimensions—particularly in projects aimed at education and engagement. It became evident that creating truly impactful educational experiences requires more than just technical excellence; it also demands attention to the aesthetic, experiential, and emotional facets that make a project compelling and accessible. This insight catalysed my philosophical journey, prompting me to explore diverse perspectives and integrate them into my work to foster more holistic and engaging XR experiences.

Embracing this emotional dimension became a significant turning point. It taught me that engaging learners on an emotional level enhances their sense of agency and connection to the material, making educational experiences more meaningful and memorable. This critical and self-reflective insight led me to advocate for the importance of adding the emotional component to the 4E framework, recognising it as essential for creating holistic and impactful educational applications.

After the delivery of the project, I began developing an immersive version of Airbox using the Microsoft HoloLens 2. The goal was to demonstrate the potential of the physical and virtual worlds interacting with each other, highlighting how XR technologies and devices (namely HoloLens) can enrich our understanding of environmental data. This immersive experience aimed to provide users with a more intuitive and engaging way to explore air quality data, making abstract scientific concepts more tangible. Additionally, this project allowed me to delve into new possibilities for interaction design within XR, exploring how users could interact with IoT-generated data in a mixed-reality and extended-reality environment.

By integrating real-time data from IoT sensors with the virtual overlays provided by HoloLens, I sought to create an interactive platform that visualised air quality information and facilitated a deeper, more embodied understanding of environmental science (Figures 5.19).



Figures 5.19 - HoloLens 2 Hand Interaction.

Note. Designed and Developed by Taheri. Copyright, Taheri, 2020.

I encourage you to explore more videos and photographs of the Airbox project on my website. By visiting the link https://www.fablesofnaranj.com/portfolio/NIWA-Air-Box, you can access a comprehensive collection of visual materials showcasing the project's innovative integration of XR and IoT technologies[21]. These resources offer an in-depth look at the project's design and implementation.

[21] At first, the website was planned as a small extra part of the thesis—a place to show animated GIFs, images, videos, code links, and a mind map of the project. But when I decided to hold the whole exhibition online, I made the website bigger and added more videos and features. This was to make sure it could work well and keep visitors interested as the main place to experience the exhibition.

5.3.2.2. Digital Twin Robot

The Digital Twin Robot project originated from my personal interest in integrating the Microsoft Mixed-Reality Toolkit (MRTK) and the Microsoft Azure ecosystem with the HoloLens device. The aim was to create a seamless interaction between real-world and virtual-world objects through HoloLens MR. This project aimed to establish an interactive framework where a robot, equipped with sensors, collects data and transmits it to the Azure cloud. This data is then accessed and visualised through HoloLens and other mobile devices, enabling users to interact with both the physical robot and its virtual representation (Figure 5.20).

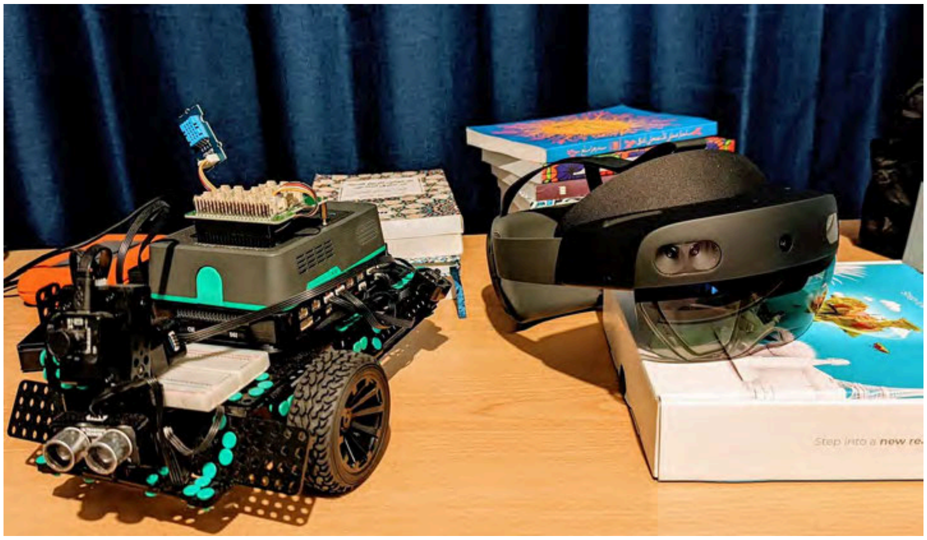
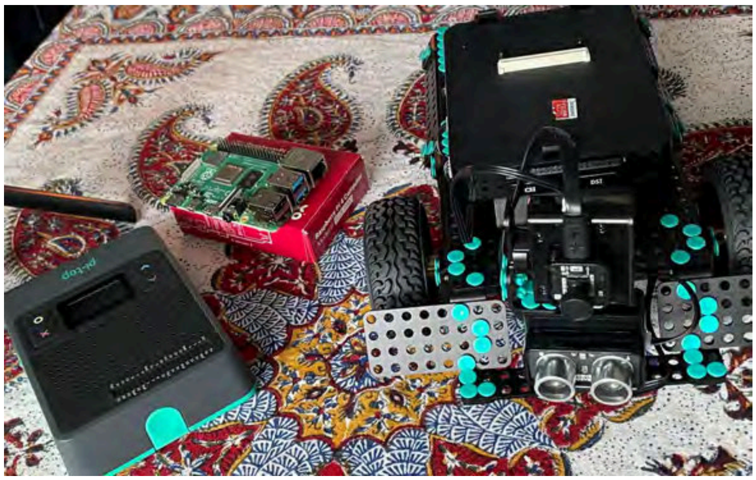
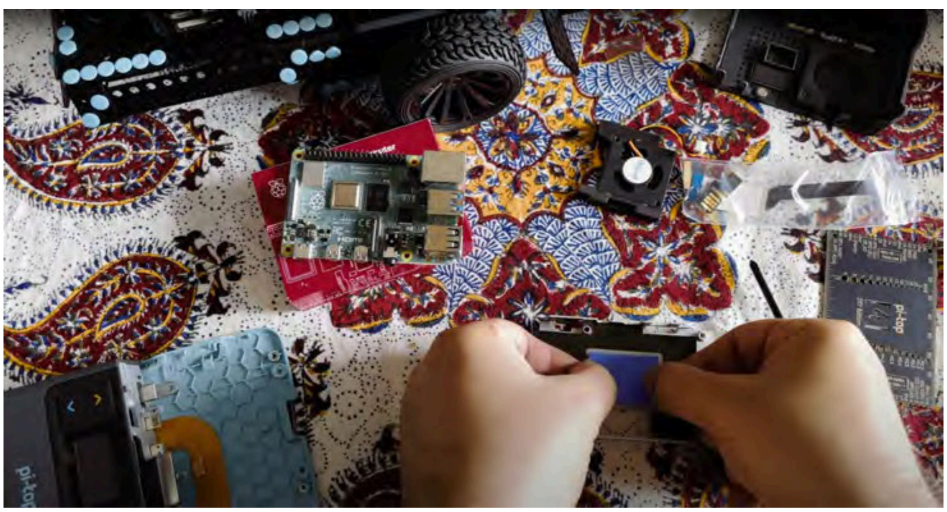


Figure 5.20 - The Robot and the HoloLens 2.
Note. Copyright by Ali Taheri, 2020-2021.

As the sole developer and designer of this project, I was responsible for all aspects of its conception and implementation. This included programming the Raspberry Pi to handle data collection and transmission, integrating IoT sensors, developing the AR interfaces using MRTK, and ensuring seamless communication between the physical robot, cloud services, and the HoloLens device. This project provided a practical platform to explore and apply theoretical frameworks from my research, particularly in Human-Computer Interaction (HCI), Human-Robot Interaction (HRI), and the 4E+ Cognition framework.

For this project, I employed the Pi-top 4 robotic kit (see Figures 5.21 and 5.22), a user-friendly and versatile platform powered by Raspberry Pi. The Pi-top 4 is ideal for educational and experimental purposes due to its ease of use and compatibility with various sensors. The robotic car was outfitted with multiple data-gathering sensors that were capable of capturing a range of environmental and operational metrics.





Figures 5.21 and 5.22 - Pi-top 4 Robot and RP Board before and during Assembly.

Note. Watch the assembly videos by following this link: Digital Twin Robot

Copyright by Ali Taheri, 2021.

The sensors on the Pi-top 4 robot collected real-time data, which was then transmitted to the Azure cloud (see Figure 5.23). This process involved programming the Raspberry Pi to handle data collection and ensure the seamless transmission of data to the cloud.

Utilising Azure's robust cloud computing capabilities allowed for efficient data storage, processing, and retrieval, ensuring that the information gathered by the robot was readily available for further analysis and interaction.

The project also involved integrating the HoloLens device to create an immersive AR experience. The data transmitted to the Azure cloud was accessed through the HoloLens, which provided a virtual interface for users to interact with the robot. The HoloLens allowed for the visualisation of real-time data, enabling users to monitor the robot's performance and environmental conditions in a highly interactive manner.

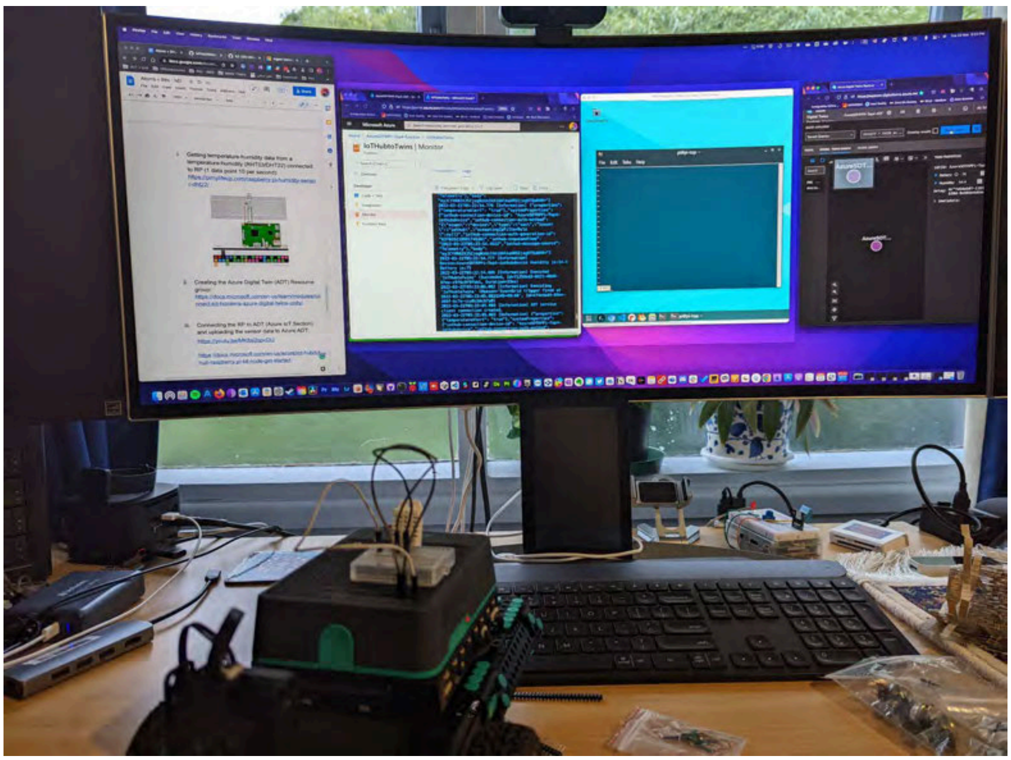


Figure 5.23 - The Robot Collects Real-World Data and Sends Them to Azure Cloud.
Note. Copyright by Ali Taheri, 2021.

Furthermore, the Raspberry Pi controlled the motors of the robotic car, which could be programmed to respond to user commands issued through the HoloLens or an AR application on mobile devices. This feature allowed users to manipulate the robot's movements and functions directly, enhancing the interactive experience and providing a tangible connection between the physical and virtual worlds.

The integration of the Microsoft MRTK, Azure, and HoloLens in this project underscored the potential for creating seamless interactions between real-world objects and their virtual representations. By leveraging these advanced technologies, it was possible to develop an interactive framework that collected and visualised it, and also allowed for direct manipulation of physical objects through virtual interfaces.

From a technical perspective, this project demonstrated the feasibility and benefits of integrating IoT, cloud computing, and MR technologies. The use of Raspberry Pi and Pi-top 4 robotic kits highlighted the importance of choosing versatile and user-friendly hardware platforms for experimental and educational projects. Additionally, the successful transmission and visualisation of data through Azure and HoloLens emphasised the critical role of robust cloud infrastructure in supporting real-time data interaction in XR environments.

Philosophically, this project illustrated the convergence of physical and virtual realities, reflecting broader themes in XR research related to embodied and extended cognition. The ability to interact with a physical robot through virtual interfaces exemplified how XR technologies can bridge the gap between tangible and digital experiences, enhancing users' cognitive and sensory engagement (see Figure 5.24). From an educational standpoint, the project offered valuable insights into how XR technologies can be utilised to create immersive learning environments. By enabling users to interact with physical objects in a virtual context, the project demonstrated the potential for XR to facilitate experiential learning and foster deeper understanding of complex systems and concepts.

Reflecting on the development of the NIWA AirBox project and recognizing its shortcomings in affective interaction, I approached the Digital Twin Robot project with a renewed focus on enhancing user engagement and usability by deeply integrating emotional and affective dimensions into HCI and HRI. This ambition was driven by the understanding that fostering an emotional connection is crucial for creating meaningful and impactful user experiences, especially in educational and interactive environments.

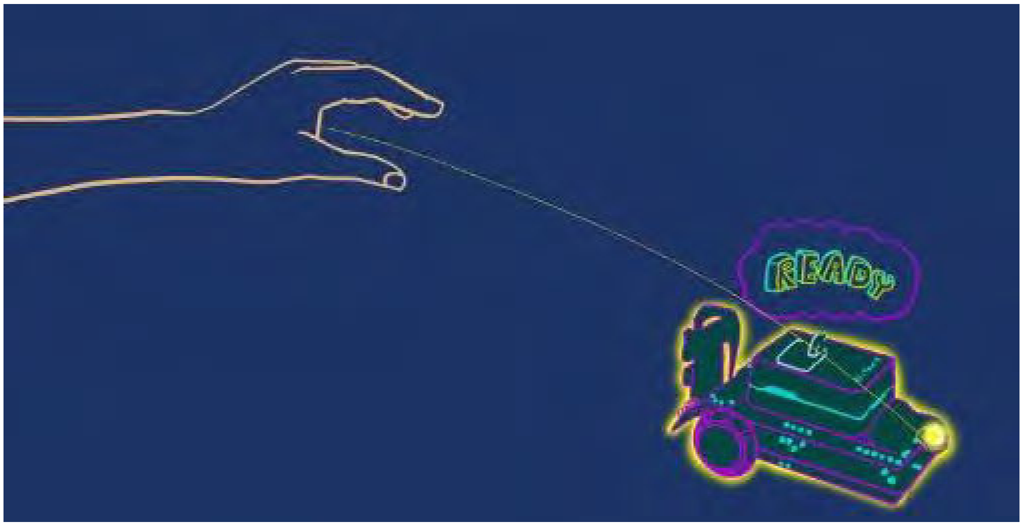


Figure 5.24 - The Design Idea for Interaction with the Robot-Car.
Note. Designed by Taheri, Copyright by Ali Taheri, 2020.

In the realm of HCI, I prioritised usability and user experience, recognising that the ease with which a user can navigate and interact with a system is paramount, I focused on designing an interface that was both intuitive and accessible. Implementing natural gestures and voice commands allowed users to control the robot seamlessly, mirroring the efficiency of human communication. This approach mirrored the efficiency of human communication and also used the principles of extended cognition, where the interface acts as an extension of the user's cognitive processes. By leveraging natural interactions, the system augmented the user's ability to engage with the robot, thereby enhancing both functionality and the overall user experience. By incorporating real-time data visualisation, users receive immediate feedback on their commands, which enhances their sense of agency. This instant responsiveness was instrumental in keeping users engaged, as they could see the direct impact of their interactions without delay.

Transitioning to HRI, the emphasis was on teleoperation and control. Enabling users to control the physical robot through the AR interface bridged the gap between virtual commands and physical actions. Observing the robot respond in real-time to their inputs strengthened the connection between action and outcome, making the interaction more tangible and satisfying. Moreover, the introduction of a social presence and embodiment through the virtual representation of the robot in AR added a personal dimension to the interaction. Users began to perceive the robot not just as a machine but as an extension of themselves. This extended embodiment fostered a more meaningful connection, as users felt more personally invested in the robot's actions and responses.

A significant aspect of the project was the implementation of the 4E+ Cognition framework to deepen user interaction and understanding. Embodied cognition was realised through physical interaction. By allowing users to engage with the system using natural gestures that were recognised by the HoloLens, I facilitated a deeper cognitive connection. This physical involvement meant that users were not just passive observers but active participants, engaging multiple senses in the process. With embedded cognition, contextual awareness played a pivotal role. By operating the robot within the user's physical environment and overlaying virtual information onto the real world, users could relate the digital content directly to their immediate surroundings. This integration made the data more relevant and easier to comprehend, as it was presented within a familiar context.

Enactive cognition was encouraged through active exploration. The system was designed to promote learning through doing, allowing users to manipulate the robot and interact with the data directly. This hands-on approach enabled users to construct knowledge through their experiences, making the learning process more engaging and effective. In terms of extended cognition, the HoloLens and AR interface served as extensions of the user's cognitive processes. By offloading certain tasks to the technology, such as data visualisation and complex calculations, users could focus on higher-level thinking and decision-making. This cognitive augmentation enhanced their capabilities, allowing for more sophisticated interactions with the robot. Through the integration of HCI, HRI, and the 4E+ Cognition principles, the project significantly enhanced user interaction with the robot. Users benefited from intuitive control mechanisms, utilising natural gestures and voice commands that made the technology accessible and user-friendly. Real-time data visualisation improved their understanding of the robot's operations and environmental conditions, fostering a deeper comprehension of the system's functionality.

The immersive AR environment blended the physical and virtual worlds, creating an experience that captivated users. This immersion increased engagement and empowered users to experiment and explore, enhancing their creativity and problem-solving skills. By incorporating affective elements, the interaction became more enjoyable, encouraging users to remain engaged over longer periods.

Reflecting on the project's outcomes, I recognise the profound impact that thoughtful integration of interaction principles and cognitive frameworks can have on user experience. The success of the project underscores the importance of designing technology that is functional while also intuitive, engaging, and responsive to the user's cognitive and emotional needs. Moving forward, I am inspired to continue exploring the intersection of technology and human experience, striving to create systems that enrich and empower users in meaningful ways.

In conclusion, the integration of Microsoft MRTK, Azure, and HoloLens in this project highlights the transformative potential of XR technologies in creating interactive and immersive experiences. The project's success underscores the importance of combining technical innovation with philosophical inquiry to develop holistic and impactful XR applications. This endeavour advanced my technical expertise and enriched my understanding of the broader implications of XR in education and beyond.

I invite you to explore additional videos and photographs of the Digital Twin Robot project on my website. By visiting https://www.fablesofnaranj.com/portfolio/Digital-Twin-Robot, you can access a comprehensive collection of visual materials that showcase the project's innovative integration of XR and IoT technologies[22]. These resources offer an in-depth look at the design and implementation of the project.

[22] Initially, the website was conceived as a supplementary component of the thesis—intended primarily to host animated GIFs, images, videos, code repositories, and a conceptual mind map of the project. However, following the decision to transition the entire exhibition to an online format, the website evolved into a more comprehensive and feature-rich platform. Additional videos were integrated to ensure the site could serve as the primary venue for engaging audiences with the exhibition content. It is important to note that the project remained partially in the design phase, a consequence of constraints imposed by the COVID-19 pandemic and its aftermath. These limitations affected access to resources, collaborative opportunities, and the feasibility of physical prototyping and user testing—factors that would have otherwise enabled the project's full realisation.

5.3.3. Abstract Ideas for Interaction Design - Conscious Particles

Inspired by the principles of autopoiesis, the design of HCI in XR seeks to establish a symbiotic relationship between users and virtual environments based on organic principles found within living systems. By considering virtual objects as organic entities with awareness, my designs aim to evoke a sense of connection and responsiveness, akin to interacting with a living being. This approach draws from cinematic influences and the desire to create interactions where users feel engaged with the digital world on a deeply personal level (Dourish, 2001).

Within the framework of 4E+ Cognition, emotion is acknowledged as a fundamental aspect of human cognitive processes and experience. Affective Interaction signifies a substantial paradigm shift in the field of human-computer interaction (HCI), moving beyond the limitations of traditional computing paradigms to adopt a holistic perspective on emotions as dynamic, embodied, and socially constructed phenomena. This approach aims to cultivate a deeper and more nuanced understanding of the interplay between technology and human emotional experiences, challenging conventional models and advocating for systems that encapsulate the complexity and richness of human affect.

During my research on autopoiesis and 4E+ interaction design, I came across an exciting work by Jeffrey Ventrella called Clusters (Figure 5.25). The Clusters project (2016-2024) utilises a unique algorithm that gives life-like behaviour to particle systems. Interestingly, the algorithm used by Ventrella was inspired by the theories of Lynn Margulis, an evolutionary biologist, including her Endosymbiosis theory (Margulis & Bermudes, 1985; Margulis & Chapman, 1988). Thus, Margulis proposed that a significant organisational event in the history of life likely involved the merging of two or more lineages through symbiosis and that some early Earth bacteria developed such intimate symbiotic relationships that they fused into composite organisms—meta-organisms known as eukaryotes (Archibald, 2011; Gray, 2017; Margulis, 1974).

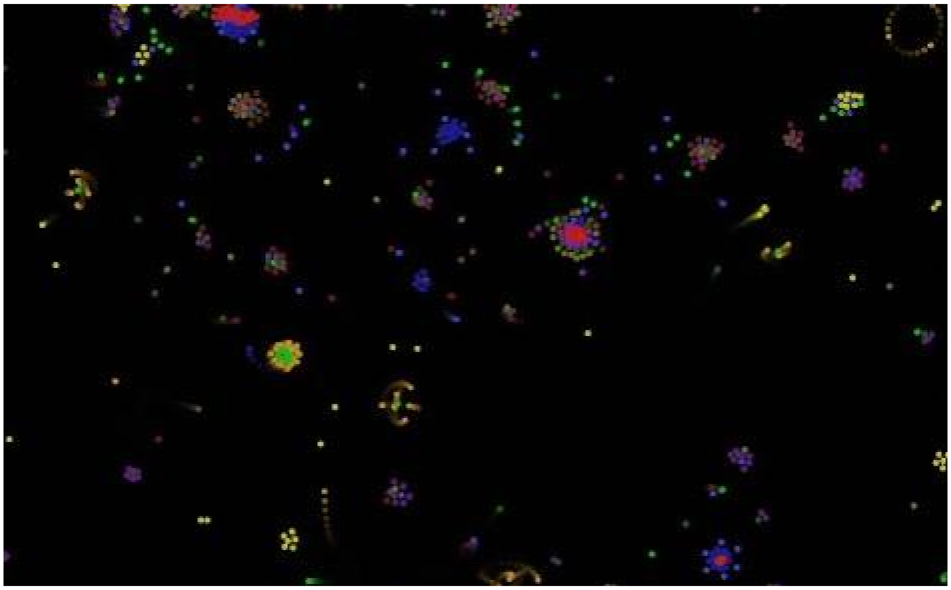


Figure 5.25 - Clusters by Jeffrey Ventrella.
Note. Copyright by Jeffrey Ventrella, 2016.

In his blog, Ventrella (2017-2024) described his project by observing that organisms naturally tend to be attracted to certain other organisms while being repelled by others. In his simulation, particles interact through attractions and repulsions based on differing colours. They form social clusters or disperse and flee, often emulating behaviours seen in biological systems. These clusters change shape and exchange parts of their identities, much like the microscopic organisms that, according to Margulis, merged during early evolution to form symbiotic relationships.

Additionally, In "Eukaryotic Virtual Reality" (1995), Jeffrey Ventrella explored the convergence of artificial life and VR, advocating for an ecosystem-based approach to virtual environments. He critiqued the conventional lonely nature of virtual reality, often characterised by the immersion of the human subject in a simulated three-dimensional space. Instead, Ventrella proposed a more dynamic form of VR populated by adaptive artificial life forms, where interaction and behaviour take precedence over visual representation. Thus, drawing on the principles of artificial life, which abstract the dynamics of life beyond physical manifestation, Ventrella envisioned virtual ecosystems that focus on inner processes, growth, and adaptation rather than mere visual aesthetics.

Ventrella (1995) aligned this approach with the concept of "Eukaryotic Reality", inspired by Lynn Margulis's theory of symbiosis in early Earth bacteria, which led to the evolution of eukaryotes (Margulis, 1970). He extended this analogy to virtual environments as complex, interdependent systems. Ventrella saw artificial life as an emergent art form that merges science and creativity and that promotes interactions among autonomous agents, including human participants (Ventrella, 1995). It is my perspective that the future of VR lies in creating environments where life-like behaviours and interactions foster a sense of presence and purpose beyond mere visual immersion.

Lynn Margulis's theory of endosymbiosis revolutionised our understanding of the evolution of complex life forms. According to this theory, eukaryotic cells—cells with a nucleus and organelles—originated through a symbiotic relationship between different species of prokaryotes (simple cells without a nucleus). This symbiosis led to the integration of these distinct organisms into a single, more complex cell type, with mitochondria and chloroplasts as remnants of the original prokaryotic organisms. Margulis's theory of endosymbiosis emphasises the importance of cooperation and symbiosis in evolution, highlighting how different lineages can merge to create new, complex systems that exhibit characteristics greater than the sum of their parts.

By emphasising the importance of relational dynamics (i.e., “structural coupling” as per Maturana and Varela’s perspective) and the organisation of living systems, Margulis's endosymbiosis can be seen as a process that leads to an expanded form of autopoiesis. Through symbiotic relationships, separate organisms come together to form a new, self-maintaining entity that can interact with its environment in a novel way.

The connection lies in the understanding of life as a process of ongoing creation and re-creation. While Margulis focused on the evolutionary mechanisms that lead to the emergence of complex life forms through symbiosis, Maturana and Varela focused on the operational logic that underpins the maintenance and persistence of life forms. In both cases, the emphasis was on the relational processes—whether through the integration of different organisms or through the self-referential nature of autopoietic systems—that give rise to new forms of life and complexity.

In the context of XR and interaction design, these biological concepts can inspire the creation of systems that are interactive, self-sustaining, and adaptive. Just as in biological systems, where the interaction between components leads to the emergence of new properties, XR environments can be designed to evolve and adapt based on user interactions and internal processes.

The idea of autopoiesis can be applied to create XR experiences that are not static but dynamic and responsive, offering a form of interaction that feels alive and engaging. Similarly, the concept of symbiosis can inspire collaborative and integrative design approaches that bring together diverse elements—such as visual, auditory, and haptic feedback—into a coherent and immersive experience. With this understanding, I began experimenting with different designs, searching for one that inherently included reciprocal interaction. I envisioned a space where the other side, possessing its independent intelligence, could perform actions and reactions, learn through experience, and adapt to user needs. This intelligent, evolving environment could engage users in a continuous, dynamic interaction, creating a truly immersive and transformative experience.

By adopting the mentioned principles and integrating them into XR design, I aimed to develop an environment where users could engage deeply with the digital world as they experience a level of interaction that transcends traditional media and fosters a unique, symbiotic relationship between user and technology. Later, I discovered that the team at *Ultraleap*, a company known for its hardware and software developments for interaction across XR, automotive and touchless interfaces, and manufactures one of the best hand tracking hardware on the market (Leap Motion Controller, which I use as one of my primary tools), had already created an XR app (called Particles) based on Ventrella's work (Figure 5.26).

Figure 5.26 - The Leap Motion Version of the Cluster Particles.
Note. Copyright by LeapMotion and Jeffrey Ventrella, 2018.

Inspired by the works of Ventrella and Margulis and drawing on my experience with particle-based design as my tacit knowledge, I began to explore and design HCI for various mixed-reality platforms. As a cinema studies graduate, I was able to apply my tacit knowledge of media to enhance interactions created in the XR environment by incorporating sound and cinematic design.

Such an approach led me to the design you see below (Figures 5.27 to 5.32). My vision was that when a user approaches the object, it would react and determine if the user wants to engage with it or simply pass by. Once the user reaches out to grab something or make contact with an object, the object would respond with a gentle animation and initiate an interaction. This setup would give the user the sense of the object holding their wrist softly.

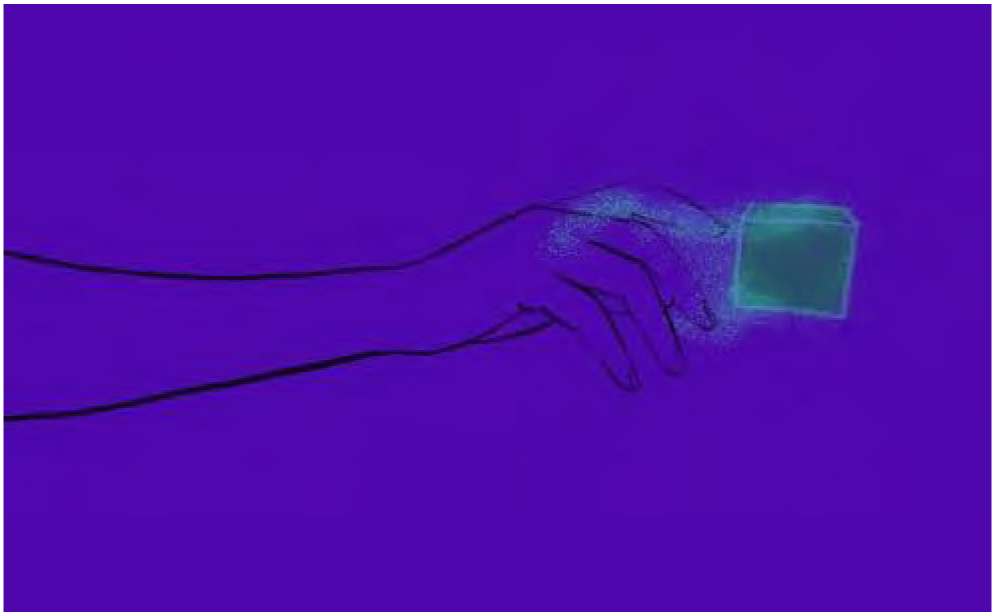


Figure 5.27 - Sensitive Objects with Feelings.
Note. Designed by Taheri, Copyright by Ali Taheri, 2022.

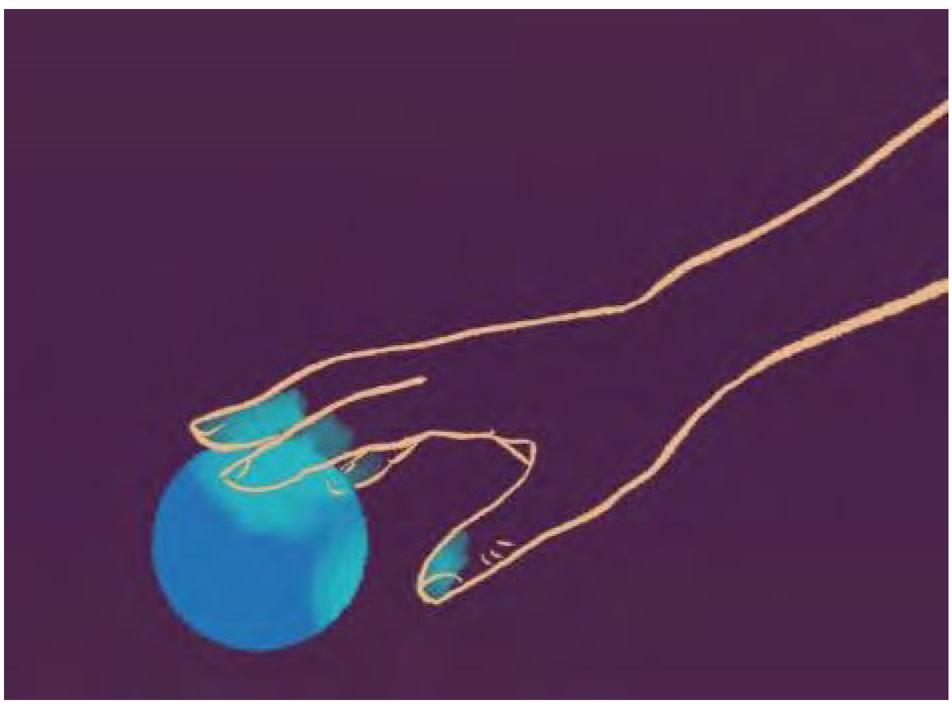


Figure 5.28 - Light and Colour Play between the User's Hand and the Virtual Object.
Note. Designed by Taheri, Copyright by Ali Taheri, 2022.

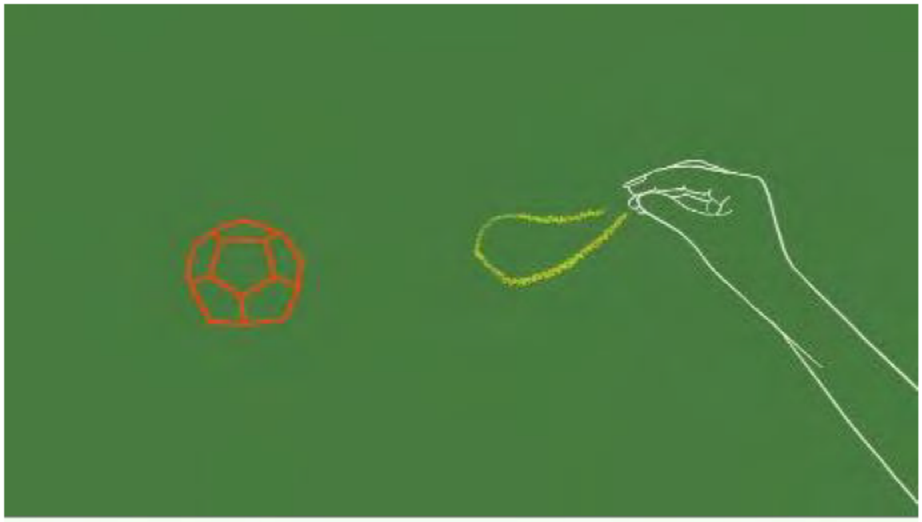
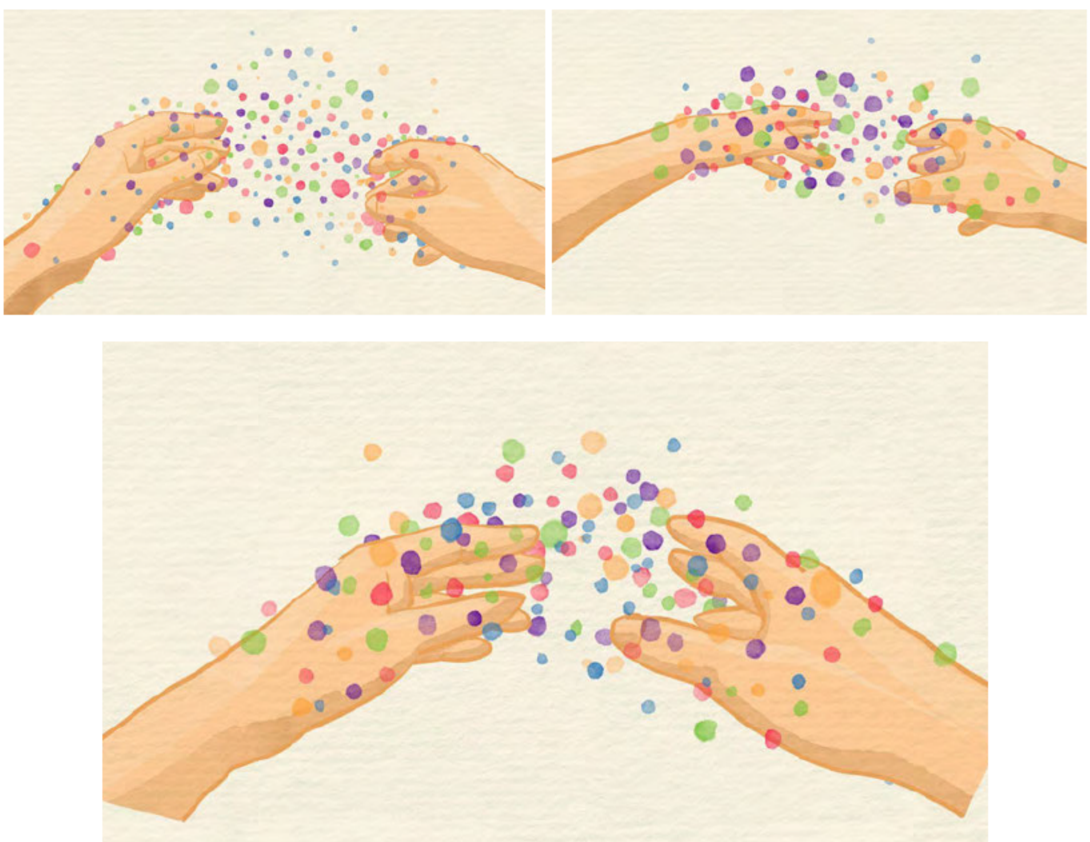


Figure 5.29 - Interacting with the Spirit of the Object.
Note. Designed by Taheri, Copyright by Ali Taheri, 2022.



Figures 5.30 - Interacting with the Spirit of the Object.
Note. Designed by Taheri, Copyright by Ali Taheri, 2023.

During my research, I found that one of the most promising solutions for developing an interaction design between humans and virtual objects was to consider the virtual environment as living beings with which the user can establish a symbiotic and autopoietic relationship. The additional integration of 4E+ Cognition principles into such organic interaction design within XR represents a groundbreaking approach to creating immersive experiences that resonant with human cognitive processes.

By leveraging the capabilities of life-like smart particles enhanced with machine learning, XR environments can achieve a level of interactivity and responsiveness that has not been possible before. This exploration delves into the theoretical underpinnings of 4E+ Cognition—embodied, embedded, enactive, and extended cognition, along with the affective dimension of human experience—and their application in designing XR interactions that are intuitive, engaging, and meaningful.

Users, as living beings with minds, bodies, and emotions, respond better to two-way communication in an environment that evokes these same aspects. By engaging the mind and intellect, involving the body in the interaction, and tapping into emotions, digital beings can also feel more alive, more like us, with a sense of intelligence and emotions or even a spirit. This allows users to connect with them more effectively.

To have better results when working and connecting in the digital world, it is beneficial to feel like we are interacting with objects that have a sense of awareness (see Figures 5.31 and 5.32) and can respond to us. When objects react to our actions and respond back to us, it makes us feel more comfortable and engaged in the virtual world, leading to longer usage before the user loses interest and stops using the device.

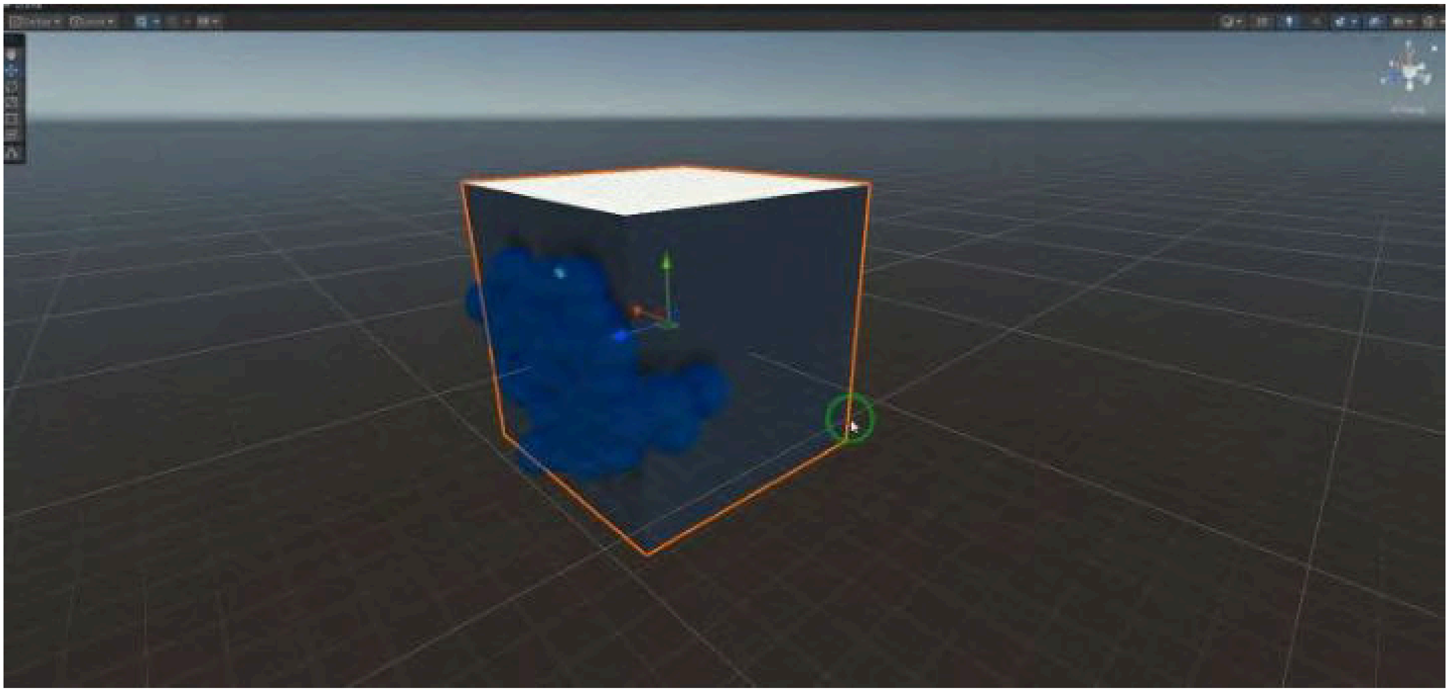


Figure 5.31 - Particles Early Interaction with an Object with a Sense of Awareness.
Note. This is the result of an early design and development using manual programming and machine learning (Unity ML-Agents) integrated together.
Designed by Taheri, Developed by Taheri & Jamali. Copyright by Ali Taheri, 2022-2024.

The importance of having a good interaction in design can be illustrated through an analogy; Imagine you are having a conversation with someone who shows no reaction, positive or negative, even though the conversation is making sense. The interaction may be functional, but there is no chemistry. On the other hand, imagine having a conversation with someone on a similar topic but feeling a wonderful connection and sensing that the other person is responsive to your body language. Not only is the outcome of the conversation better, but there is also chemistry. This is what I strive for in my design - a functional interaction and a sense of connection.

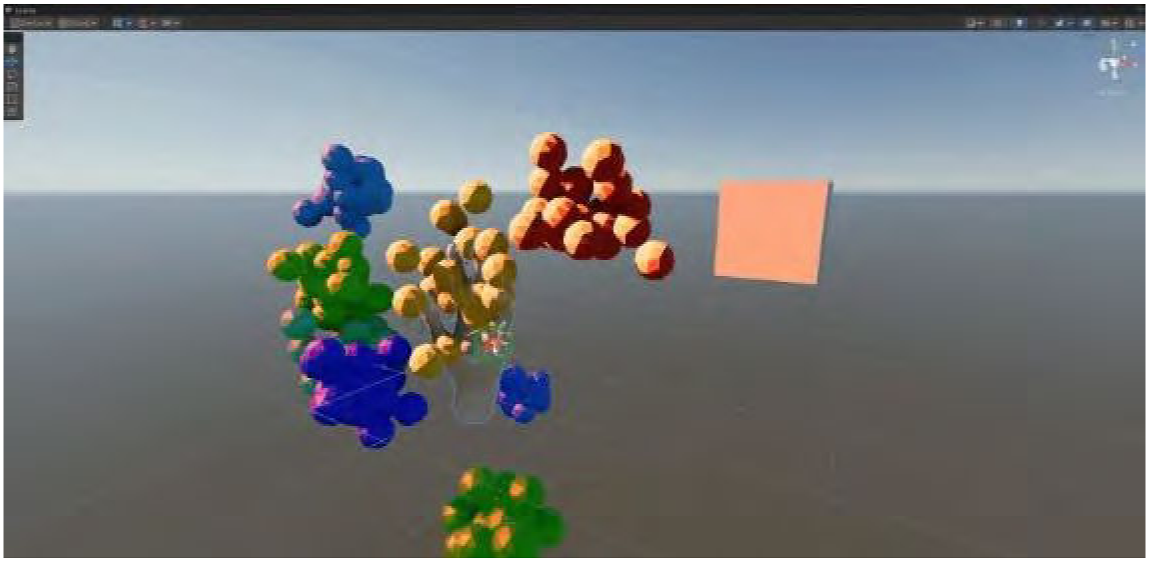


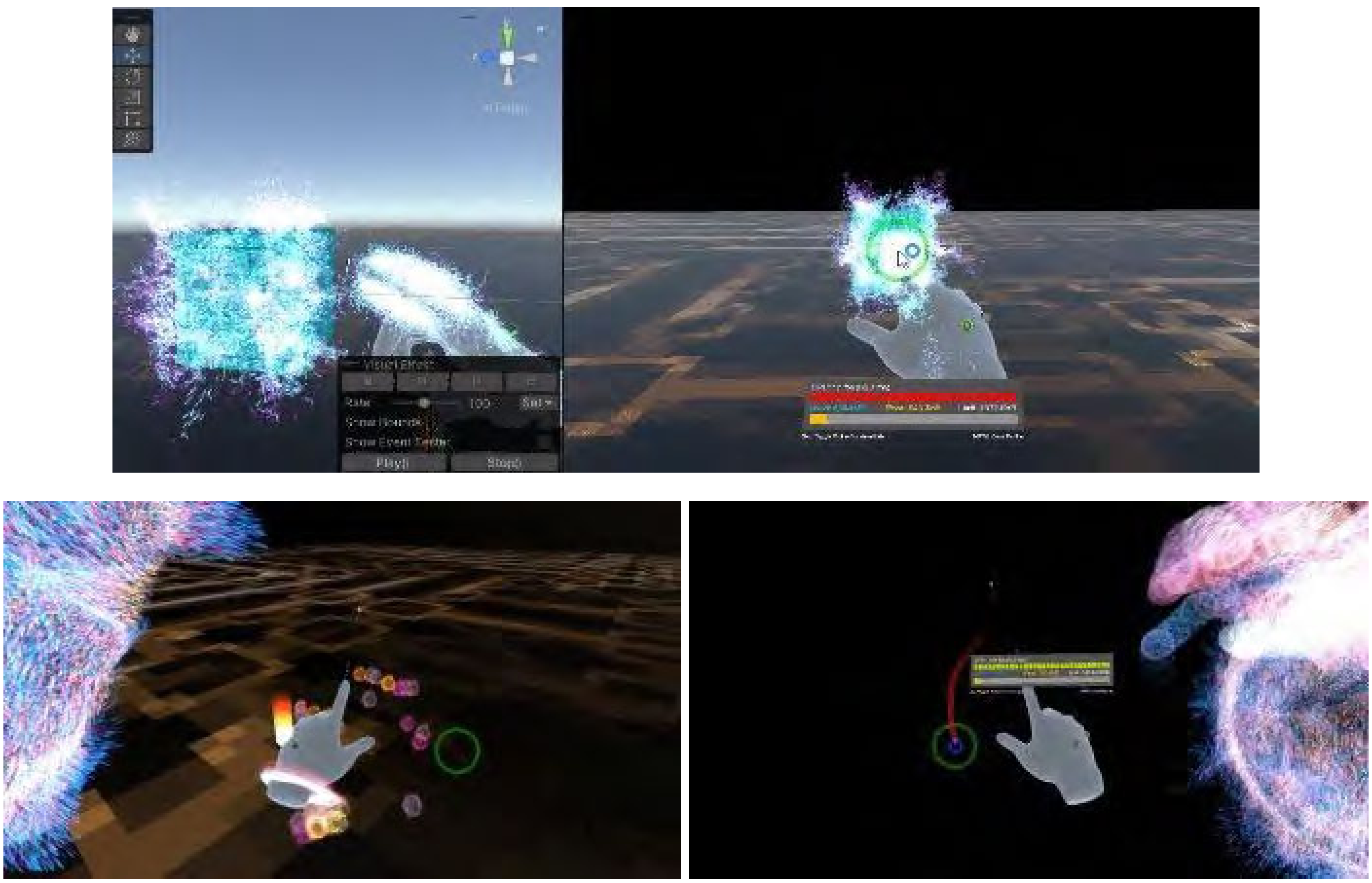
Figure 5.32 - Virtual Hand Model Interacting with Smart Particles.
Note. Designed by Taheri, Developed by Taheri & Jamali.
Copyright by Ali Taheri, 2022-2024.

My assumption was that an interaction in which the user feels engaged with a virtual object—as if it were another living being with a soul or spirit, despite knowing it is only a soulless machine and code—would create a sense of connection for the user. The feeling of the virtual being responsive to the user's touch, and the sensation of the XR holding the user's wrist, would enhance this connection.

Figure 5.33 to 5.35 illustrates the innovative implementation of Smart Particles, enhanced by machine learning algorithms. These particles dynamically respond to the user's hand movements, creating a visually engaging and interactive experience. This figure showcases how advanced computational techniques can be seamlessly integrated into XR environments to enhance user interaction and engagement. The Smart Particles system employs ML to interpret and predict user gestures, allowing the particles to react in real-time with fluidity and precision.

This responsiveness exemplifies the principles of embodied and enactive cognition within the 4E+ framework. By requiring users to perform natural hand movements to interact with the particles, the system fosters a more intuitive and immersive experience.

For instance, when a user waves their hand, the particles disperse and reform in patterns that mirror the gesture, thereby reinforcing the connection between physical actions and digital responses. Additionally, in the convergence of hand movements and the virtual environment, users enact and interpret their experiences through a constant perception-action-perception-action feedback loop, deepening their understanding and engagement with the digital interface.



Figures 5.33 - Smart Particles, Enhanced by ML.
Note. The particles are responding to the user's hand movement.
Designed by Taheri, Developed by Taheri & Jamali. Copyright by Ali Taheri, 2022-2024.

Machine learning algorithms enable these particles to learn from interactions over time, adapting their behaviour to better suit the user's preferences and the nuances of the environment. This organic-like adaptability ensures that XR experiences remain relevant and engaging, even as the context changes. The extended aspect of 4E+ Cognition highlights the extension of the mind beyond the physical body through tools and technologies. XR environments, enhanced with smart particles, can act as extensions of the user's cognitive processes, offering new ways to manipulate and interact with digital content. The affective dimension plays a crucial role in this framework by integrating emotional responses into the interaction design. In the Smart Particles project, emotional engagement is achieved through visually stimulating effects and responsive behaviours that evoke feelings of wonder and curiosity. For example, particles that glow or change colour in response to user interactions can create a sense of delight and satisfaction, enhancing the overall user experience. Additionally, the unpredictability and fluidity of particle movements can elicit feelings of excitement and intrigue, encouraging users to explore and interact more deeply with the virtual environment. Furthermore, in the future, the smart particles can be programmed to respond to users' emotional states, detected through physiological signals or voice modulation, by adjusting the environment's ambiance, colour schemes, and dynamics.

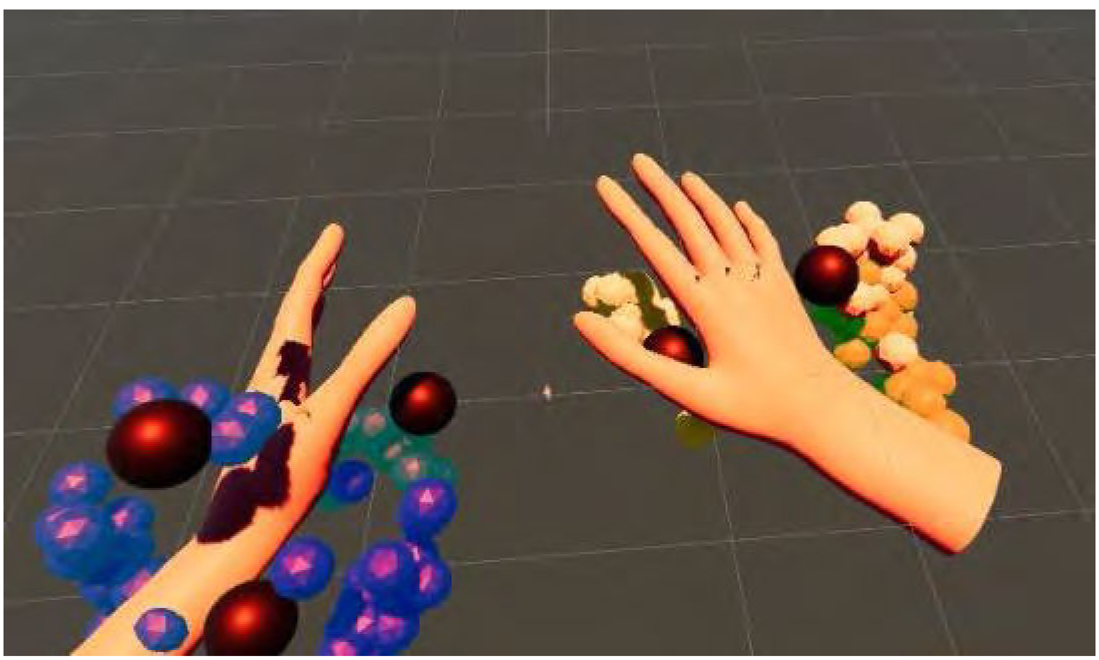


Figure 5.34 - Hand Interaction Development.

Note. Designed by Taheri, Developed by Taheri & Jamali.

Copyright by Ali Taheri, 2023-2024.

The incorporation of machine learning into smart particle systems is pivotal for achieving a high degree of responsiveness and personalisation in XR. Through reinforcement learning, particles can optimise their behaviour based on user feedback, in order to improve the quality of interaction over time. Furthermore, in the near future, it is likely that natural language processing (NLP) techniques can enable smart particles to understand and respond to voice commands, making the interaction more intuitive and accessible. The application of 4E+ Cognition principles in XR interaction design, through the use of life-like smart particles enhanced with machine learning, represents a significant advancement in creating experiences that are immersive and cognitively resonant. By grounding XR interactions in the embodied, embedded, enactive, and extended dimensions of cognition along with affectivity, designers can create environments that are more intuitive, engaging, and meaningful for users. Machine learning plays a crucial role in realising this vision, enabling smart particles to adapt and evolve in response to user interactions, thereby pushing the boundaries of what is possible in XR.

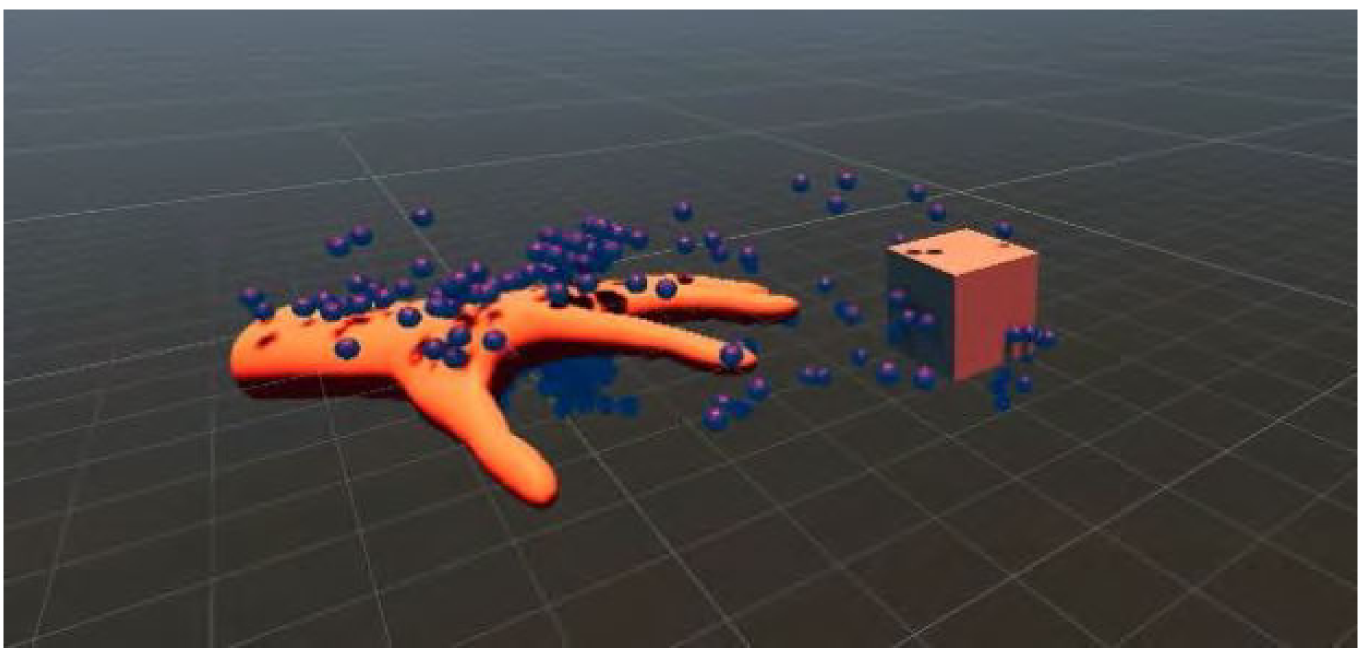


Figure 5.35 - Hand IxD with Smart Particles.

Note. Designed by Taheri, Developed by Taheri & Jamali.

Every stage of the project was meticulously documented through photographs and screen recordings, paired with comprehensive explanations of the techniques employed and their contextual relevance at the time. This visual archive traces the project's technical progression while weaving a narrative of its development through a philosophical lens. More interaction ideas are presented on my website (https://www.fablesofnaranj.com/portfolio/xr-ixd), which features a collection of animated designs, moving Gifs, interactions videos, and making of videos. These resources provide detailed insights into the design and execution process of the Smart Particles project.

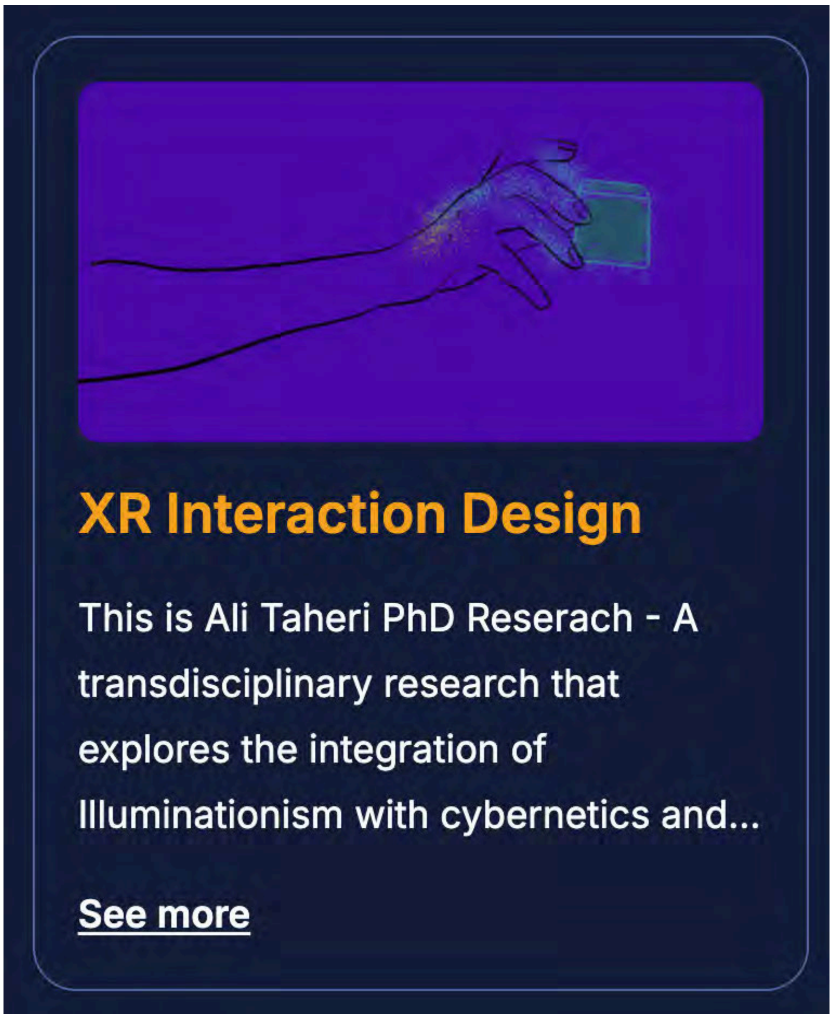


Figure 5.36 - XR Interaction Design Webpage.
Copyright by Ali Taheri, 2024.

5.3.4. Cultural Heritage in Interactive Space

Cultural heritage gamification is a powerful educational tool that leverages XR technologies to create interactive and engaging learning experiences. By gamifying cultural heritage, educators and developers can transform traditional methods of learning into dynamic and immersive experiences. This approach makes the learning process more enjoyable and facilitates a deeper understanding of cultural narratives and histories. XR technologies allow users to interact with digital representations of cultural artefacts, historical events, and traditional practices in a way that is both informative and experiential. The *AUT Virtual Marae* project, which uses advanced 3D modelling and VR to digitally recreate the Auckland University of Technology's Marae (traditional Māori meeting house) and the pre-urban landscape of Auckland, exemplifies this approach. This project not only preserves and promotes Māori culture but also transforms cultural education into an interactive experience. By incorporating game-like elements, such as exploration and discovery, it fosters a deeper understanding and appreciation of cultural traditions and values among users, making the learning process both enjoyable and informative.

An even more compelling example is the *Rapua te Mārama* project, which demonstrates the profound impact of gamifying cultural heritage through XR. This project offers an interactive experience that presents the findings of a study on Māori whānau experiences during the COVID-19 pandemic. By immersing users in the lived experiences of these families, *Rapua te Mārama* fosters empathy and understanding, enabling users to engage with the material on an emotional level. The use of interactive media to convey cultural and historical narratives in an interactive format allows users to actively participate in the experience, which deepens their connection to the content. This approach not only educates but also encourages users to reflect on the significance of cultural heritage, making the experience both impactful and transformative. For these projects, XR technologies prove to be powerful tools for preserving and sharing cultural knowledge as they enhance the accessibility and resonance of cultural education for diverse audiences.

By integrating considerations on cognitive dimensions, XR projects create immersive environments that engage users holistically. Embodied cognition enhances learning through physical interaction with XR environments and the content. Embedded cognition situates learning within meaningful cultural contexts, making the material relevant and resonant. Enactive cognition encourages active participation in storytelling and exploration, enabling users to construct knowledge and meaning-making through direct experience. Extended cognition leverages XR technologies as cognitive tools, expanding users' capabilities to perceive and understand complex cultural concepts. Adding an affective dimension to the immersive experience heightens emotional engagement, fostering deeper connections to the material. By weaving in spiritual wisdom and philosophical insights, XR projects like *Rapua te Mārama* and the *AUT Virtual Marae* not only educate but also inspire users to reflect on profound cultural and existential themes. This approach aligns with the broader objectives of my research, which seeks to harmonise technological innovation with cultural, philosophical, and cognitive frameworks to create transformative educational experiences.

XR technologies significantly enhance affective engagement by evoking emotional resonance through immersive experiences. By placing learners in emotionally charged scenarios or culturally rich environments, XR fosters empathy and emotional intelligence, encouraging a deeper, more personal connection with the material. This emotional engagement enhances motivation and interest, making the learning process more enjoyable and memorable. Furthermore, the immersive nature of XR facilitates mindfulness and reflection, providing learners with moments of introspection that contribute to their overall well-being and personal growth.

The affective dimension is crucial in integrating cinematic and video game elements into XR environments. Cinematic techniques—such as lighting, music, editing, visual storytelling, advanced visual effects, sound design, and spatial audio—are pivotal in creating immersive atmospheres that are both realistic and emotionally captivating. These elements also enrich virtual spaces, providing an authentic and dynamic aura. Similarly, video games contribute interactive narratives where user choices shape outcomes, along with dynamic feedback systems and sophisticated world-building techniques that foster expansive, navigable environments. These interactive storytelling methods engage users emotionally, making the experience more compelling and personal.

Spiritual engagement, often underrepresented in traditional educational frameworks, finds a unique avenue for exploration through XR. By integrating spiritual and philosophical elements into XR environments, educators can create experiences that transcend purely intellectual engagement, fostering a sense of connectedness and purpose. This integration aligns with the illuminationist tradition and perennial wisdom, which emphasise the interconnectedness of all things and the pursuit of deeper understanding and enlightenment. XR can therefore serve as a medium for spiritual exploration, enabling learners to engage with profound philosophical concepts and existential questions in an interactive and meaningful way (Aguayo, 2023).

Incorporating cultural and ethical considerations into XR-based educational projects is essential for creating inclusive and respectful learning environments. XR technologies offer unique opportunities to represent diverse cultural narratives and perspectives, promoting cultural awareness and sensitivity among learners. By immersing students in culturally rich XR environments, educators can facilitate a deeper understanding of different traditions, values, and worldviews, fostering empathy and global citizenship (Aguayo et al., 2023a).

Ethical considerations are equally important in the design and implementation of XR educational experiences. Ensuring that XR content is culturally responsive, accurate, unbiased, and respectful of all cultures is crucial for maintaining the integrity and effectiveness of the educational process. Developers must be mindful of cultural sensitivities and strive to authentically represent the cultures depicted, involving community members in the development process where possible. This collaborative approach not only enhances the authenticity of the content but also promotes mutual respect and understanding.

5.3.4.1. Rapua te Mārama

Embarking on the *Rapua te Mārama* project (2021-2022) was a pivotal moment in my PhD journey, marking a significant shift in how I integrated technical proficiency with cultural and philosophical depth. This project emerged from a collaboration with a team at the University of Auckland (UoA) and aimed to create an interactive experience that showcased the results of their study on Māori whānau experiences during the COVID-19 pandemic (Morgan et al., 2023; Moeke-Maxwell, Egan & et al., 2024; Moeke-Maxwell, Robinson, & Gott., 2024) while also presenting elements of Māori culture in a profound and engaging way.

The COVID-19 pandemic imposed unprecedented restrictions on the movement of New Zealanders. Many experienced the loss of loved ones during lockdown at Alert Levels 3 and 4, often without the opportunity to attend to those who had fallen ill due to social distancing guidelines as well as visitor bans in hospitals and aged care facilities. The weight of these experiences called for a medium that could convey the emotional and cultural nuances of these events, and XR technologies presented a unique opportunity to do so.

When I joined the project, the initial concept proposed by the clients—a team primarily composed of Māori members—was to create a straightforward virtual gallery. Reflecting on my journey and the philosophical insights I had gained, I felt compelled to propose an alternative that would offer a more immersive and meaningful experience. Drawing upon the 4E+ Cognition framework and my understanding of perennial wisdom, I suggested transforming the virtual gallery into an interactive island embodying the natural beauty and cultural significance of Aotearoa New Zealand.

This approach was not merely a subjective preference but a deliberate design choice aimed at addressing the project's core objectives more effectively. By creating an environment that users could explore freely, we fostered a deeper engagement with the material, allowing users to experience the narratives in a context that resonated culturally and emotionally. One of the significant challenges was ensuring cultural authenticity while integrating my own design perspectives. Collaborating closely with the UoA Māori team members, I learned about the importance of co-design and cultural sensitivity.

Technically, developing a dynamic and interactive island demanded meticulous attention to detail. I decided against using pre-designed assets, opting instead to create bespoke models of New Zealand's flora and landscapes. This decision, while time-consuming, was essential in capturing the unique essence of the environment and honouring the cultural significance of the natural elements.

The perennial wisdom approach, particularly the teachings of Rumi and Suhrawardi, profoundly influenced the project's conceptualisation. These philosophies emphasise inner illumination and the journey toward understanding, aligning with the project's aim to foster empathy and insight into Māori experiences during the pandemic.

Incorporating the 4E+ Cognition framework was central to our design, creating an immersive educational experience deeply rooted in Māori culture. Users navigated the virtual island using natural movements, embodying the experience and enhancing physical engagement with the environment. This embodiment allowed them to connect physically with the narratives, deepening their immersion. The island setting itself embedded the learning within a culturally rich context; by situating stories within significant natural landscapes, users appreciated the interconnectedness of the narratives and the environment. Active participation was encouraged as users made choices about which paths to follow and which gallery to explore, embodying enactive cognition through direct interaction and personal agency. The XR technology extended their cognitive capacities, enabling them to perceive a culturally immersive environment and interact with cultural narratives beyond physical limitations. Emotional engagement was further enhanced through traditional Māori music, chants, and visual symbolism, evoking emotional responses and fostering empathy—a key aspect of the affective dimension.

The *Rapua te Mārama* project directly addressed my main research question: How can integrating 4E+ Cognition and spiritual wisdom in eXtended Reality inform holistic experience and interaction design for enhanced cognitive, emotional, and spiritual

engagement? By integrating cultural wisdom and XR technology, the project demonstrated how immersive environments could facilitate deeper understanding and empathy.
The application of perennial wisdom and 4E+ Cognition provided a robust foundation for the design principles employed, ensuring that the XR experience was not only engaging but also culturally and philosophically meaningful. By creating an interactive island that users could explore, the XR environment became a living narrative, embodying cultural stories and values in a tangible and experiential manner.

Reflecting on the project's outcomes, I recognise both its successes and areas for improvement. The immersive island experience resonated deeply with users, who reported feeling a strong connection to Māori culture and a heightened understanding of the whānau experiences during the pandemic. The use of natural elements and seasonal changes enriched the experience, aligning with the cultural significance of nature in Māori traditions.

However, the project also highlighted challenges in balancing technical constraints with creative aspirations. Developing custom assets and ensuring high-performance graphics required significant resources and optimisation efforts. Additionally, ensuring accessibility across different devices without compromising the experience was an ongoing concern.

This project was a transformative experience for me personally. It allowed me to synthesise my technical expertise with my philosophical insights, moving beyond a purely Cartesian, modernist approach to one that embraced a more holistic perspective. The integration of illuminationist philosophy and concepts from Islamic mysticism, such as those articulated by Henry Corbin and Ibn Arabi, provided deeper layers of meaning to the project.

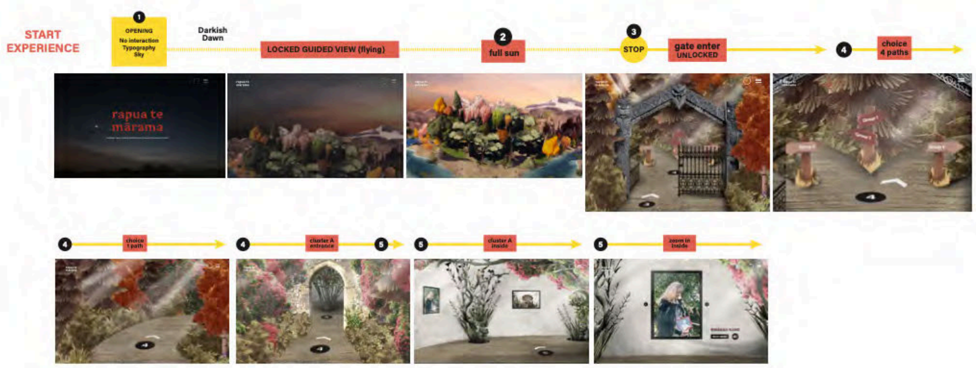
The idea of the Imaginal World, where symbols and metaphors manifest with tangible reality, resonated with the creation of the virtual island. Users could engage with spiritual truths through imaginative and visionary experiences, aligning with the Sufi journey of personal transformation and enlightenment.

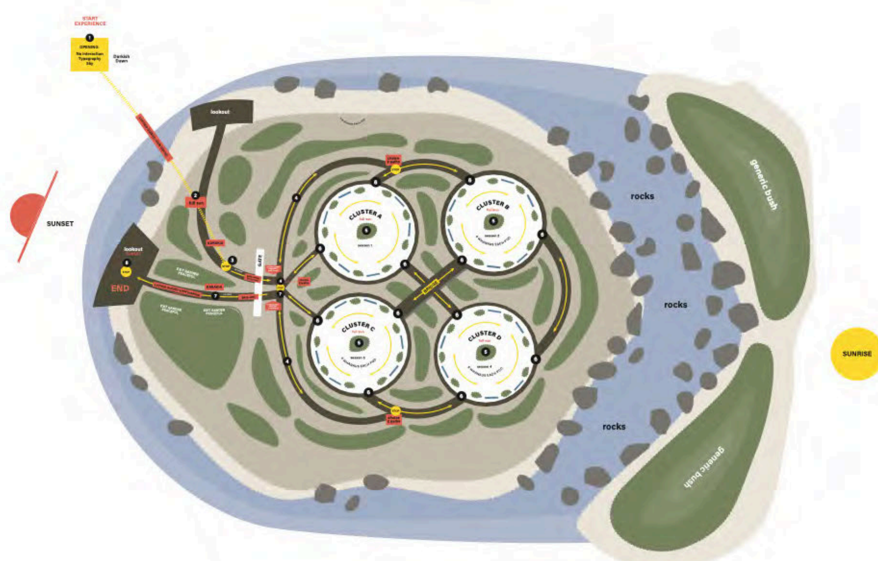
The *Rapua te Mārama* project exemplifies how XR technologies can be harnessed to create immersive, culturally rich educational experiences. By integrating the 4E+ Cognition framework and philosophical teachings, the project provided users with an environment that was not only informative but also transformative.

This endeavour demonstrated the effectiveness of the design process chosen, addressing the need to convey complex cultural narratives in an accessible and emotionally engaging manner. It balanced subjectivity and objectivity by grounding creative choices in cultural authenticity and user-centred design principles.

Moving forward, this project has reinforced the importance of integrating technical innovation with cultural sensitivity and philosophical depth. It has underscored the potential of XR technologies to serve as bridges between cultures, fostering empathy, understanding, and personal growth.

Each stage of the project was captured with photographs and screen recordings, each supplemented by thorough explanations of the methods employed and the surrounding context at the time. This visual record showcases the project's technical advancements and presents a narrative of its growth from a philosophical standpoint. I encourage you to explore more videos and photographs of the *Rapua te Mārama* project. On my website https://www.fablesofnaranj.com/portfolio/Rapua, you will find a comprehensive collection of visual materials that highlight the project's innovative XR environments and the immersive learning experiences they offer. Examples of this visual documentation are provided in Figures 5.37 to 5.45.





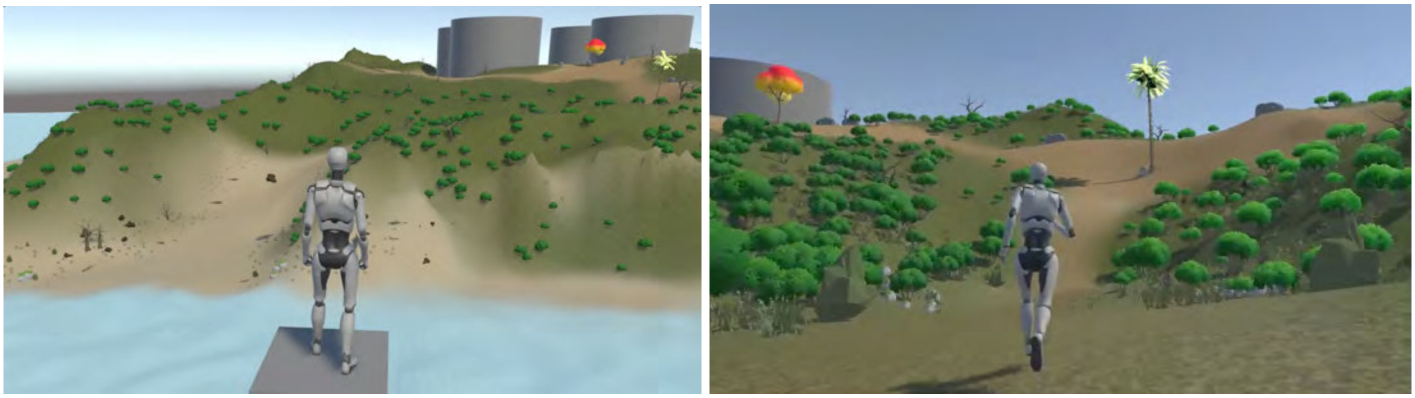
Figures 5.37 - Initial Environment Designs.

Note. Designed by Taheri & Tavares, Developed by Tavares & Taheri.

Copyright Ali Taheri, 2021.

Figures 5.38 - Trees and Foliage Native to Aotearoa.

Note. Over 100 native trees and foliages native to Aotearoa were prepared.



Figures 5.39 - Early Unity Project Progress.

Note. Designed by Taheri & Shirazi, Developed by Taheri.

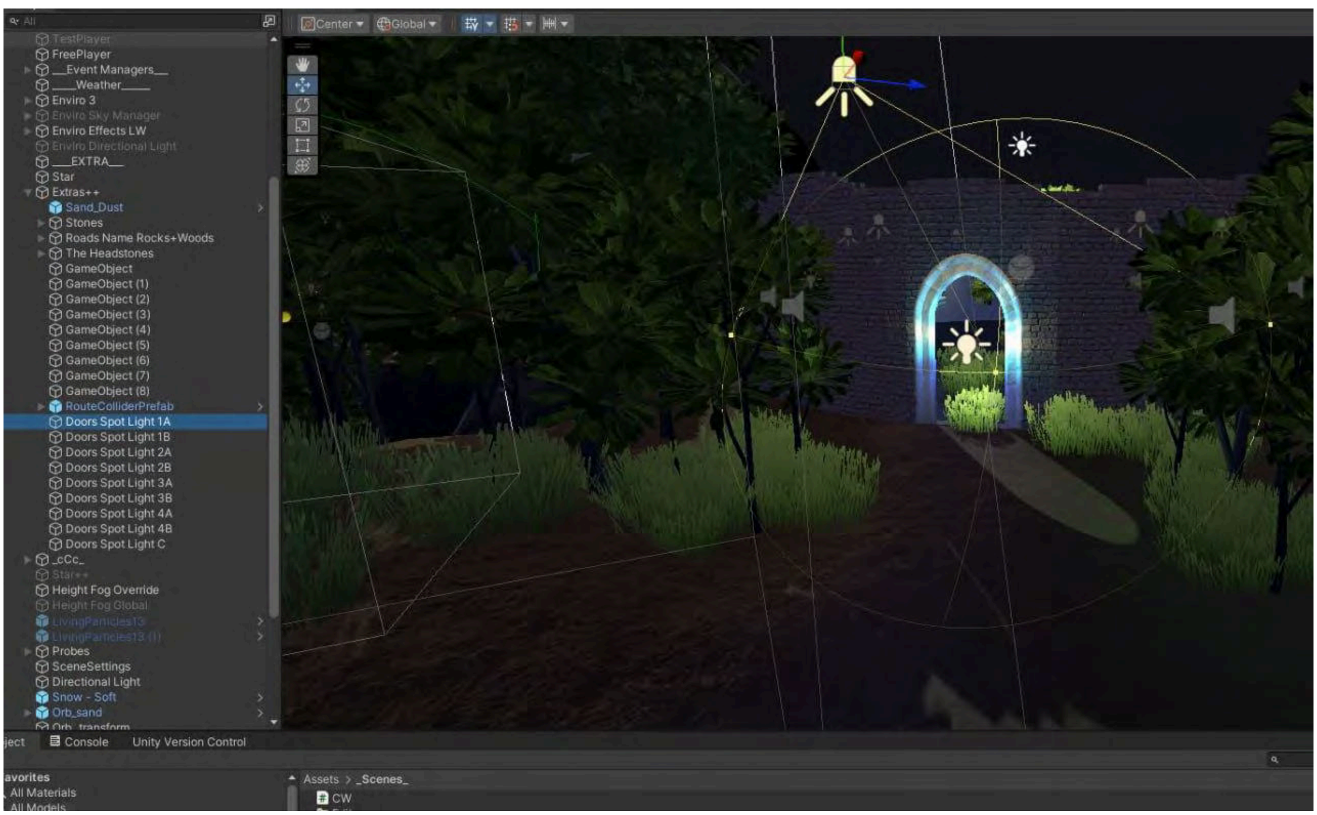


Figure 5.40 - Unity Project.

Note. Designed by Taheri & Shirazi, Developed by Taheri.

Figures 5.41 - Extended VR Version of the *Rapua* project.
Note. Designed by Taheri & Shirazi, Developed by Taheri & Jamali.
Copyright by Ali Taheri, 2023-2024.

Figures 5.42 - Various Environment of the Project.

Note. Designed and Developed by Taheri.

Figures 5.43 - The Galleries Environment.

Note. Designed and Developed by Taheri. Copyright by Ali Taheri, 2023-2024.

Figure 5.44 - Poster of the Interactive Experience.

Note. You can watch the trailer here: Rapua Te Mārama - Trailer

Designed by Taheri & Shirazi, Edited by Shirazi. Copyright by Ali Taheri, 2023-2024.

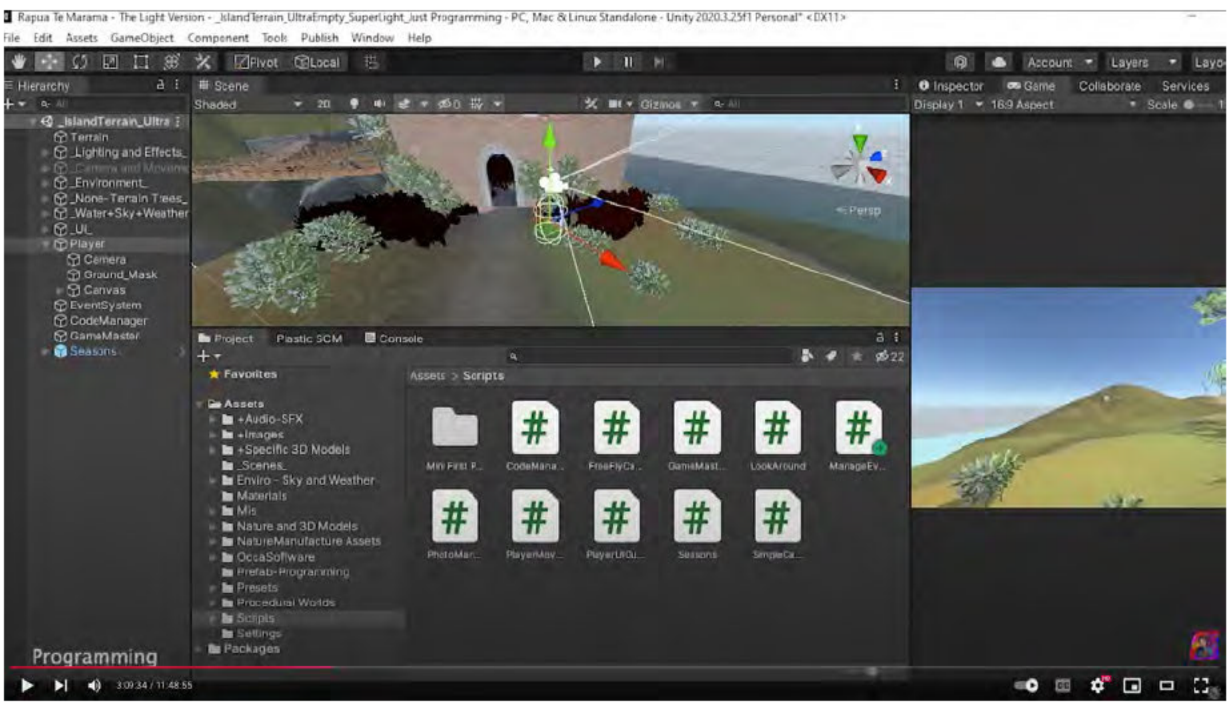


Figure 5.45 - The Making of *Rapua te Mārama*.

Note. You can watch the making of here: Rapua Te Mārama - Making of

Edited by Taheri, Copyright by Ali Taheri, 2023-2024.

Chapter 5, Section 5.3.4.2, redacted to preserve and maintain cultural tikanga, safety and integrity of the AUT Marae.

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Chapter 5, Section 5.3.4.2, redacted to preserve and maintain cultural tikanga, safety and integrity of the AUT Marae.

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Chapter 5, Section 5.3.4.2, redacted to preserve and maintain cultural tikanga, safety and integrity of the AUT Marae.

5.4. Extracted XR Design Principles for Designers and Developers

The development of design principles for XR has been a central objective of this research. Drawing from a diverse range of practical projects and theoretical frameworks, these principles aim to guide the creation of immersive, engaging, and meaningful XR experiences. This section consolidates the insights gained from practice-led research and theoretical explorations into a set of actionable guidelines for XR design, highlighting the key factors that contribute to effective and impactful XR environments.

Designing effective XR experiences involves a nuanced understanding of both technological possibilities and cognitive processes underlying human experience in immersive and XR environments. The integration of 4E+ Cognition and spiritual wisdom into XR design necessitates a set of guiding principles that ensure the creation of immersive, intuitive, and meaningful interactions. This section outlines the design principles derived from the practical and theoretical insights gained through the projects undertaken in this research. Integrating philosophical insights into XR design can significantly enhance the depth and meaning of the experiences, creating more profound and engaging interactions for users. Drawing from HCI philosophy, particularly embodied cognition, allows designers to create XR environments that are not only technically sophisticated but also deeply resonant on an experiential and existential level.

Embodied cognition emphasises the role of the body in shaping the mind, suggesting that cognitive processes are deeply rooted in physical interactions with the environment (Dourish, 2001). In the Pipi’s World project, embodied interaction was a fundamental design principle. Users navigated the virtual marine environments using natural gestures and movements, such as swiping to change directions or reaching out to interact with marine life. This physical engagement made the learning experience more intuitive and immersive, allowing users to connect bodily with the ecological narratives being presented. For instance, manipulating virtual objects like coral reefs or marine creatures required users to use hand motions that mirrored real-life interactions, thereby reinforcing the embodied nature of learning. This approach not only made the experience more engaging but also facilitated a deeper cognitive connection to the material, demonstrating the effectiveness of embodied interaction in educational XR applications.

Embedded cognition posits that cognitive processes are influenced by the physical and social environments in which they occur (Hutchins, 1996; Rietveld & Kiverstein, 2014). The NIWA AirBox project exemplifies this by situating air quality data within the users' immediate physical context. By leveraging AR technology, the project allowed students to visualize real-time air quality metrics overlaid onto their actual environment. For example, a student standing near a sensor could see dynamic visualizations of pollutant levels in the air around them, contextualizing abstract data within their immediate surroundings. This embedded approach made the scientific concepts more relevant and comprehensible, fostering a personal connection to environmental issues. Additionally, by integrating data from nearby instruments and comparing it with satellite remote sensing data, the project provided a holistic view of air quality, reinforcing the embedded nature of cognition by linking individual observations to broader environmental phenomena.

Enactive cognition highlights the importance of active participation and interaction in the construction of knowledge (Varela, Thompson & Rosch, 1991). In the *Rapua te Mārama* project, this principle was embodied through interactive storytelling and user-driven exploration of Māori whānau experiences during the COVID-19 pandemic. Users actively engaged with the virtual environment by making choices that influenced the narrative flow, such as selecting different paths to explore various aspects of whānau life or interacting with virtual characters to uncover personal stories. This active participation allowed users to construct their own understanding of the cultural and emotional impacts of the pandemic, rather than passively receiving information. For instance, users could choose to follow a whānau member through their daily routine, experiencing firsthand the challenges and emotional toll of isolation. This enactive engagement not only deepened users' empathy and understanding but also aligned with the project's educational objectives by promoting experiential learning through direct interaction.

Extended cognition involves the use of external tools and technologies to augment and extend cognitive capabilities beyond the individual's inherent capacities (Clark & Chalmers, 1998). The Digital Twin Robot project exemplifies this by integrating the HoloLens and Azure cloud services to create a seamless interaction between physical robots and their virtual counterparts. Users interacted with the robot through an AR interface that provided real-time data visualization and control functionalities. For example, users could issue voice commands or perform gestures to direct the robot's movements, while the HoloLens displayed augmented information about the robot's operational metrics and environmental data. This integration extended users' cognitive abilities by allowing them to perceive and manipulate data in ways that were previously inaccessible, enhancing their understanding of the robot's functions and the environmental conditions it monitored. Additionally, by enabling remote interactions and real-time data analysis, the project facilitated a more comprehensive and nuanced engagement with complex systems, demonstrating the power of extended cognition in enhancing user interaction and learning through XR technologies.

The Emotional dimension (the '+' in 4E+) acknowledges that emotions play a critical role in cognitive processes and user engagement, enhancing the overall impact of XR experiences. In the AUT Virtual Marae project, emotional engagement was meticulously integrated through the use of cinematic special effects (SFX) and spatial audio, creating an immersive and emotionally resonant environment. For instance, the virtual Marae featured dynamic lighting that shifted to reflect different times of day, coupled with ambient sounds that mirrored the natural environment, such as flowing rivers and traditional Māori chants. These elements evoked a sense of presence and connection, allowing users to emotionally invest in the virtual space. Additionally, narrative elements were woven into the experience, such as storytelling segments that highlighted the cultural significance of specific rituals and practices. By fostering an emotional connection, the project not only made the learning experience more engaging but also deepened users' appreciation and understanding of Māori culture. This integration of emotional elements exemplifies the extension of the traditional 4E framework into 4E+, highlighting the importance of affective cognition in creating meaningful and impactful educational XR applications.

In *Rapua te Mārama* and *AUT Virtual Marae* project, I incorporate spiritual and perennial wisdom into the XR design. This philosophical framework informed the creation of a virtual environment that not only preserved and showcased the culture but also facilitated a meditative and reflective user experience. By integrating symbolic elements such as dynamic lighting and ambient sounds that resonate with spiritual significance, the project creates a space where users can engage with cultural narratives on a deeper, more meaningful level.

Designing intuitive user interfaces in XR involves creating interactions that are easy to understand and use. This can be achieved by drawing on familiar gestures and natural interactions. Contextual relevance is crucial for maintaining user engagement and ensuring that XR experiences are meaningful. This involves designing scenarios and interactions that are directly applicable to the user's real-world experiences and socio-cultural context.

Multisensory engagement involves designing XR experiences that stimulate multiple senses, enhancing immersion and understanding. The *Rapua te Mārama* project employs visual, auditory, and tactile elements to engage users in marine conservation science, which makes the learning process more comprehensive and engaging.

Feedback and iterative design processes are essential for refining XR experiences. User feedback should be continuously incorporated to improve the design. The *NIWA Airbox* project used iterative design to develop an AR app that visualises air quality data, ensuring that the interface was intuitive and effective for young learners (Aguayo et al., 2021). Reflective practice in XR design involves continuously evaluating and reflecting on the design process and outcomes. This helps in identifying areas for improvement and ensuring that the design aligns with the theoretical frameworks. The

Rapua te Mārama project's reflective approach ensured that the interactive elements were continuously refined and user engagement was enhanced.

These design principles, derived from the integration of 4E+ Cognition and Spiritual Wisdom, provide a comprehensive framework for creating effective and meaningful XR experiences. By focusing on embodied interaction, intuitive UIs, contextual relevance, adaptive systems, multisensory engagement, ethical sensitivity, feedback, reflective practice, and philosophical insights, XR designers can create immersive environments that enhance learning and engagement. The projects undertaken in this research demonstrate the practical application of these principles, offering valuable insights into the evolving field of XR design. For more information see Table 5.1 which summarises of the design principles extracted from this research's practical projects:

Table 5.1 - Summary of the Design Principles

Design Principle	Description	Design Implications	The Practice and References
4E+ Interaction Design	4E+ Interaction Design focuses on creating interactions that are embodied, embedded, enactive, and extended. This approach prioritises the user's physical presence and movement within the XR environment, leveraging natural and intuitive gestures for interaction.	- Prioritise natural and intuitive gestures for interaction. - Incorporate haptic (physical or visual) feedback and sensory elements. - Design for physical movement and spatial awareness.	*Pipi's World*: Users interact with marine ecosystems, enhancing understanding through physical engagement (Aguayo, 2023; Aguayo & Eames, 2020).
Cultural Sensitivity and	Cultural Sensitivity and Ethical Considerations	- Collaborate with cultural experts and	*Rapua te Mārama* exemplifies this

Ethical Considerations	emphasises the importance of respecting and accurately representing cultural narratives and ethical standards in XR experiences. It involves the sensitive integration of cultural elements, ensuring that representations are authentic and respectful. It ensures XR experiences are respectful and inclusive of cultural narratives.	communities to ensure accurate representation and avoid cultural appropriation. - Include diverse perspectives and voices in the development process to create inclusive and equitable experiences. - Address ethical concerns, such as privacy and data security, to build trust and respect among users.	principle by creating an interactive XR experience that immerses users in the natural environment and exhibition of lived experiences of Māori whānau during the COVID-19 pandemic. The project was developed in close collaboration with Māori community members and cultural experts to ensure authenticity and respect for Māori traditions and values.
Intuitive and Cognitive Engagement	Intuitive and Cognitive Engagement focuses on designing XR experiences that are easy to navigate and understand while also stimulating the user's cognitive faculties. The goal is to create environments that are both user-friendly and intellectually enriching.	- Develop intuitive user interfaces that reduce cognitive load and facilitate ease of use. - Incorporate puzzles, challenges, or exploratory elements that engage users' cognitive abilities. - Use visual and auditory cues to guide users through the experience,	*Explora* demonstrates this principle by using augmented reality to present cultural artefacts and narratives in an engaging and accessible manner. The app's design encourages exploration and discovery, making learning about Chilean

		enhancing comprehension and retention.	heritage an interactive experience (Aguayo et al., 2020).
Adaptive and Responsive Environments (Autopoietic Environments)	Adaptive and Responsive Environments are designed to respond dynamically to user interactions and environmental changes. This principle is based on creating flexible and adaptable XR experiences that can evolve based on user input and contextual factors. This principle represents a characteristic of organic or autopoietic systems.	- Implement adaptive algorithms that personalise the experience based on user preferences and behaviours. - Design environments that respond to real-time data, such as biometric feedback or environmental sensors. - Ensure that the XR experience can adjust to different user contexts, such as varying levels of accessibility or expertise.	The *NIWA Airbox* project integrates real-time air quality data into an AR application, allowing users to visualise and interact with this information in a dynamic and engaging way. The app's responsiveness to real-world data exemplifies the potential for adaptive XR environments (Aguayo, 2023; Aguayo & Cochrane, 2019).
Narrative and Storytelling	Narrative and Storytelling is concerned with the power of storytelling to create compelling and immersive XR experiences. This principle involves constructing a narrative framework that guides the	- Develop a cohesive narrative that ties together various elements of the XR experience, providing context and purpose. - Use storytelling techniques, such as	The *Pipi's World* project uses a narrative-driven approach to teach users about marine conservation, with the character Pipi guiding them through various

	user's journey through the virtual environment, making the experience more engaging and meaningful.	character development and plot progression, to deepen user engagement. - Create multiple narrative pathways or branching storylines to allow for user agency and exploration.	ecological scenarios. This storytelling method helps contextualise scientific data within relatable stories, making the learning experience more impactful (Aguayo & Eames, 2020).
Heutagogical Learning and User Agency	This principle emphasises the importance of user-driven learning in XR environments. This principle supports self-directed learning where users have control over their educational journey, which fosters a sense of ownership and engagement.	- Design XR experiences that allow users to set their own learning goals and pace. - Include features that enable users to explore content non-linearly and according to their interests and curiosity. - Provide tools and resources within the XR environment that support self-directed learning and critical thinking.	*Pipi's World* and *Explora* were heutagogical in essence, and I would say that Rapua and Digital Marae also, but including some cultural tikanga restrictions in and out of the experience.

These holistic design principles, drawn from practical experiences and theoretical insights, provide a robust framework for developing future XR applications that are not only technologically innovative but also deeply connected to human cognition and cultural values.

Creating effective and engaging user experiences (UX), user interfaces (UI), and interaction designs (IxD) for VR, AR, and MR projects requires a comprehensive understanding of the unique characteristics and challenges of each medium. The following principles outline detailed considerations for designing immersive and interactive XR experiences across these platforms, integrating theoretical insights and practical examples (Table 5.2).

Table 5.2 - Detailed Design Principles and their Implications

Design Area	Design Principle	Description	Design Implications
UX Design	Consistency and Predictability	Ensure visual and interactive elements are uniform and reliable to build user familiarity and confidence.	Maintain a consistent visual style, use standard gestures and controls across the experience.
	User-Centred Design	Focus on the needs, behaviours, and preferences of users throughout the design process.	Conduct regular usability tests, design for accessibility and diverse abilities.
	Immersive Feedback	Provide immediate, contextually appropriate feedback for user actions.	Implement haptic feedback, visual and audio cues to confirm actions and guide users.
	Personalisation and Customisation	Allow users to tailor their experience to personal preferences and needs.	Implement customisable avatars, adjustable settings for comfort and preferences.
	User Journey Mapping	Design experiences that	Create clear onboarding

		guide users seamlessly from one activity to another.	processes, use storytelling elements to guide progression.
	Emotional Engagement	Design experiences that evoke emotional responses to enhance immersion and retention.	Use storytelling, character development, and emotionally charged scenarios to engage users.
	Prioritise Users' Comfort	Focus on designing experiences that are comfortable for prolonged use.	Consider ergonomics, avoid motion sickness, and ensure easy access to exits and rest areas.
	Do Not Overwhelm the User (Cognitive Overload)	Design experiences that are engaging but not overwhelming.	Balance complexity, provide clear objectives, and avoid excessive stimuli.
	Understand Physical Affordances	This involves recognizing and designing for the natural ways users interact with their physical environment and translating those interactions into the virtual space. This principle emphasises the creation of intuitive and seamless interactions in XR experiences.	The design must consider the user's physical interaction capabilities with the virtual environment, ensuring intuitive and natural interactions.
UI Design	Minimalist and Intuitive Interfaces	Keep UI elements simple and non-intrusive to maintain immersion.	Use transparent UI elements, display menus contextually to avoid obstruction.

	Spatial UI Placement	Strategically place UI elements in the user's field of view for accessibility and comfort.	Utilise head-tracked interfaces and integrate UI elements into the environment.
	Gesture and Voice Control Integration	Incorporate natural gestures and voice commands to enhance usability.	Implement hand-tracking and voice recognition for intuitive interaction.
	Dynamic UI Elements	Use UI elements that adapt based on user interaction and context.	Implement responsive UI components that change based on user actions and environment.
	Visual Hierarchy	Design UI with clear visual hierarchy to guide user attention.	Use contrast, colour, and size to highlight important elements and create a logical flow.
	Feedback and Confirmation	Provide clear feedback and confirmation for user actions to avoid confusion.	Use visual, auditory, and haptic feedback to confirm user inputs and actions.
	Use Cues to Help Users	Provide visual, auditory, or tactile cues to guide users through the experience.	Integrate subtle hints or prompts to help users navigate and understand the environment.
	Spatial Awareness in Design		Unlike 2D interfaces, XR design requires a deep understanding of spatial relationships and the user's position in a 3D space.

	Effective Use of Signifiers		Clear visual cues are crucial in guiding users to interact with the virtual environment correctly, especially when physical feedback is absent.
	User-centric Design Approach		The design process must prioritise the user's experience, anticipating and accommodating their needs, capabilities, and expectations.
IxD	Body Interactions	Design interactions that encourage physical movement and spatial awareness.	Create experiences that require full-body movements and anchor digital objects in real-world spaces.
	Contextual Interactivity	Tailor interactions to the context and environment for realism.	Adapt digital content based on real-world context and design scenario-specific interactions.
	Multi-Sensory Engagement	Engage multiple senses to create a richer, immersive experience.	Integrate spatial audio, experiment with haptic visuality.
	Social Interactions	Design for social engagement, allowing multiple users to interact within the XR environment.	Implement multi-user functionality, support for social cues, and collaborative tasks.
	Real-World Integration	Blend virtual and physical elements to create a seamless mixed-reality	Use AR to overlay digital information on real-world objects and environments.

		experience.	
	Scalability and Flexibility	Ensure that interactions can scale across different devices and contexts.	Design interactions that work on various platforms, from VR headsets to mobile AR applications.
	Flexible Interactions and Environments	Create interactions and environments that can adapt to different user preferences and contexts.	Design flexible settings and adaptive content that can change based on user input and environmental conditions.
	Organise the Spatial Environment	Arrange virtual and physical spaces to maximise efficiency and user comfort.	Structure spaces to minimise user movement, optimise navigation, and ensure easy access to key elements.
	Allow Users to Feel in Control	Empower users by providing them with choices and control over their experience.	Offer customisable settings, easy-to-use navigation, and clear options for interaction.
	Allow for Trial and Error	Encourage exploration and experimentation without fear of failure.	Design safe environments where users can experiment with different actions and learn from their mistakes without significant consequences.
	Build Upon Real-World Knowledge	Utilise familiar real-world elements to aid user understanding and immersion.	Integrate realistic physics, recognisable objects, and intuitive controls that reflect real-world counterparts, making the virtual environment more relatable.

Table 5.2 provides a comprehensive overview of detailed design principles and their implications, summarising the robust framework for developing effective and engaging XR experiences that was developed in this study.

The next table (Table 5.3) provides a comprehensive overview of the practical design principles for XR projects, focusing on key areas such as user guidance, object interaction, visual design, user comfort and safety, and interaction models. By following these guidelines, designers can create intuitive, engaging, and effective XR experiences that are both user-friendly and technically sound.

Table 5.3 - Practical Design Principles for XR Projects

Design Aspect	Design Principle	Description	Implementation Guidelines
Guiding the Users	Visual Markers	Use visual markers to guide user interactions and indicate selectable objects.	- Use clear, distinct markers. - Ensure markers are easily visible in various lighting conditions. - Implement markers for both object selection and navigation.
	Exploration	Encourage user exploration through intuitive design.	- Utilise animations, sprites, and scripting to create engaging visuals. - Simplify actions and feedback to encourage interaction. - Use large-sized objects for better engagement.
Object	Scaling and	Maintain user	- Adjust the virtual camera's

Interaction	Positioning	experience when objects scale up or down.	distance accordingly. - Ensure scaling is smooth and intuitive. - Allow users to maintain perspective and control.
	Object Selection	Enable users to select objects intuitively.	- Implement tap-to-select functionality. - Provide visual cues for selected objects. - Allow for object manipulation through gestures like dragging and moving.
	Object Movement	Facilitate intuitive object movement.	- Allow dragging by pressing and holding. - Implement smooth and responsive dragging mechanics. - Use natural gestures for interaction.
	Object Scaling	Enable intuitive scaling of objects.	- Use pinch gestures with two fingers for scaling. - Ensure scaling feels natural and proportional. - Provide feedback for scaling actions.
	Tooltip Enhancement	Enhance user information access	- Scale tooltips based on camera proximity.

		through tooltips.	- Provide more detailed information when closer to the object. - Ensure tooltips are non-intrusive.
Visual Design	Visual Cues and Representation	Use visual cues to aid understanding and navigation.	- Use curved lines and other visual aids to represent differences (e.g., weight in 3D models). - Implement analogies like a fishing rod for navigation cues.
	Minimal UI Design	Avoid overwhelming users with excessive UI elements.	- Focus on a minimalistic design. - Ensure clarity and simplicity in UI layout. - Provide essential controls and information only.
	Holographic Frame	Consider how users perceive overlaid content.	- Understand how users see content in the real world. - Ensure overlay content aligns with real-world contexts.
	Coordinate Systems	Position holograms meaningfully.	- Position holograms with real-world anchors. - Use physical surfaces for spatial mapping.
	Spatial Mapping	Anchor objects in the	- Utilise the physical

		user's world.	environment for context. - Ensure objects are well-integrated into the real world.
	Hands and Motion Controllers	Enable close-range and long-range interactions.	- Use hands for close-range interactions. - Implement precise controls for long-range interactions. - Provide a seamless transition between interaction ranges.
Interaction Models	Voice Input	Integrate voice commands for control.	- Use voice commands for hands-free interaction. - Ensure accurate and responsive voice recognition. - Provide clear voice command options.
	Eye Tracking	Utilise eye-tracking for enhanced interaction.	- Use gaze information for context-aware interactions. - Implement eye-tracking for selection and focus.
	Common Controls and Behaviours	Standardise frequently used interactions.	- Implement standard UI elements and controls. - Ensure familiarity and ease of use. - Create a consistent user experience across applications.

	Colour, Light, and Materials	Design with visual quality in mind.	- Consider colour, lighting, and material properties. - Ensure assets are visually appealing and contextually appropriate.
	Object Scale	Use real-world visual cues.	- Help users understand object size and material. - Ensure consistent scaling across objects.
Sound & Audio Design	Spatial Audio and Sound Effects	Utilise spatial audio for immersive experiences.	- Use sound cues to draw attention and provide context. - Implement ambient sounds to enhance immersion.
	Specific Sound Effects	Use real-world sounds for more natural interactions.	- Employ sounds, for e.g., for door openings, to direct user focus. - Use voice and musical notes to enhance the experience.
Technical Considerations	Device-Specific Design	Design around the capabilities and limitations of the hardware.	- Consider device-specific features and constraints. - Optimise for different platforms like HoloLens, Oculus, and mobile devices.
	Real-Time Data Integration	Use real-world data to influence virtual environments.	- Integrate IoT devices and sensors for real-time data updates.

			- Use data to dynamically adjust virtual conditions and interactions.
Advanced Interaction	Mixed Reality Framework	Leverage MRTK, LeapMotion SDK, and embedded systems for interaction design.	- Create natural and intuitive interactions using mixed reality frameworks. - Implement proximity and intersect shaders for enhanced interactivity.
	Puppeteering and Puppet Control	Use puppeteering concepts for creative control mechanisms.	- Allow users to manipulate virtual objects as if they were puppets. - Implement puppet-in-puppet mechanisms for complex interactions.
User Experience	Compelling Experiences	Create engaging and immersive experiences that captivate users.	- Use storytelling and narrative techniques to enhance engagement. - Ensure a cohesive and compelling user journey throughout the experience.
	Customisation and Personalisation	Allow users to customise their experience.	- Provide tools for users to modify their environment. - Encourage personalisation to increase user engagement and satisfaction.

The following Table (Table 5.4) describes principles that were designed to provide a holistic approach to XR design, ensuring that experiences are not only technically sound but also immersive, intuitive, and user-centred. They emphasise the importance of considering the unique aspects of XR technology and human perception in creating compelling and effective interactions.

Table 5.4 - Holistic Approach to Design Principles for XR Projects

Design Principle	**Description**	**Implementation Guidelines**
Spatial Computing Mindset	Adopt a holistic view of the XR experience, considering the unique capabilities and limitations of VR, AR, and MR.	- Avoid merely porting content from other media. - Focus on creating experiences that leverage the full potential of spatial computing.
Consider Human Perception of Reality	Design experiences that align with how the human brain perceives and interprets sensory information. 4E+ frameworks is an example of such a type of consideration of human perception of reality.	- Use sensory information (visual, auditory, etc.) to create convincing virtual environments. - Consider proprioception and other sensory inputs.
Real-World Integration	Blend virtual elements seamlessly with the real world to enhance the user's perception of reality.	- Use real-time data integration to reflect real-world changes in the virtual environment. - Ensure smooth transitions between physical and digital realms.

Locomotion and Movement	Design intuitive and comfortable locomotion methods for navigating virtual spaces.	- Implement teleportation, room-scale movement, and other techniques to minimise motion sickness. - Ensure fluid movement and control options.
Proprioception and Body Awareness	Enhance the user's sense of their own body within the virtual space.	- Use techniques like inverse kinematics to track and display the user's body in VR. - Design interactions that reinforce body awareness.
Hybrid Interaction Models	Combine kinematic and physics-based interactions to create a more dynamic and responsive experience.	- Use kinematic models for simple, fast interactions. - Implement physics-based models for tasks requiring realism and precision.
Trick the Brain	Use neuroscientific techniques to enhance immersion and user experience.	- Employ techniques like the rubber hand illusion to create a sense of presence. - Explore the limits of sensory manipulation to maintain immersion.

5.5. Reflecting on Challenges and Opportunities

Immersive experiences in XR present a multitude of opportunities, however, the journey to harnessing these potentials is fraught with challenges that must be addressed to realise their full impact. XR presents a unique set of challenges and opportunities that significantly influence the design and implementation of educational technologies. This section explores these dynamics, providing an in-depth analysis of how immersive XR environments can enhance user experience while addressing the inherent obstacles in their development and deployment.

Indeed, one of the foremost challenges in creating immersive experiences in emerging media is innovation itself. As new technologies emerge with novel affordances, we often find ourselves in uncharted territory, developing tools and experiences without an established frame for comparison or reference, emphasising the importance of theoretical guidelines to follow. The need to conceptualise and build experiences that take full advantage of XR's unique capabilities, such as spatial computing and embodied interaction, requires us to think beyond traditional design paradigms. Additionally, the cost of XR equipment, such as VR headsets and AR devices, not to mention technical development costs, can prevent potential users from accessing the technology, particularly in educational settings where budget constraints can hinder widespread adoption.

Another significant challenge is the design of intuitive user interfaces that facilitate seamless interaction within immersive environments. Traditional interaction paradigms, such as keyboard and mouse inputs, are often inadequate in XR contexts. Instead, designers must develop novel interaction techniques, such as gesture control and eye-tracking, which can provide a more natural and engaging user experience. However, these technologies are still in their nascent stages and require substantial refinement to be effectively integrated into educational tools.

The UX design also poses a considerable challenge in XR environments. Designing intuitive and user-friendly immersive interfaces is crucial for fostering engagement and ensuring that users can navigate and interact with digital content effectively. This involves understanding the cognitive and perceptual processes of users and designing XR experiences that are both immersive, intuitive, and easy to use. This challenge is increased within cross-cultural audiences, given the divergent types of audience groups in terms of culturally and socially determined cognitive frameworks, and underlying meaning-making processes (Aguayo, 2014; Menzel & Bögeholz, 2009).

For example, the *AUT Virtual Marae* project exemplifies this challenge as it seeks to recreate a culturally significant and meaningful space in a virtual environment. To achieve this, the project had to balance the technical requirements of creating a realistic 3D model with the need to provide an accessible and meaningful user experience that respects and conveys the cultural significance of the Marae – a traditional meeting house in Māori culture.

Furthermore, XR technologies facilitate experiential and situated learning, which are critical components of the 4E+ Cognition framework. For instance, users can explore detailed 3D models of historically relevant locations and artefacts, listen to stories narrated by local experts, and more. Such multisensory engagement creates an immersive experience that goes beyond passive observation. By allowing users to physically interact with these digital elements, the project fosters a sense of presence and connection, making the cultural content more relatable and memorable. This embodied interaction aligns with the 4E+ Cognition framework as it involves the entire body in the learning process, enhancing comprehension and retention through physical and emotional engagement.

Furthermore, the insights presented by Taheri and Aguayo (2021) significantly enhance the framework of embodied immersive design for experience-based learning and self-illumination. They critique the traditional, reductionist educational paradigms that have long dominated Western education, advocating instead for a holistic, multidisciplinary approach that resonates with the 4E+ Cognition framework. By emphasising embodied cognition and enactive learning, Taheri and Aguayo (2021) highlighted the importance of integrating ethical and critical philosophical dimensions into immersive technologies such as VR. Their argument underscored the necessity of creating learning environments where users engage with content through direct, bodily experiences rather than solely through abstract concepts. This approach not only fosters a deeper emotional and physical connection to the material but also promotes self-driven illumination, allowing learners to construct knowledge through personal and experiential interactions. Consequently, Taheri and Aguayo's (2021) perspectives complement and reinforce the notion that immersive, embodied interactions are essential for meaningful and lasting educational experiences, aligning seamlessly with the principles of 4E+ cognition.

Moreover, the philosophical principles derived from the spiritual dimensions of perennial wisdom, particularly the concept of enlightenment through experiential knowledge, can further enrich XR educational tools. XR can be used to illuminate complex cultural and environmental phenomena, making them more comprehensible and impactful for audiences/learners. I exercised this interaction in the Rapua te Mārama project, where the project uses XR to immerse users in the lived experiences of Māori whānau, fostering empathy and insight through direct engagement with cultural narratives pertaining to the COVID-19 Pandemic context.

5.5.1.Looking Back

Perfectionism has been a double-edged sword in my life. On the one hand, it has been this incredible driving force that pushes me to always aim for the highest standards. It is like having this inner voice that constantly whispers, '*You can do better'*. In truth, that inner voice has guided me to create some truly remarkable work. I remember diving into projects, whether it was a complex research question or a technical challenge, and just losing myself in the details. I would explore every angle, leave no stone unturned, and the result would often be something I was genuinely proud of. That pursuit of excellence has definitely made me a more disciplined and committed person.

But on the other hand, perfectionism also has a dark side. IIt can feed the relentless pursuit of an unattainable ideal, and that is where things can go wrong. I have found myself stuck in an endless loop of tweaks and revisions, obsessing over every little detail, trying to make everything flawless. It is like you are chasing this mirage, and no matter how close you get, it never feels good enough. There were times when I would delay finishing a project because I was so fixated on perfecting it. That need for everything to be just right often led to procrastination, not because I was lazy, but because I was afraid of falling short of those impossibly high standards I had set for myself.

This drive for perfection can also turn into a form of self-sabotage. I would spend so much time on endless loops of tweaks, sometimes losing sight of the bigger picture. And let us not even get started on self-criticism. The bar was always set so high that anything less felt like a failure. It did not matter if others thought the work was great; if I saw a flaw, it would eat at me. That pressure to meet these self-imposed standards has been exhausting, and it drained me at times both mentally and emotionally.

Looking back, I realise how important it is to find a balance. Perfectionism is not all bad; it has helped me grow and achieve a lot. But I have also learned the hard way that sometimes, good enough is what I should be after. It has been a journey of learning to let go, to understand that perfection is an illusion, and to accept that sometimes the best thing you can do is to move forward. It has been about finding peace with imperfection and knowing when to call it a day. And that, more than anything, has been a liberating lesson.

Channelling perfectionism properly has been a journey of self-awareness and acceptance. I realised that the key was not to eliminate my drive for excellence but to harness it in a way that was constructive rather than destructive. I started by setting more realistic goals and timelines for myself. Instead of getting caught up in the minutiae, I focused on what truly mattered—the core aspects of my projects that would make a real impact.

5.5.2. Lessons Learnt

One of the biggest changes I made was embracing the concept of iteration. Instead of aiming for a flawless final product from the get-go, I began treating my projects as works in progress. This shift in mindset allowed me to release my work at different stages, gather feedback, and then refine it based on real-world input. It was liberating to know that I did not have to get everything right on the first try. This approach not only helped me manage my time better but also made the whole process more dynamic and engaging.

Another crucial step was learning to prioritise. I started to distinguish between what was important and what was simply a perfectionist's quirk. This meant letting go of the obsession with every minor detail and instead focusing on the elements that would truly make a difference. It was about understanding that not every aspect of a project required the same level of scrutiny. Some things just needed to be good enough, and that was perfectly okay.

I also leaned into collaboration. Working with others helped me see the value of different perspectives and approaches. It taught me that perfection does not mean doing everything by myself or in a particular way. By opening up to feedback and trusting my peers, I found that the end results were often richer and more well-rounded than what I could have achieved alone. This collaborative spirit not only enhanced the quality of the work but also made the experience more enjoyable and less isolating.

In embracing these changes, I found a sense of peace and satisfaction that I had not experienced before. It was not about lowering my standards but about being kinder to myself and more practical in my approach. I learned to celebrate progress rather than obsess over perfection. This shift allowed me to move on from projects with a sense of accomplishment rather than lingering doubt and dissatisfaction.

As I moved forward, I continued to channel my perfectionism in ways that fuelled growth and creativity rather than hindering them. I became more confident in my ability to produce quality work without the constant need for it to be perfect. It was a lesson in balance—knowing when to push for excellence and when to let things be. This newfound perspective not only improved my work but also enriched my life, allowing me to focus on the bigger picture and enjoy the journey.

5.6. Final Thoughts on the Research Journey

Reflecting on the research journey undertaken in this PhD, it is essential to acknowledge the intricate interplay between theoretical insights and practical applications in the realm of XR. This research has sought to explore the harmonious integration of 4E+ Cognition and Ishraq hikmah-philosophy within XR, providing a comprehensive understanding of how these frameworks can inform and enhance embodied interaction experience design.

The core findings of this research emphasise the transformative potential of XR technologies when grounded in robust theoretical foundations. By integrating 4E+ Cognition—comprising embodied, embedded, enactive, and extended cognition along with the affective dimension—with Ishraq hikmah, this study has demonstrated how XR can create immersive, meaningful, and intuitive experiences. The application of these principles has been validated through various projects, such as *Pipi's World* and *Explora*, which highlight how XR can be employed to enhance ecological literacy and cultural appreciation (Aguayo & Eames, 2020; Aguayo et al., 2020).

One of the significant contributions of this research is the development of a set of design principles that bridge the gap between abstract theories and practical design. These principles provide a roadmap for XR designers to create experiences that are not only technologically advanced but also deeply resonant with human cognitive and emotional processes. The emphasis on embodied interaction, intuitive UIs, and adaptive systems ensures that XR experiences are engaging and meaningful.

The implications of this research for the future of XR and interactive design are far-reaching. By demonstrating the practical applications of 4E+ Cognition and spiritual perennial wisdom, this study provides a framework for developing XR experiences that are not only immersive but also cognitively and emotionally engaging. This approach has the potential to revolutionise educational, cultural, and environmental applications of XR, making complex concepts more accessible and engaging for diverse audiences.

Furthermore, the emphasis on ethical and cultural sensitivity in XR design underscores the importance of creating inclusive and respectful digital environments. Projects like the *AUT Virtual Marae* serve as a model for how XR can preserve and promote cultural heritage while fostering a deeper connection with cultural practices and values.

Throughout this research journey, the iterative process of designing, testing, and refining XR experiences has highlighted the dynamic relationship between theory and practice. Each project has provided valuable insights into the practical challenges and opportunities of applying theoretical frameworks to XR design. Engaging in real-world projects has been particularly beneficial, as it allowed for the application of academic concepts in tangible settings, facilitated direct user feedback, and exposed me to diverse real-world constraints and requirements. This hands-on experience enhanced my problem-solving skills and ensured that the theoretical models were grounded in practical applicability. The reflective practice adopted in this research has enhanced the quality of the XR experiences and also contributed to a deeper understanding of how these experiences can impact users cognitively and emotionally.

This chapter has traversed the practical landscape of XR design, critically examining the interplay between theory and practice. Through a reflective analysis of visual design, interaction design, sound design, and the technical aspects of XR, we have uncovered the nuanced ways in which theoretical principles inform and are manifested in XR experiences. The exploration of embodied interaction design and the gamification of cultural heritage further illustrates the multifaceted potential of XR as a tool for education, engagement, and exploration. As we continue to push the boundaries of what is possible in XR, the insights gained from this practice-led research contribute to a deeper understanding of the medium's capabilities and its transformative potential.

The critical commentary on these XR projects illustrates the profound connection between philosophical principles, particularly those derived from Ishraq hikmah-philosophy, and the practical design and implementation of XR experiences. Each project serves as a testament to the potential of XR to bridge the gap between abstract theoretical concepts and tangible, immersive experiences. Through the lens of 4E+ Cognition and spiritual knowledge, these projects not only advance our understanding of XR technologies but also enrich our engagement with the world around us, highlighting the indelible link between theory and practice in the realm of XR design.

In conclusion, while the development and implementation of immersive XR experiences present significant challenges, the opportunities they offer for enhancing education and engagement are vast. By addressing the technological, accessibility, and UX design challenges, we can harness the full potential of XR to create transformative learning experiences. This section has highlighted how various projects have navigated these challenges, providing valuable insights for future XR developments. The dynamic interplay between theory and practice in these projects underscores the importance of a transdisciplinary approach, integrating technological innovation with cognitive and philosophical insights to create meaningful and impactful XR experiences. The findings in this research highlight the potential of XR to create immersive, intuitive, and meaningful experiences that bridge the gap between abstract theories and real-world applications. As XR technologies continue to evolve, the principles and insights gained from this research can be used as a guiding framework for future innovations, ensuring that XR remains a powerful tool for education, cultural preservation, and cognitive engagement.

Chapter 6: Conclusion

This research has journeyed through the intricate intersections of technology, philosophy, and art, culminating in an exploration of how eXtended Reality (XR) can be designed to resonate deeply with human experience, cognition, culture, and spirituality. By integrating the principles of 4E+ Cognition and Illuminationism into the design of XR experiences, this study has ventured into uncharted territories of Human-Computer Interaction (HCI), offering new insights into the potential of human-centred interaction design. This practice-oriented research has been informed by a diverse range of philosophical, cultural, and technological perspectives, each contributing to a nuanced understanding of how XR can be used to create meaningful, immersive experiences.

In this concluding chapter, I revisit the key contributions of my research, explore the limitations and potential avenues for further study, reflect on the personal and academic impact of my journey, and discuss the broader significance of the findings for the fields of HCI, XR, and beyond. By synthesising the insights gained throughout the research, this chapter aims to provide a comprehensive overview of the study's achievements and its implications for the future.

6.1. Contributions

This research has made targeted contributions to the fields of XR and HCI by developing and applying a novel framework that integrates the holistic principles of Illuminationism and 4E+ Cognition into the design of immersive digital experiences. The central premise of this study—that technology, when informed by ancient wisdom and contemporary cognitive science, can enhance human interaction with and experience of the digital world—has been rigorously explored and validated through a series of theoretical and practical investigations.

One of the most significant contributions of this research is the development of the Ishraqi Heuristic Methodology. This methodology, which synthesises the intuitive, experiential approach of Suhrawardi's Illuminationism with Moustakas' heuristic inquiry, offers a new way of approaching design in the context of XR. It emphasises the importance of lived experience, intuitive insight, and active participation, providing a robust framework for creating XR environments that are both intellectually and spiritually enriching. This approach has been practically applied in various projects developed at AUT's AppLab, where the theoretical insights gained from the study were translated into tangible digital artefacts.

The research also makes a substantial contribution to the understanding and application of the 4E+ cognitive framework in the context of XR. By integrating these principles into the design process, the study has demonstrated how XR can be used to create experiences that purposely attend to and target the embodiment of users through culturally-embedded and technologically-extended enacted and affective interactions. XR can engage users on a deep cognitive level, fostering a more holistic understanding of interaction. The projects explored in the study, such as *NIWA Air Box* and *Rapua te Mārama*, exemplify how these principles can be effectively applied to create educational and culturally responsive XR environments.

Another key contribution of this research is its challenge to reductionist paradigms within HCI. Traditional approaches to HCI often focus on breaking down complex systems into simpler components, prioritising efficiency and control over holistic engagement. This study, however, advocates for a more integrated approach that recognises the interconnectedness of knowledge, experience, and cultural context. By incorporating philosophical insights from Cybernetics, 4E+, Neoplatonism, and Illuminationism, the research proposes a framework for HCI that is technically sophisticated and also deeply attuned to the complexities of human cognition and cultural heritage.

The practical contributions of this research are also noteworthy. Through the development of digital artefacts and the application of the Ishraqi Heuristic Methodology, the study has provided concrete examples of how XR can be used to enhance cultural preservation, educational practices, and creative industries. These artefacts serve as a blueprint for future XR design, offering a model for how technology can be used to create experiences that are both immersive and culturally meaningful.

In summary, this research has made significant contributions to the fields of XR and HCI by developing a novel framework for design that integrates ancient wisdom with modern cognitive science. It has provided new insights into how XR can be used to create meaningful, immersive experiences that are intellectually and spiritually enriching, offering a blueprint for future research and practice in these fields.

6.2. Limitations

While this research has offered valuable contributions to the fields of XR and HCI, particularly through the integration of 4E+ Cognition and Spiritual Wisdom into XR design, several limitations must be acknowledged to provide a comprehensive and critical understanding of the study's scope and boundaries. These limitations primarily stem from the complexity of synthesising diverse philosophical, cognitive, and technological frameworks, the inherent subjectivity of the methodologies employed, and practical challenges encountered during the research process.

Methodological Constraints: The study employed a holistic and transdisciplinary methodology, blending philosophical insights with cognitive science. While this approach enriched the research, it introduced complexities in maintaining methodological coherence and balance. The synthesis of diverse disciplinary perspectives required meticulous planning and extensive expertise, which may have limited the depth with which each individual discipline was explored.

Another methodological limitation arose from the challenge of integrating 4E+ Cognition with Ishraq Hikmah through a common frame of reference. To address this, the research employed Neoplatonism as a unifying conceptual bridge, providing a common ground that aligned ancient philosophical traditions with modern cybernetics and cognitive approaches. This solution, while effective, required carefully navigating and adapting concepts across vastly different epistemological domains, which may have impacted the interpretative precision of each framework. Future studies could further investigate this integration, examining how alternative frameworks might serve as similarly effective but potentially more nuanced common grounds.

Complexity and Scope: The transdisciplinary approach adopted in this research, while innovative, also posed challenges in maintaining coherence across multiple domains. Achieving methodological consistency and ensuring that each discipline was adequately represented necessitated a high level of expertise. Given the ambitious scope of this research, there was a risk that certain nuances from each discipline, particularly those of philosophical traditions, may have been oversimplified or diluted during my review of contextual knowledge, in the discussion of the research design, and in the account of their practical application. Future studies could benefit from collaboration with specialists in each field to ensure a deeper engagement with the theoretical frameworks employed.

Subjectivity in Heuristic and Methods: The reliance on heuristic inquiry methods introduced a degree of subjectivity, potentially affecting the objectivity and reproducibility of the findings. Personal introspection and the researcher's deep philosophical engagement could have inadvertently influenced the interpretation of results, despite efforts to maintain reflexivity and transparency. These methods rely heavily on my personal experiences and introspection, which can lead to biases in interpretation and analysis. Although reflexivity and transparency were employed to mitigate these effects, the findings may still reflect a subjective lens. Future research could incorporate additional external validation methods, such as participant triangulation, to balance the personal insights gained through with broader, more generalisable perspectives.

Scope and Generalisability: The practice-oriented nature of the research, conducted primarily within Auckland University of Technology's AppLab, presents limitations in terms of generalisability. The projects developed and tested in this specific institutional and cultural context may not fully represent diverse settings or user populations. As a result, the applicability of the design principles and frameworks developed may be constrained when extended to different cultural or geographic environments. Future studies should consider broader participant demographics and multiple institutional settings to enhance the generalisability of the findings; and, transferability studies to explore how design principles from this study can be transferred, adapted, and applied within other contexts and settings.

Practical Challenges in Translating Theory into Application: A significant limitation arose from the practice-oriented nature of the research, which sought to apply complex theoretical concepts, such as 4E+ Cognition and Illuminationist epistemology, within real-world XR projects. Translating these concepts into functional, immersive experiences within the confines of available XR technology proved to be resource-intensive and required multiple iterations. The iterative nature of design-based research often led to time and resource constraints, making it difficult to fully explore all theoretical concepts in practical applications. This limitation highlights the need for future studies to allocate sufficient time and resources for the iterative testing and refinement of theory-driven XR designs.

Ethical and Cultural Sensitivity Balancing: Ensuring cultural sensitivity and avoiding the misrepresentation or appropriation of ancient philosophical traditions was a critical consideration in this research. Balancing the integration of diverse cultural insights with ethical design practices remains a complex task. Developing comprehensive ethical guidelines to safeguard user privacy, autonomy, and cultural heritage in XR environments is essential for responsible technological innovation.

Cultural and Contextual Generalisability: While this research emphasised cultural sensitivity and sought to integrate diverse philosophical perspectives, the findings may be contextually limited. Although the study focused on designing culturally resonant XR environments, future research should explore how these principles can be adapted and tested across broader cultural groups. Ensuring the general applicability of the findings requires further investigation into how these design principles might resonate with other cultural perspectives and philosophies.

Scalability of Design Principles: The design principles formulated in this study were tested within specific projects at AppLab. Scaling these principles to larger or more diverse user bases may present practical challenges, including resource constraints and varying user needs. The transferability of the principles to different contexts requires further investigation to ensure their effectiveness and adaptability in broader applications.

Technological Limitations: The research faced constraints imposed by the current state of XR technologies. While the field of XR is rapidly evolving, some of the technological tools and platforms available during the research may not have been sufficiently advanced to fully realise the immersive and interactive potentials envisioned by the theoretical frameworks. Limitations in hardware capabilities, software features, and user interface designs sometimes restricted the level of embodied interaction and spiritual engagement that the research aimed to foster. As XR technology continues to develop, future research should re-examine these design principles within more advanced technological landscapes, allowing for more sophisticated applications of 4E+ Cognition and Illuminationist wisdom.

Technological Evolution: Finally, the rapid pace of advancement in XR technologies poses a challenge to the longevity and relevance of some of the study's findings. As XR technologies continue to evolve, some of the design principles and methodologies proposed may become less applicable or require significant adaptation. This technological obsolescence underscores the need for ongoing research to update and refine XR design frameworks in line with emerging theoretical, technical, and technological innovations.

In summary, the limitations of this study reflect both the ambitious scope of the research and the inherent challenges of integrating diverse and complex theoretical frameworks with rapidly evolving XR technologies. These challenges, while significant, also offer opportunities for future exploration and refinement. By addressing these limitations in subsequent studies, researchers can continue to push the boundaries of XR design, creating more holistic, culturally sensitive, and intellectually enriching experiences in the digital age.

6.3. Implications of the Study

The implications of the contributions presented above are several. First, the integration of 4E+ Cognition and Illuminationism into XR design challenges the current paradigms of Human-Computer Interaction by introducing a holistic and culturally nuanced approach to interaction design. This has significant implications for both academic discourse and creative practice, as it opens new avenues for the exploration of how cognitive frameworks and philosophical traditions can enrich user experiences. By bridging ancient wisdom with contemporary cognitive science, this study encourages a rethinking of how we approach emerging technologies and their role in shaping human cognition, engagement, and interaction.

Second, in the academic sphere, this research can foster interdisciplinary dialogue across fields such as philosophy, cognitive science, and technology studies. The framework proposed could serve as a foundation for developing new theories of user experience design that consider cognitive processes as well as emotional and spiritual dimensions. This can influence future research agendas by encouraging a deeper exploration of philosophical principles in the study of HCI and immersive media. For example, scholars in philosophy and cognitive science may now be more inclined to investigate the impact of embodied and affective cognition on human interaction with digital environments, opening new perspectives on the integration of metaphysical traditions with technological design.

Third, in the creative industry, the implications are equally transformative. This study provides a design framework that can be applied across various sectors, including education, cultural heritage preservation, and entertainment. By promoting cultural sensitivity and spiritual engagement in XR environments, the principles developed here can help guide the creation of experiences that are meaningful and culturally relevant. For instance, institutions involved in cultural preservation could use XR technologies informed by 4E+ Cognition to create immersive experiences that educate and engage younger generations in the importance of cultural heritage.

Fourth, this study highlights the importance of cultural sensitivity and ethical considerations in the development of XR environments, calling attention to the need for institutional policies that ensure these technologies are applied responsibly. As XR technologies become increasingly integrated into various sectors, there is a pressing need for ethical guidelines and regulatory frameworks that address concerns around user privacy, autonomy, and cultural heritage. These ethical considerations are not only relevant for designers and developers but also for policymakers who must ensure that the deployment of XR technologies is aligned with societal and cultural values. Given the immersive and potentially transformative nature of XR, policy implications are particularly significant in areas such as privacy protection, data security, and user consent.

As XR technologies become more embedded in daily life, especially in education, healthcare, and cultural heritage preservation, it is essential that policies are developed to mitigate risks associated with data collection, privacy, surveillance, and manipulation of user experiences. This research advocates for the establishment of ethical guidelines that prioritise the well-being of users and the preservation of cultural identities, especially when these technologies are applied across different cultural contexts. Policymakers should ensure that the design of XR environments respects local traditions, beliefs, and values, preventing the homogenisation of cultural experiences.

Furthermore, the intersection of XR with other advanced technologies, such as Artificial Intelligence (AI) and machine learning, introduces additional ethical concerns that require further policy attention. As these technologies are used to create adaptive and personalised experiences within XR environments, there is a need for regulations that govern the use of personal data, ensuring that it is handled responsibly and that users retain control over their digital identities. Policymakers could explore the development of ethical standards that safeguard user agency while preventing exploitation in commercial applications of XR and AI technologies. Additionally, policy frameworks should encourage interdisciplinary collaboration between technologists, philosophers, ethicists, and cultural experts to create XR experiences.

For example, industry standards could be introduced to guide the ethical use of XR in sensitive cultural settings, such as the gamification of cultural heritage or the creation of therapeutic environments. These standards could outline best practices for ensuring informed consent, cultural appropriateness, and responsibility in the creation and use of XR technologies. In terms of funding policies, the implications of this study suggest that research institutions and government bodies should prioritise funding for interdisciplinary projects that explore the cultural, ethical, and cognitive dimensions of XR design.

Given the potential for XR technologies to impact healthcare, education, and cultural heritage preservation, increased investment in research is needed to further investigate how these principles can be applied to create therapeutic, educational, and culturally enriching experiences. This could include developing policy frameworks that incentivise collaborative research between academic institutions, industry leaders, and cultural organisations to explore the potential of XR in fostering empathy, cross-cultural understanding, and social cohesion.

6.4. Further Research

While this study has laid a robust foundation for the integration of 4E+ Cognition and Spiritual Wisdom into XR design, it also opens several avenues for further research and other types of recommendations. The findings of this study suggest numerous potential areas of exploration that could build on the insights gained and extend the impact of this research across different contexts and industries.

One of the most promising areas for further research is the practical application of the design principles developed in this study across various industries. Future studies could investigate how these principles can be adapted to suit the needs of different sectors, such as healthcare, education, cultural heritage preservation, architecture and urban planning, sports and physical training, tourism and virtual exploration, corporate training and professional development, mental health and wellness, and disaster preparedness and crisis management. Each of these fields presents unique opportunities for applying XR design principles informed by 4E+ Cognition and Illuminationist philosophy, showing how technology can be adapted to support human-centred applications in diverse real-world contexts. Expanding the use of XR in these areas could bring significant benefits, fostering more ethical, sustainable, and culturally resonant experiences across sectors.

Another important area for further research is the exploration of how the design principles developed in this research can be adapted to different cultural groups and contexts. As XR technologies become more widespread, it will be crucial to ensure that these experiences are accessible and relevant to users from diverse cultural backgrounds. Future studies could explore how the principles of embodied interaction, cultural sensitivity, and ethical considerations can be tailored to meet the specific needs and values of various communities and societies, thus preserving cultural heritage while embracing technological innovation.

The ethical implications of XR technologies also warrant deeper investigation. As these technologies continue to evolve, ensuring that they are used in ways that are responsible, transparent, and aligned with users' best interests is critical. Future research could explore how ethical guidelines can be developed and implemented to protect users' privacy, autonomy, agency, and cultural heritage in XR environments. Such a line of inquiry could include investigating the potential risks and benefits of XR in various contexts and developing strategies for mitigating any negative impacts.

The intersection of XR with other advanced technologies, such as Artificial Intelligence (AI) and machine learning, presents another exciting frontier for future research. By exploring how these technologies can be harmonised with the 4E+ Cognition framework, researchers could uncover new ways to create adaptive, personalised, and culturally resonant XR experiences. For example, AI could be used to tailor XR environments to individual users' needs and preferences, enhancing the effectiveness and impact of these experiences.

Further research could also delve into the potential of XR to foster cross-cultural understanding and empathy. By designing experiences that allow users to step into the lives of people from different cultural backgrounds, XR can help break down barriers and promote a more inclusive, intercultural, and interconnected world. Research in this area could explore the effectiveness of such experiences in fostering empathy and understanding as well as their impact on social cohesion and cultural exchange.

In addition to these areas, future research could explore the expansion of the Ishraqi Heuristic Methodology to other forms of digital media and interactive technologies. This approach could potentially uncover new ways to integrate cultural and spiritual perspectives into the design and use of emerging technologies, fostering a more holistic and human-centred approach to technological innovation. Furthermore, incorporating Corbin's concept of Imaginal could significantly enrich AI design. By drawing on imaginal exploration, AI systems can be developed to better understand and emulate the nuanced ways in which humans engage with the environment.

In addition to the previously discussed areas, VR can provide a dynamic experimental arena to explore what people seek when they desire a sense of 'realness' in their experiences. Researchers repeatedly identify 'presence' as a critical factor in achieving this realness. Presence refers to the psychological state where users feel genuinely 'there' in the virtual world, and the virtual environment feels present to them (Vervaeke, 2019). This mutual presence creates a sense of being embedded within the virtual space, aligning with the embedded aspect of the 4E+ Cognition framework. The concept of presence in VR is deeply connected to Perspectival Knowing, one of the 4P of Knowing[24]. Perspectival Knowing involves understanding the world from a particular viewpoint, encompassing situational awareness and the subjective experience of "what it is like" to be in a specific environment. By leveraging VR to create immersive experiences that emphasise presence, researchers can further investigate the intricacies

[24] The 4Ps of Knowing—Propositional, Procedural, Perspectival, and Participatory—are a framework within cognitive science that categorises different types of human knowledge and cognition. This concept has been discussed extensively by cognitive scientist John Vervaeke in the context of 4E+ Cognition (Vervaeke, 2019).

of Perspectival Knowing. This can be useful in understanding the 4Ps of Knowing within the 4E+ cognitive science framework.

Beyond avenues for further research, the findings of this study also suggest several practical recommendations for the adoption of XR technologies in various sectors, where the principles of 4E+ Cognition and Illuminationist philosophy can be directly implemented to support meaningful and culturally resonant experiences. Educational Institutions: Schools and universities can adopt XR as part of their teaching methodologies to foster embodied and experiential learning. By implementing XR in subjects such as history, science, and the arts, educators can create immersive environments that enhance students' understanding through hands-on virtual experiences, allowing them to explore complex topics in a tangible and engaging way. This aligns well with XR's potential to support experiential engagement and deeper learning, promoting an educational shift towards active, interactive learning.

Healthcare and Mental Wellness: In the health sector, XR technologies informed by 4E+ Cognition principles could be used to develop therapeutic environments and virtual rehabilitation programmes. Hospitals and mental health facilities could adopt XR applications to create soothing, interactive environments that support patient well-being. This could include virtual therapy for anxiety management, immersive physical therapy for rehabilitation, and guided meditations, which leverage the affective and embodied dimensions of XR to promote emotional and physical healing.

Corporate Training and Workforce Development: Companies could integrate XR for workplace training and professional development, using immersive environments to simulate challenging or high-stakes situations for skill development. For instance, training in fields like emergency response, customer service, or technical repairs can become more impactful with XR, allowing employees to practice in a risk-free, controlled setting. This supports human-centred training approaches and enhances skill acquisition through practical, experiential learning.

Ecological Conservation and Public Awareness Campaigns: Conservation organisations and environmental advocacy groups could implement XR to raise awareness about ecological preservation by creating immersive experiences that allow the public to experience and visualise vulnerable ecosystems, while engaging with scientific knowledge. By virtually showcasing endangered habitats, such as coral reefs or rainforests, XR can foster empathy and drive engagement in conservation efforts, connecting people more deeply to the natural world and encouraging conservation action.

In conclusion, while this research has made specific contributions to the fields of XR and HCI, it also opens numerous avenues for further exploration. By building on the insights and principles developed in this study, future research can continue to push the boundaries of what is possible in XR, creating experiences that are not only technologically advanced but also ethical, deeply meaningful, and culturally relevant.

6.5. Significance Claim

The significance of this research lies in its comprehensive approach to integrating technological, philosophical, cultural, and ethical dimensions into the design of XR experiences. By bridging the gap between ancient wisdom and modern technology, this study offers a new approach and framework for XR design that is both innovative and deeply connected to the human experience. The research has challenged traditional approaches to HCI, promoting a more holistic and embodied understanding of Human-Computer Interaction.

The study's emphasis on cultural sensitivity and ethical considerations in XR design is particularly significant in the context of the Fourth Industrial Revolution (4IR), where digital technologies are increasingly influencing how cultures are represented and experienced. By advocating for a design approach that prioritises embodied interaction, cultural responsiveness, and spiritual engagement, this research offers a blueprint for creating human-centred XR environments.

The research also holds significant implications for educational methodologies. By shifting from traditional concept-based teaching to an embodied, affective, and experiential-based approach in XR, the study suggests a transformative impact on how knowledge is conveyed and absorbed. This approach, informed by the epistemological shift from Cartesian dualism to embodied cognition and human-centred design, has the potential to revolutionise education, making learning more immersive, interactive, and aligned with the realities of human cognition.

In the broader context of creative technology, this research contributes to a more nuanced understanding of how emerging technologies can be approached, designed, and be used to problem solving. It underscores the importance of integrating philosophical and cultural perspectives into technological development, ensuring that innovation is guided by a deep respect for human cognition and cultural heritage. The study also contributes to the broader discourse on the ethical and cultural dimensions of technology design, advocating for a more inclusive and humane approach to technological innovation.

As we move further into the 4IR, the insights gained from this research will play a crucial role in shaping the future of XR and HCI. The principles developed through this study have the potential to revolutionise the design of XR experiences, making them more immersive, accessible, and culturally relevant. The study’s emphasis on the integration of philosophy, culture, and technology offers a vision of a future where XR is not only a tool for innovation but also a medium for fostering deeper connections between people, cultures, and the world around them.

In conclusion, this research has contributed to the fields of XR and HCI by offering a new framework for understanding and designing immersive digital experiences. The study’s integration of 4E+ Cognition and Illuminationism into XR design has provided new insights into how technology can be used to create experiences that are engaging while resonating culturally and spiritually with the users. The research has also highlighted the importance of cultural sensitivity and ethical considerations in XR design, offering a blueprint for creating human-centred XR environments that are aligned with the values of diverse user communities. The significance of this research extends beyond the technicalities of XR design to encompass a profound rethinking of how we approach technology, culture, and cognition in the digital age.

6.6. Final Reflection

Reflecting on this research journey, it becomes evident that the integration of Persian philosophical traditions, particularly Illuminationism, with modern cognitive theories such as 4E+ Cognition has been transformative, both academically and personally. This journey has expanded the boundaries of HCI and XR design while also providing a new perspective on how technology can be aligned with cultural, ethical, and spiritual values.

Throughout this research, the blending of ancient wisdom with contemporary technology has offered a unique lens through which to explore the potential of XR as a medium for cultural preservation, education, and creative expression. The integration of Suhrawardi's Illuminationist philosophy, with its emphasis on light as a symbol of knowledge and spiritual insight, has provided a conceptual framework for understanding the role of XR in fostering deeper cognitive and spiritual connections. This approach has challenged traditional paradigms in HCI, advocating for a more holistic and embodied understanding of Human-Computer Interaction.

The personal impact of this research has been profound. The process of exploring the intersection of technology, philosophy, and culture has deepened my understanding of the interconnectedness of these domains and has reinforced the importance of viewing technology as a tool for enhancing human connection, cultural understanding, and spiritual growth. This journey has also underscored the value of approaching technological development with a sense of responsibility and respect for the cultural and philosophical heritage that informs our collective knowledge.

The research has also highlighted the importance of cultural sensitivity and ethical considerations in XR design. By weaving these elements into the design process, the study has illustrated how XR can be employed to forge experiences that resonate culturally, emotionally, and spiritually. This approach has the potential to transform the way we think about and design XR technologies, ensuring that they are aligned with the needs and aspirations of diverse user communities.

On an academic level, this research has contributed to the ongoing discourse on the integration of technology and culture, offering new insights into how XR can be used to preserve and promote cultural heritage. The projects developed based on the design principles proposed in this research, such as the *Rapua Te Mārama* (2021-2022) and *AUT Virtual Marae* (2017-2024), have provided practical examples of how XR can be used to create immersive experiences that celebrate cultural diversity and foster cross-cultural understanding. These projects have also demonstrated the potential of XR to transform educational practices, offering new ways to engage learners and enhance their understanding of complex subjects.

On a personal level, this journey of discovery has been instrumental in terms of both the knowledge gained but, more importantly, in terms of personal and academic growth. The challenges encountered along the way have shaped the direction of the study, prompting deeper reflection and leading to the development of new ideas and approaches. The experience of blending ancient wisdom with modern technology has been both rewarding and enlightening, offering a new perspective on how we can use technology to enrich our lives and the lives of others.

As this research comes to a close, it is clear that the insights gained and the principles developed have the potential to shape the future of XR and HCI in significant ways. The journey has been transformative, and the lessons learned will undoubtedly inform future research and practice in these fields. The integration of philosophy, culture, and technology has opened new avenues for exploration, offering a vision of a future where technology is connected to the human emotional experience.

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Appendices

Appendix 4 - The Methods

Research methods might be understood as “specific techniques and tools for exploring, gathering, and analysing information” (Gray & Malins, 2004). The methodology of this transdisciplinary exploration is bifurcated into multiple distinct yet interconnected sets of methods: Technological Framework, experimental visualisation, autoethnographic approaches, and reflective evaluation. In the context of the XR medium, this multifaceted approach facilitates a comprehensive understanding of the medium and its sensory impacts.

The AppLab methods span five key phases: pre-production, production, post-production, external feedback, and Final Adjustments and Evaluations. Each phase incorporates specific methods tailored to the objectives and challenges of that stage. The preproduction phase focuses on conceptual framework development, journaling, and initial testing. Tools such as Evernote, Journey, and The Brain were instrumental in organising thoughts and reflections. Additionally, photography, videography, and screen recording documented the evolving visual and conceptual elements.

The production phase involves strategic feedback mechanisms, interdisciplinary collaboration, and rigorous documentation. Despite the constraints of the pandemic, innovative approaches to feedback and collaboration ensured continuous progress. Strategic use of GitHub and Unity for version control facilitated efficient project management and collaboration.

In the post-production phase, user testing, feedback collection, and collaborative refinement processes ensured the final product met the desired standards and objectives. Real-world project processes at AppLab, including client meetings, brainstorming sessions, and iterative feedback loops, provided practical insights and enhanced the relevance of the research.

By integrating these diverse methods, the research aims to bridge the gap between philosophical inquiry and technological innovation, contributing to a holistic and embodied approach to human-computer interaction design within the realm of XR. The synthesis of ancient wisdom and modern insights, inspired by philosophical allegories and contemporary scholars, has shaped this methodological framework into a path of continuous ascent toward knowledge and self-realisation.

1. The Journey

During my PhD studies, there were numerous moments of struggle and self-doubt, compounded by an overwhelming workload and the isolation brought about by the COVID-19 pandemic. This internal turmoil often made concentration difficult, leading to questions about my capabilities and the value of pursuing a PhD. However, these challenges became integral to my research methodology, shaping the ways I approached and developed my work.

The journey was one of constant evolution, mirroring the ascent described in Plato's allegory of the cave. As I encountered philosophical teachings and ancient wisdom from figures such as Avicenna, Aristotle, and Suhrawardi, I began to see my own academic and personal growth as a journey from darkness to light. This transformative process, deeply reflective and introspective, informed my methodological framework, emphasising both intellectual and spiritual awakening.

Autoethnographic methods allowed me to document this personal journey, capturing the internal dialogues and identity crises that accompanied my academic progress. Reflective journaling, self-dialogue, and internalising dialogue became crucial tools in navigating these experiences, enabling me to integrate personal insights with academic research. The challenges I faced and overcame were akin to emerging from multiple caves, each experience contributing to a broader, brighter worldview.

Internally, I felt there was another reason behind these struggles, but I couldn't identify it. I knew my worldview was spinning around itself, but I wasn’t fully aware of what was happening to me. The world was spinning around me, and I felt completely numb.

Despite this, I managed to read a few words and make some progress with great difficulty. Around that time, I encountered Plato's allegory of the cave through discussions on identity crises. Besides taming my inner lion and beast, I realised that all these experiences were small identity crises I was facing on my PhD journey. These were the very challenges a traveller encounters during their doctoral journey. Am I not good enough? Of course, I am, but does that mean I won't doubt myself, work better, think differently, and improve until I start?

I was growing and evolving to align with the worldview I was developing, a worldview that was forming daily. It was I who was changing, and as a result, my perception of the world around me was also changing. I began to see the world differently. I was emerging from caves one by one, transforming my world and walking into a larger space, creating a brighter world for myself with each change. However, knowing this alone didn't mean I could get my tasks done. I needed to organise my thoughts; I needed peace, mental peace.

During this internal struggle, time and space stopped, and the world went into lockdown. I delved into the quarantine of my mind. To save my mental health, I began studying all the ancient wisdom. In my passive knowledge, I knew that figures like Avicenna, Aristotle, and Suhrawardi believed in a timeless and universal philosophy. A philosophy known for its timelessness and spacelessness, a way of thinking written for all humanity, promising to be useful and salvific for all people and forever.

Now, as I approach the final days of my PhD, I affirm this belief: yes, the philosophy of eternal wisdom, the perennial philosophy, is humanity's saviour. Today, I thank that version of myself who began exploring all the ancient philosophies during the COVID days and all the civilizations that helped me be here with a better perspective. Through this journey, I became acquainted with Buddha, Shinto, Vedanta, ancient Greece, and ancient Iran. During this time, I also came across the talks and YouTube videos of Dr. Vervaeke. Vervaeke, in his unique style, had combined these teachings into what he calls the ecology of practice.

In this synthesis of ancient wisdom and modern insights, Plato's allegory of the cave took on a new meaning. The ascent out of the cave, or anagoge, symbolised my journey from ignorance to knowledge, from darkness to light. This allegory, a cornerstone of Platonic thought, depicts prisoners chained in a cave, mistaking shadows on the wall for reality. The journey out of the cave and into the sunlight represents the soul's ascent into the realm of the intelligible, the world of forms, where true knowledge resides.

This metaphor resonated deeply with my own struggles and triumphs. As I moved through my PhD, each challenge was a step toward emerging from the cave. The shadows of doubt and confusion gradually gave way to the light of understanding and self-awareness. The process was not merely academic; it was a profound transformation of the self, aligning with the Ishraqi philosophy of Suhrawardi, which emphasises the journey of illumination and the direct experience of truth (Suhrawardi, 1998).

2. Technological Framework

The technological framework of this research is the bedrock that supports the development, testing, and deployment of XR applications. It integrates a combination of advanced hardware and sophisticated software tools to create a robust infrastructure capable of handling the complexities of immersive experiences. By leveraging technologies across various fields, this framework ensures a seamless and efficient workflow throughout the research process.

The realm of XR is at the forefront of technological innovation, offering immersive experiences that blend the physical and digital worlds. The development of XR applications is a complex interplay of hardware and software components, each with its unique challenges and solutions. This research delves into the technical aspects of XR, exploring how emerging technologies such as artificial intelligence (AI), machine learning, and blockchain are integrated into XR systems. Through a research-led practice approach, the technical decisions made in the creation of XR experiences are examined, highlighting the synergies between theoretical foundations and practical implementation.

The technical underpinnings of XR, encompassing both hardware and software components, are fundamental to realising immersive experiences. Challenges such as device compatibility and rendering optimizations are addressed through the integration of emerging technologies like AI and machine learning. This section critically reflects on the technical decisions made, highlighting the alignment between theoretical insights and practical implementation (Azuma, 1997).

2.1. Hardware and Software Setup

The hardware components of XR systems include head-mounted displays (HMDs), motion tracking devices, and haptic feedback mechanisms. These devices are crucial for creating a sense of presence in virtual environments (Sherman & Craig, 2003). On the software side, development platforms like Unity and Unreal Engine provide the tools necessary for creating interactive 3D content. However, developing XR applications involves navigating a landscape of device compatibility issues. Each hardware device has its specifications and limitations, requiring developers to optimise their applications to ensure a seamless user experience across different platforms.

The hardware setup for this research includes high-performance computing systems equipped with state-of-the-art graphics processing units (GPUs). These systems are essential for managing the demanding requirements of XR simulations and visualisations. The VR headsets used, such as the Oculus Quest 1 & 2, HTC Vive, Samsung Windows VR, HP Omnicept Windows VR, Google Cardboard, and Hololens 2, provide the immersive environments necessary for testing and refining the XR experiences.

The hardware setup for this research is designed to meet the demanding requirements of XR simulations and visualisations. It includes:

- **High-Performance Computing Systems**: Equipped with state-of-the-art graphics processing units (GPUs) such as NVIDIA RTX 3080 and AMD Radeon Pro, these systems handle complex rendering and simulations.

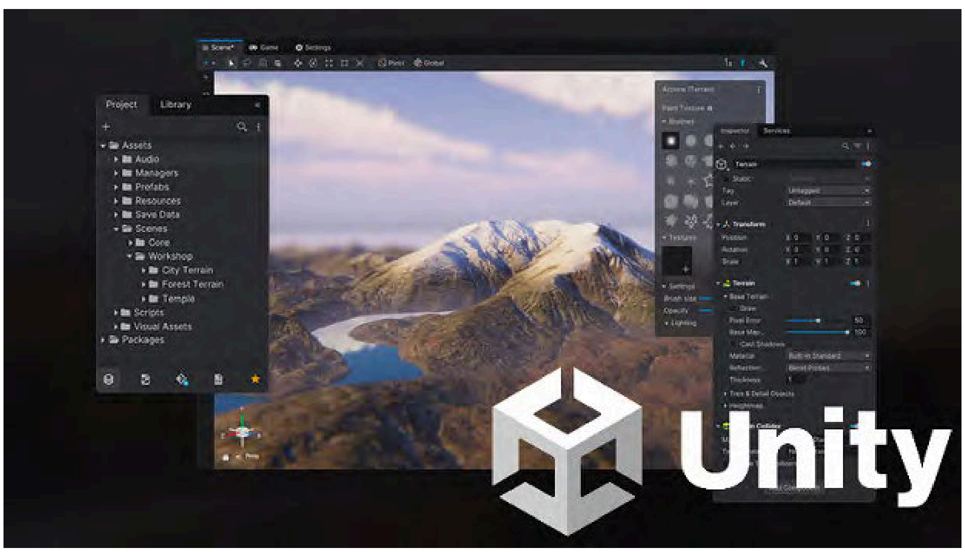
- **VR Headsets**: A variety of headsets were used to test and refine XR experiences, including:
    - Oculus Quest 1 & 2
    - HTC Vive
    - Samsung Windows VR
    - HP Omnicept Windows VR
    - Google Cardboard
    - Hololens 2
    - Zapbox
    - Aryzon

- **Peripheral Devices**: Additional devices such as photogrammetry equipment, Kineckt motion capture systems, haptic feedback devices, and 3D scanners were employed to enhance the immersive experience and gather precise user interaction data.

The software setup involves a suite of tools that facilitate the development and analysis of XR applications. Core tools include Unity3D and Unreal Engine, which are industry-standard platforms for creating immersive content. Blender is used for 3D modelling and animation, providing detailed visual elements that enhance the XR environments. Additionally, various AI and data analysis platforms are employed to support the development and evaluation of the projects, ensuring that the experiences are not only visually compelling but also data-driven and user-centric.

The software setup involves a suite of tools that facilitate the development, analysis, and refinement of applications. Core software tools include:

- Unity3D: Industry-standard platforms for creating immersive content, used extensively for developing interactive simulations and environments.
- Blender: A powerful tool for 3D modelling and animation, essential for creating detailed visual elements.
- Blender: Advanced 3D modelling and animation software used for complex character and environment designs.
- Autodesk Recap and Reality Capture: Tools for reality capture and 3D scanning, providing accurate 3D models from real-world objects.
- 3DF Zephyr: Software for photogrammetry and 3D reconstruction from photographs.
- Adobe Substance Series: For texturing and material creation, adding realism to 3D models.



Unity Engine Poster

This comprehensive hardware and software setup forms the backbone of the technological framework, enabling the creation of sophisticated and immersive XR experiences that are integral to the research.

2.2. Technical Specifications

This section explores the significance of the Unity Game Engine in the context of Human-Computer Interaction (HCI), eXtended Reality (XR), and the Fourth Industrial Revolution (4IR). By examining the engine's capabilities and applications, and highlights how Unity supports innovative research and development, providing a versatile platform for prototyping, simulation, and implementation in diverse technological landscapes. I will explore how Unity serves as a versatile platform for prototyping, simulation, and the implementation of interactive experiences.

The integration of Unity in research has profound implications for educational methodologies, industry applications, and cultural heritage preservation. By enabling the creation of immersive and interactive experiences, Unity supports the development of new paradigms in HCI and XR, aligning with the goals of the 4IR.

The Fourth Industrial Revolution (4IR) signifies a fundamental shift in the way we interact with technology, characterised by the fusion of digital, biological, and physical worlds. Central to this transformation are technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and eXtended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Human-Computer Interaction (HCI) research has increasingly focused on these domains to understand and improve the ways humans engage with emerging technologies. The Unity Game Engine, initially developed for creating video games, has evolved into a powerful tool for research and development in HCI, XR, and 4IR.

Unity3D plays a pivotal role in this research, providing a versatile and powerful platform for developing and deploying XR applications. Unity’s capabilities align seamlessly with the objectives of HCI, XR, and 4IR research. Its real-time rendering and cross-platform support enable the creation of interactive prototypes and simulations, essential for studying user interactions and behaviours in immersive environments. Its capabilities span various domains, enhancing the robustness and effectiveness of the technological framework.

The Unity Game Engine, launched by Unity Technologies in 2005, has become one of the most widely used development platforms for creating 2D, 3D, VR, and AR experiences. Its intuitive interface, robust feature set, and active community have made it a preferred choice for developers and researchers alike. Unity's capabilities align seamlessly with the objectives of HCI, XR, and 4IR research. Its real-time rendering and cross-platform support enable the creation of interactive prototypes and simulations, essential for studying user interactions and behaviours in immersive environments.

Unity supports development across multiple platforms, including desktop, mobile, web, and various VR/AR headsets. This cross-platform compatibility allows researchers to create and test applications in diverse environments, ensuring broader accessibility and usability. One of Unity's core strengths is its real-time rendering engine, which provides high-quality visual outputs essential for creating realistic and immersive experiences. This feature is particularly valuable for simulation and prototyping, where real-time feedback is crucial for iterative design processes.

Unity offers comprehensive tools for asset creation, management, and integration. Researchers can easily incorporate 3D models, animations, audio, and other assets into their projects. Additionally, Unity's compatibility with various software and hardware tools enhances its flexibility and utility in research. The engine's scripting capabilities, primarily through C#, provide researchers with the flexibility to customise functionalities according to their specific needs. This adaptability is vital for developing tailored interactive experiences and conducting detailed user studies. Unity boasts a large and active community that provides extensive resources, including tutorials, forums, and collaborative opportunities. This community support is invaluable for researchers, offering guidance and shared knowledge that can accelerate development and problem-solving processes.

Unity's robust feature set makes it ideal for creating interactive prototypes and simulation environments. These prototypes allow researchers to test and refine their designs in controlled settings, gathering essential data on user interactions and behaviours. Unity's capabilities facilitate the development of educational tools and applications that provide immersive learning experiences. Projects like Pipi's World Marine Education leverage Unity to create engaging XR experiences that enhance marine ecological literacy among students. Unity has been instrumental in projects focused on cultural heritage and preservation. The Mahia Ecological Map project, for instance, uses Unity to create interactive maps that document and promote understanding of local ecosystems and cultural heritage. These applications not only preserve important cultural knowledge but also educate the public about environmental stewardship.

Methodological Approaches

- **Experimental Visualisation Methods:** Researchers utilise Unity for various experimental visualisation methods, including prototyping and simulation tools. By iterating on visual design elements within Unity, researchers can explore and refine their ideas, ensuring that the final product meets the desired objectives and user needs.
- ~~**Autoethnographic Approaches:** Unity supports autoethnographic approaches by enabling researchers to integrate personal narratives and cultural insights into their projects. Reflective journaling and documentation practices within Unity projects help researchers capture their experiences and insights, fostering a deeper understanding of the design process and outcomes.~~
- **Reflective Evaluation Methods:** Unity facilitates reflective evaluation methods through formative and summative assessments. Researchers can collect iterative feedback from users and incorporate these insights into their design process. Documentation practices within Unity projects ensure that all stages of development are well-documented, supporting thorough evaluation and dissemination of findings.

Challenges and Limitations

- **Technical Challenges:** Despite its strengths, Unity presents certain technical challenges, including performance optimisation and hardware requirements. Balancing the quality and efficiency of applications can be demanding, particularly for high-fidelity simulations and complex interactive experiences.
- **Usability and Learning Curve:** New users may face a steep learning curve when first engaging with Unity. However, the availability of extensive resources and community support can mitigate these challenges, providing the necessary training and guidance for effective utilisation.
- **Ethical and Cultural Considerations:** As with any technology, the use of Unity in research must consider ethical and cultural implications. Researchers must be mindful of cultural sensitivity in their designs and ensure that their applications respect and preserve cultural values and traditions.

Unity's Special Features Related to this Research

- **Visualisation**: Unity3D's rendering capabilities enable the creation of high-fidelity visualisations. Its Scriptable Render Pipeline (SRP), including the High Definition Render Pipeline (HDRP) and the Universal Render Pipeline (URP), allows for the development of realistic graphics and cross-platform compatibility. These tools ensure that the visual quality of XR experiences is maintained across different devices.

- **Programming and Scripting**: Unity3D uses C# for scripting, offering a robust environment for developing complex interactive behaviours. Its comprehensive API allows for the integration of various systems and functionalities, making it possible to create dynamic and responsive XR applications. Features such as the Unity Editor, Play Mode, and Prefabs streamline the development process, allowing for efficient prototyping and iteration.

- **Implementation**: Unity3D supports the implementation of various XR functionalities through its extensive library of plugins and assets. The XR Interaction Toolkit simplifies the creation of complex interactions within virtual environments. Additionally, Unity's support for Digital Twins enables the development of virtual replicas of physical assets, processes, or systems, which are used to simulate, predict, and optimise performance in real-time.

- **Data-Oriented Technology Stack (DOTS)**: Unity's DOTS framework enhances performance by enabling the creation of highly efficient code. This is particularly useful for large-scale simulations and real-time data processing, ensuring that XR applications run smoothly even under demanding conditions.

- **ML-Agents**: Unity's ML-Agents toolkit integrates machine learning into XR applications. This allows for the development of intelligent, adaptive systems that can learn from user interactions and improve over time. ML-Agents are used to create smart particles behaviours and enhance user engagement through personalised experiences.

- **Rendering Optimizations and Device Compatibility**: Rendering optimizations are essential for maintaining high performance and visual fidelity in XR applications. Techniques such as occlusion culling, level of detail (LOD) adjustments, and efficient use of shaders can significantly improve rendering efficiency. These optimizations are particularly important in XR, where maintaining a consistent frame rate is crucial for preventing motion sickness and ensuring user comfort. Developers must also contend with the challenge of device compatibility, ensuring that XR applications can function across a range of HMDs and input systems. This often involves creating adaptable user interfaces and control schemes that can accommodate different devices.

- **Delivery**: Unity3D facilitates the deployment of XR applications across multiple platforms, including VR headsets, mobile devices, and desktops. Its build and deployment tools ensure that applications are optimised for performance on different hardware configurations. Unity's Asset Bundles and Addressable Assets systems enable efficient content delivery and management, allowing for updates and modifications without requiring complete rebuilds.

2.3. Implementation Process

The implementation process involved several key stages, each meticulously documented and iteratively refined based on feedback and performance evaluations.

1. **Initial Setup**: Establishing the technological infrastructure, including hardware installation, software configuration, and ensuring compatibility across all tools and devices.
2. **Development**: Using Unity3D and Unreal Engine to create immersive environments and interactive simulations. Blender and Autodesk Maya were employed for 3D modelling and animation, while AI platforms assisted in enhancing the user experience through intelligent interactions.
3. **Testing and Refinement**: Iterative testing phases where prototypes were evaluated using VR headsets and peripheral devices. Feedback from these sessions was used to make necessary adjustments, ensuring the XR experiences were intuitive and engaging.
4. **Integration of Philosophical Principles**: Throughout the development and refinement stages, philosophical principles from Persian Ishraq hikmah-philosophy and second-order cybernetics were integrated into the design and functionality of the XR applications, providing a unique conceptual framework.
5. **Final Deployment**: Once the applications were thoroughly tested and refined, they were deployed for user interaction studies and further evaluation.

By leveraging the advancements of the Fourth Industrial Revolution (4IR) and integrating technologies from various fields, this technological framework supports the exploration and development of innovative XR applications. The comprehensive hardware and software setup, along with meticulous technical specifications and a structured implementation process, ensures that the XR experiences developed are sophisticated, immersive, and impactful in their respective applications.

The integration of AI and machine learning into XR systems opens new possibilities for creating dynamic and responsive virtual environments. AI algorithms can be used to generate and personalise the XR experience based on user preferences. Machine learning techniques, such as deep learning, can enhance object recognition and spatial mapping capabilities, enabling more seamless interaction between the physical and virtual worlds.

The technical decisions made in the development of XR applications are not made in isolation; they are deeply influenced by the theoretical foundations of the field. The principles of human-computer interaction (HCI), cognitive psychology, and media theory inform the design of XR interfaces, guiding the development of user-centred experiences that are intuitive and engaging. By aligning technical implementations with theoretical insights, developers can create XR experiences that not only push the boundaries of technology but also offer meaningful and transformative experiences for users.

In conclusion, the technical aspects of XR development represent a critical bridge between abstract theoretical concepts and their tangible manifestations in the digital world. By addressing challenges such as device compatibility and rendering optimizations, and by integrating emerging technologies like AI, machine learning, and blockchain, XR developers can create immersive experiences that are both technologically advanced and deeply rooted in theoretical principles. The synergy between theory and practice in XR not only advances the field technologically but also enriches our understanding of the potential of digital environments to shape human experience.

3. Experimental Visualisation Methods

The experimental visualisation methods employed in this research are integral to the development of immersive XR experiences. These methods involve the use of advanced tools and iterative design processes to create, test, and refine visual elements and interactive environments. The integration of philosophical principles further enriches these visualisations, providing depth and context to the immersive experiences.

3.1. Prototyping and Simulation Tools

Prototyping and simulation tools are crucial for the initial stages of development. They allow for the rapid creation and testing of concepts, enabling researchers to explore different design possibilities and make informed decisions based on feedback and performance.

The first set of methods focuses on experimental visualisation, employing a variety of techniques to capture, create, and analyse visual and auditory data. These methods include observation, visualisation, photography, videography, and audio recording, which are foundational for capturing real-world phenomena and user interactions with XR environments.

Advanced digital techniques such as 3D digital modelling in desktop and in VR are utilised to create immersive and interactive representations of data and concepts. Simulations and data visualisation further augment the analysis, providing insights into complex patterns and interactions within XR environments. The use of the Unity game engine for interactive game-based development, accompanied by video or screen recording of the creation process, allows for detailed examination and analysis of the design and user experience.

Interaction design forms the core of XR experiences, shaping how users engage with and navigate through virtual and augmented environments. This section delves into the intricacies of interaction design, shedding light on the methodologies employed to create intuitive and meaningful user interactions. From gesture-based controls to voice commands and haptic feedback, the design choices made in this realm significantly impact the user's immersion and engagement. Through the critical lens of practice-led research, we analyse the evolution of interaction design concepts and their alignment with the theoretical foundations of the study.

At the core of XR experiences lies interaction design, which dictates how users engage with and navigate through virtual and augmented environments. Drawing from principles of Human-Computer Interaction (HCI), User Experience (UX), and Interaction Design (IxD), the creation of intuitive and meaningful user interactions is paramount. Iconic video games have demonstrated the power of innovative interaction mechanics, influencing XR design to create engaging narratives and gameplay experiences.

To exemplify the significance of interaction design, we can turn to renowned video games that have pushed the boundaries of user engagement. Games like "Half-Life" introduced innovative first-person interaction mechanics, blending storytelling and gameplay seamlessly. In the psychological horror masterpiece "Silent Hill," the use of sound and environmental design deeply affected players' emotions and immersion. The "Metal Gear" series revolutionised stealth mechanics and narrative delivery, demonstrating the power of well-crafted interactions. Furthermore, the indie game "Journey" showcased minimalist UI and communication through non-verbal gestures, highlighting the potential for intuitive and emotionally resonant interaction design in XR.

- **ShapesXR**: This tool is used for creating VR and AR prototypes quickly and efficiently. ShapesXR allows designers to sketch and iterate in 3D space, making it ideal for early-stage concept development.

- **Figma**: Figma is used for creating user interface (UI) designs and prototypes. It supports collaboration and real-time feedback, which are essential for refining UI elements and ensuring a user-friendly experience.

- **Procreate:** Procreate's animation features enable the creation of fluid, hand-drawn motion graphics and character animations, which is useful for designing interactions. These can be easily exported and integrated into XR platforms like Unity3D, ensuring that animated elements maintain their expressive quality within interactive 3D spaces.

- **Unity3D**: Unity3D is the primary tool used for prototyping and simulation. Its real-time rendering capabilities and extensive library of assets and plugins make it ideal for creating interactive prototypes quickly. Unity's XR Interaction Toolkit is particularly useful for developing complex interactions within virtual environments.

In addition to visuals, sound design is a crucial element in XR, contributing to the sensory richness and realism of virtual environments. This section explores the role of sound design in creating immersive XR experiences, delving into techniques used to spatialize audio, synchronise sound with visuals, and evoke emotional responses through auditory cues. Sound design in XR extends beyond traditional stereo audio, encompassing spatial audio, binaural rendering, and interactive soundscapes. Through a practice-oriented perspective, we examine how sound design choices have been informed by the theoretical framework and contribute to the overall 4E+ interaction experience. Sound design in XR leverages interactive spatial sound techniques available in game engines to create a dynamic auditory experience. These techniques enhance immersion by allowing soundscapes to adapt to the user's position and movements within a virtual environment. Unity3D, a leading game engine, provides robust tools and features to implement these advanced sound design techniques.

- **Spatial Audio**: Unity3D's Audio Spatializer provides the ability to place sounds in a 3D space, allowing users to perceive the direction and distance of audio sources accurately. This spatialization is crucial for creating a realistic auditory environment, where sounds behave as they would in the real world.
- **Binaural Rendering**: By simulating the way sound waves interact with the human head and ears, binaural rendering creates a 3D audio effect that is highly

immersive when listened to through headphones. Unity supports various plugins that enable binaural audio, enhancing the sense of presence in XR experiences.

- **Interactive Soundscapes**: Unity allows developers to create interactive soundscapes that respond to user actions and environmental changes. This interactivity is achieved through scripting and the use of Unity's Audio Source component, which can adjust parameters such as volume, pitch, and spatial position in real-time.

Sound design in XR can evoke powerful emotional responses, contributing significantly to the user experience. By carefully selecting and designing auditory cues, developers can influence the user's emotional state and enhance the immersive quality of the virtual environment.

- **Music and Ambient Sounds**: Background music and ambient sounds play a crucial role in setting the mood and tone of an XR experience. Unity’s audio mixer allows for dynamic adjustment of audio levels, enabling real-time changes to the auditory atmosphere based on user interactions or narrative developments.

- **Sound Effects**: Well-designed sound effects can heighten the realism and emotional impact of interactions within the XR environment. Unity supports a wide range of audio formats and effects, allowing developers to create detailed and expressive soundscapes.

Leveraging XR Headsets and Sensors for Spatial Sound

XR headsets equipped with sensors such as accelerometers and gyroscopes capture head movement, enabling users to perceive sound sources in 3D space. As users turn their heads or move through the XR environment, the sound dynamically adjusts its position and orientation, providing a truly immersive and realistic auditory experience.

- **Head Tracking**: Unity3D supports head tracking through its integration with various XR platforms. By using the headset's sensors, Unity can adjust the spatial position of audio sources relative to the user's head movement, maintaining the illusion of a consistent and immersive sound field.

- **3D Audio Plugins**: Unity's support for third-party 3D audio plugins, such as Oculus Spatializer, enhances the spatial audio experience. These plugins use advanced algorithms to simulate how sound waves interact with the environment and the user's head, providing a high level of realism.

The integration of interactive spatial sound in XR environments involves leveraging Unity's capabilities to align with the theoretical foundations of the study. The sound design choices are informed by principles of 4E+ cognition, which emphasise the embodied, embedded, enacted, and extended nature of human experience.Spatial sound design in XR enhances embodied interaction by providing auditory cues that align with the user's physical movements and actions. This alignment fosters a deeper sense of presence and immersion, as users perceive the virtual environment as an extension of their own sensory experiences.By creating soundscapes that respond dynamically to user interactions and environmental changes, the research ensures ecological validity. The realistic auditory feedback reinforces the user's sense of being in a real, responsive environment, supporting the 4E+ framework's emphasis on real-world relevance.

Through the lens of practice-led research, these sound design choices are critically reflected upon, considering their alignment with the theoretical foundations of the study. The implications of interactive spatial sound for 4E+ interaction and its role in shaping the overall XR experience are evaluated, underscoring the seamless integration of theory and practice in crafting immersive soundscapes that contribute to the holistic embodiment of users in XR environments.

3.2. Visual Design Iterations

Visual design iterations involve a cyclical process of designing, testing, and refining visual elements. This iterative approach ensures that the final product meets the desired aesthetic and functional requirements.

Initial Concept Design: The process begins with the creation of initial concept designs using tools like Blender and Autodesk Maya. These designs are then imported into Unity3D or Unreal Engine for further development.

Prototyping: Initial prototypes are created to test the feasibility of the designs. These prototypes are evaluated based on visual quality, performance, and user feedback.

Feedback and Refinement: Based on the feedback received, the designs are refined and improved. This process may involve multiple iterations to ensure that the final product is both visually appealing and functionally robust.

Final Visualisation: Once the designs have been refined, final visualisations are created and integrated into the XR environment. These visualisations are tested thoroughly to ensure they meet the research objectives.

Visual design within XR is a critical element in crafting immersive experiences that captivate and engage users. Drawing upon a rich array of visual effects techniques, cinematic approaches, and lighting techniques, the design process in XR is a complex amalgamation of art and technology. By integrating cinematic techniques such as framing, composition, and camera movement, XR experiences are endowed with a narrative depth and focus that guide user attention and foster a sense of progression.

In the realm of XR, visual design plays a pivotal role in crafting immersive and engaging experiences. This section delves into the nuances of visual design within the context of this research. It explores the creative choices made in terms of aesthetics, graphical elements, and the use of visuals to convey concepts and emotions. Visual design in XR extends beyond traditional 2D interfaces, encompassing 3D environments, holographic displays, and mixed reality overlays. Through a practice-led approach, we examine how visual design principles have been applied to enhance the embodiment and interaction of users in XR spaces.

Visual design within the realm of XR draws inspiration from a rich tapestry of visual effects techniques, cinematic approaches, and lighting techniques, often seen in the realms of cinema and cinematic video games. This section navigates the intricate landscape of visual design, emphasising the fusion of these cinematic elements with XR to create captivating and immersive experiences.

Incorporating cinematic techniques into XR design enhances storytelling and user engagement. Techniques such as framing, composition, and camera movement from the world of cinema are adapted to guide users' attention within XR environments. Just as a well-directed film captures the viewer's gaze, XR experiences strategically utilising these cinematic techniques to direct users' focus and create a sense of narrative progression.

The application of visual effects (VFX) techniques in XR, inspired by the film industry, introduces dynamic elements and special effects that blur the boundaries between reality and virtuality. Lighting, borrowed from cinematic traditions, sets the mood and atmosphere, enhancing the realism and emotional impact of XR environments. Furthermore, insights from cinematic video games inform XR storytelling, ensuring users are not merely observers but active participants in the narrative (Jenkins, 2004).

Lighting plays a pivotal role in setting the mood and atmosphere in both cinema and XR. From the chiaroscuro of film noir to the dynamic lighting of action sequences, cinematic lighting techniques inspire XR designers to craft visually compelling environments. Real-time lighting simulations in XR enhance realism and evoke emotional responses, making users feel truly present in the digital realm.

Cinematic video games have revolutionised storytelling through interactivity. XR design leverages insights from this genre to create engaging narratives and gameplay experiences. From cinematic camera angles to scripted sequences, elements borrowed from cinematic video games enrich XR storytelling, ensuring that users are active participants in the unfolding narrative.

Throughout this section, we delve into the practical integration of these cinematic and visual effects techniques within XR. We explore how these elements enhance immersion, storytelling, and the overall visual quality of XR experiences. Moreover, we critically reflect on how the fusion of cinematic aesthetics with XR aligns with the theoretical foundations of the study, highlighting the seamless integration of theory and practice in the realm of visual design.

3.3. Experimental Visualisation Methods

The experimental visualisation methods employed in this research are diverse and multidisciplinary, integrating tools and techniques from various fields to create immersive and engaging XR experiences.

Observation and Visualisation: Fundamental methods such as observation and visualisation are employed to capture real-world phenomena and user interactions with XR environments. These techniques provide a baseline understanding of how users engage with immersive experiences.

Photography, Videography, and Audio Recording: These traditional methods are used to document user interactions and environmental contexts. The captured media serve as reference points for developing and refining XR simulations.

3D Digital Modelling and Painting: Advanced techniques like 3D digital modelling, voxel modelling, and 3D digital painting in VR are utilised to create detailed and immersive representations of data and concepts.

Simulations and Data Visualisation: Simulations and data visualisation tools are used to analyse complex patterns and interactions within XR environments. These methods provide insights into how different elements interact and evolve over time.

Interactive Game-Based Development: The Unity game engine is used for developing interactive, game-based applications. This approach not only enhances user engagement but also allows for detailed examination and analysis of the design and user experience through video or screen recording of the creation process.

3.4. Documentation and Brainstorming Tools

The primary documentation and brainstorming tool utilised in this research is an application named 'The Brain', which supports associative hyper-textual mapping. This digital mapping system allows for the organisation and interconnection of ideas, written information, multimedia content, and online resources in an interactive mind map environment.

- **Associative Hyper-Textual Mapping**: 'The Brain' enables the exploration of ideas and concepts through a web of connections. This non-linear approach to documentation and analysis mirrors the intellectual process of the researcher, promoting the development of thinking through associative links (Nonaka & Takeuchi, 1995).

- **Interactive Mind Map Environment**: 'The Brain' application facilitates non-linear navigation through the creative and research process. It supports the organisation of complex information, showcasing the research path, various elements, and their interrelationships. Figures x and y illustrate the application interface, highlighting the non-linear descriptive connections between different bodies of knowledge.

- **Dynamic Framework for Exploration**: This methodological approach underscores the complexity and interconnectedness of knowledge within the field and its applications. 'The Brain' application provides a flexible and dynamic framework for exploring and understanding the multifaceted nature of this research.

In the process of my research, digital archiving and visual noting played a critical role in organizing and synthesizing contextual material and visual inspirations. For this purpose, I utilized The Brain and Google Docs software as my digital journal. These tools afforded me convenient ways of notating my thinking and provided a networked, easily tracked archive. Cristy suggests that such electronic environments can enable a user to accomplish all of the operations typically performed with a hardcopy text, in addition to functions not possible with paper books.

Sedig and Parsons (2013, 2016) point out that computational tools incorporating visualisations can enhance a wide range of complex cognitive tasks, such as analytical reasoning, understanding, decision-making, problem-solving, learning, planning, and uncovering new knowledge. Utilising a digital journal allowed me to synthesize information in sophisticated ways, which proved beneficial for both the design of Saints of Paradox and the associated exegetical writing. By creating interconnected indexes, categorizing thoughts into folders and tabs, and developing an interactive platform, I significantly improved the organization and retrieval of information.

The use of The Brain for associative hyper-textual mapping allowed for a non-linear exploration of ideas and their interconnections. This digital mapping system supported the organisation and visualisation of complex relationships between different bodies of knowledge, enhancing the research's depth and coherence. Nonaka and Takeuchi (1996) highlight that such associative mapping facilitates a non-linear navigation through the creative and research process, promoting the development of thinking through associative links.

Mind mapping as a technique, supported by tools like The Brain, has been widely recognized for its effectiveness in enhancing learning and information retention. Buzan (2006) suggests that mind mapping harnesses the full range of cortical skills—word, image, number, logic, rhythm, colour, and spatial awareness—in a single, uniquely powerful manner. This method of note-taking and visualisation is not only beneficial for organising information but also for stimulating creative thinking and improving memory.

Moreover, Davies (2011) notes that mind mapping can significantly improve learning and information retention, particularly in complex and multifaceted research contexts. By visually representing the relationships between concepts and ideas, mind maps facilitate a deeper understanding and better recall of information. This visual approach to note-taking is particularly suited to the needs of practice-led research, where the ability to dynamically interact with and explore complex information is paramount.

Overall, the integration of digital tools for archiving and visual noting has significantly enhanced the efficiency and effectiveness of my research process. The ability to dynamically interact with a networked archive of information has provided invaluable support for both creative and analytical aspects of my work, underscoring the importance of these tools in contemporary academic research.

By employing these experimental visualisation methods, the research aims to push the boundaries of what is possible with XR technologies. These methods create experiences that are not only immersive and interactive but also meaningful and enriching, integrating traditional and digital techniques to provide a comprehensive understanding of the research subject.

4. Philosophical Insight Approaches

philosophical insight approaches in this research encompass a range of methods that integrate philosophical reflections, personal experiences, and cultural insights into the research process. These approaches are designed to provide a deeper, multi-layered understanding of the sensory and cognitive dimensions of XR technologies.

4.1. Application of Philosophical Principles

The integration of philosophical principles, particularly those from Persian Ishraq hikmah-philosophy and second-order cybernetics, provides a unique conceptual framework for the visualisations. These principles guide the design and development processes, ensuring that the XR experiences are not only visually compelling but also intellectually enriching.

- **Ishraq Philosophy**: This philosophy emphasises illumination and direct experience of truth. In the context of XR, this translates to creating visualisations and experiences that evoke a sense of enlightenment and deeper understanding.

- **Second-Order Cybernetics**: This principle focuses on the observer's role in the system. In XR, it involves designing interactive environments that respond dynamically to user inputs, creating a reciprocal relationship between the user and the environment.

These philosophical principles, combined with diaristic entries, enhance the depth of inquiry by incorporating personal experiences and reflections into the research process. This introspective method, combined with photography and animation, offers a rich, multi-layered understanding of the sensory and cognitive dimensions of XR technologies (Ellis, Adams, & Bochner, 2011).

4.2. Ecology of Practices

An ecology of practice is a structured arrangement of meaningful practices designed to stimulate mental, spiritual, and physical connections. It encompasses an integrated network of activities aimed at fostering connections with oneself, others, and the broader world. Traditional intellectual learning alone is inadequate for the pursuit of philia sophia, or the love and cultivation of wisdom, which requires engaging the whole person—mind, body, and spirit. This holistic approach involves movement and stillness, sociability and solitude, spontaneous creativity, and methodical reasoning.

The "Ecology of Practices" is a methodological framework developed primarily by the Vervaeke Foundation, designed to integrate and harmonise various practices and methodologies within a coherent, adaptive, and holistic approach to research. This framework is particularly relevant in the context of practice-oriented, transdisciplinary research, where multiple methodologies and practices intersect to address complex research questions. The Ecology of Practices emphasises the interconnectedness and interdependence of different practices, advocating for a flexible, iterative, and context-sensitive approach to research.

In the context of this research, the Ecology of Practices serves as a meta-methodological framework that encompasses various experimental and reflective methods employed in the study. It integrates different cognitive and practical approaches, facilitating a comprehensive understanding of the dynamic interplay between human cognition, technological systems, and environmental contexts (Vervaeke, 2022).

The Ecology of Practices framework is inherently transdisciplinary, drawing on methods and insights from diverse fields such as cognitive science, philosophy, educational technology, and design. This integrative approach is essential for exploring the multifaceted nature of XR technologies and their applications in learning and cognition. By fostering a dialogue between different disciplines and practices, the Ecology of Practices allows for the emergence of novel insights and innovative solutions that might not be achievable through a single disciplinary lens (Vervaeke, 2022).

Central to the Ecology of Practices is its emphasis on adaptability and iteration. Research within this framework is not a linear process but an evolving journey that responds to the changing dynamics of the research context and the insights gained along the way. This adaptive methodology aligns with the principles of cybernetics, particularly the concepts of feedback and self-regulation, ensuring that the research process remains responsive and resilient (Schön, 1983 in Visser, 2010; Kinsella, 2010).

Incorporating embodied and enactive cognition within the Ecology of Practices highlights the importance of bodily and experiential engagement in the research process. Methods such as physical prototyping, gesture-based interaction design, and immersive VR simulations are employed to explore how bodily movements and sensory experiences shape cognitive processes within XR environments. This approach not only enhances the understanding of XR interactions but also informs the design of more intuitive and engaging XR experiences.

Reflective and reflexive practices are integral to the Ecology of Practices, promoting continuous critical reflection on the research process and outcomes. Techniques such as iterative sketching, reflective role-playing, and audio reflection enable researchers to evaluate and refine their design ideas and methodologies continually. This reflexive approach ensures that the research remains aligned with its theoretical foundations and responsive to new insights and challenges.

4.3. Personal Narrative Documentation

Personal narrative documentation involves recording the researcher's personal experiences, reflections, and insights throughout the research process. This method is essential for capturing the subjective aspects of the research, providing a deeper understanding of the personal and emotional dimensions of XR interactions.

Diaristic Entries: Regular diaristic entries document the researcher's thoughts, feelings, and experiences, offering a rich, qualitative data set that informs the reflective and iterative aspects of the research.

Photography and Animation: Visual documentation through photography and animation enhances the narrative by capturing the visual and dynamic aspects of the research process. These visual elements provide a tangible record of the research journey and its evolving nature.

4.3.1. Reflective Journaling

Reflective journaling is used to record daily experiences, thoughts, and reflections. Tools like Evernote and Journey facilitate this practice, allowing for organised and accessible documentation of personal insights and observations.

Structured Reflection: Reflective journaling involves structured reflection on the research process, capturing insights, challenges, and breakthroughs. This method supports continuous learning and adaptation.

Integration with Visuals: Journals often incorporate visual elements such as sketches, photographs, and diagrams, providing a comprehensive record of the researcher's intellectual and creative journey.

4.3.2. Integration of Cultural and Philosophical Insights

Cultural and philosophical insights are integrated into the research through continuous reflection and dialogue. This approach ensures that the XR experiences are grounded in a deep understanding of the relevant philosophical concepts and cultural contexts.

Cultural Contextualisation: Reflecting on cultural narratives and traditions informs the design of XR experiences, ensuring they resonate with the intended audience and convey meaningful messages.

Philosophical Dialogue: Engaging with philosophical texts and concepts shapes the researcher's perspective, guiding the conceptual development of the XR applications.

4.3.3. Self-Dialogue and Internalising Dialogue

Self-dialogue and internalising dialogue are critical for processing and understanding personal experiences and their impact on the research. These methods help internalise philosophical concepts and apply them to the design and development processes.

Self-Dialogue: Engaging in self-dialogue allows the researcher to articulate and explore their thoughts, fostering a deeper understanding of their intellectual and emotional responses.

Internalising Dialogue: Internalising dialogue involves reflecting on external inputs, such as feedback from peers and mentors, and integrating these insights into the research process. This method ensures that the research remains dynamic and responsive to new ideas and perspectives.

By employing these autoethnographic approaches, the research aims to create a rich, multi-layered understanding of XR technologies. These methods provide a comprehensive framework for integrating personal, cultural, and philosophical insights into the research, enhancing the depth and relevance of the findings.

4.4. Reflective Evaluation Methods

The second set of methods is reflective and evaluative, aimed at reiterating and refining design ideas through an iterative process. Techniques such as sketching, reflective and empathic role-playing, and audio reflection are employed to critically assess and evolve design concepts. Experimentation with various technologies and gadgets, alongside the iterative development of prototypes, facilitates a hands-on approach to design improvement. These activities are contextualised within an online associative hyper-textual mapping environment, enabling a dynamic and interconnected visualisation of ideas and their evolution over time (Kwon & Jonassen, 2011).

4.4.1. Formative and Summative Assessments

Formative and summative assessments play a crucial role in evaluating the effectiveness and impact of the XR applications developed during the research.

Formative Assessments: These are conducted throughout the development process to provide ongoing feedback and guide iterative improvements. Methods include user testing sessions, peer reviews, and expert evaluations. Formative assessments help identify areas for enhancement and ensure that the project remains aligned with its objectives.

Summative Assessments: These assessments evaluate the final outcomes of the project. They involve comprehensive testing and analysis to determine whether the project has met its goals and objectives. Summative assessments provide a holistic view of the project's success and its potential for real-world application.

4.4.2. Voice Recording and Written Reflections

Voice recording and written reflections are integral to capturing the researcher's thoughts, insights, and experiences throughout the project.

Voice Recording: Recording thoughts and reflections in real-time allows for the capture of spontaneous insights and ideas. This method is particularly useful for documenting immediate reactions and reflections during user testing sessions or design iterations.

Written Reflections: Written reflections provide a more structured and detailed account of the researcher's experiences. They allow for deeper analysis and synthesis of information, contributing to a comprehensive understanding of the research process and outcomes.

4.4.3. Near-Sleep Technique to Open the Mind Box

The near-sleep technique involves leveraging the hypnagogic state—a transitional phase between wakefulness and sleep—to access creative insights and ideas.

Hypnagogic Exploration: This technique involves recording thoughts and ideas that emerge during the hypnagogic state. The relaxed yet alert state of mind can facilitate unique insights and creative problem-solving, contributing to the research's innovative aspects.

Application in XR Design: The insights gained from hypnagogic exploration are used to inform and inspire design decisions, providing a unique perspective on user experience and interaction.

4.4.4. Lucid Dreaming & Out-of-Body Experience

Lucid dreaming and out-of-body experiences (OBEs) offer unique methodologies for practice-led research in the fields of artistic and cultural inquiry. These altered states of consciousness provide a rich terrain for exploring the boundaries of perception, creativity, and cultural narratives, allowing researchers to access and engage with experiential knowledge in ways that transcend conventional methodologies.

Lucid Dreaming: This involves becoming aware of and controlling one's dreams. In the context of XR research, lucid dreaming can be used to explore and experiment with new design ideas and concepts in a dream state, where the boundaries of reality are fluid and flexible.

Out-of-Body Experiences: OBEs involve the sensation of floating outside one's body and perceiving the physical world from an external perspective. This method can provide unique insights into spatial awareness and interaction design, informing the creation of more intuitive and immersive XR environments.

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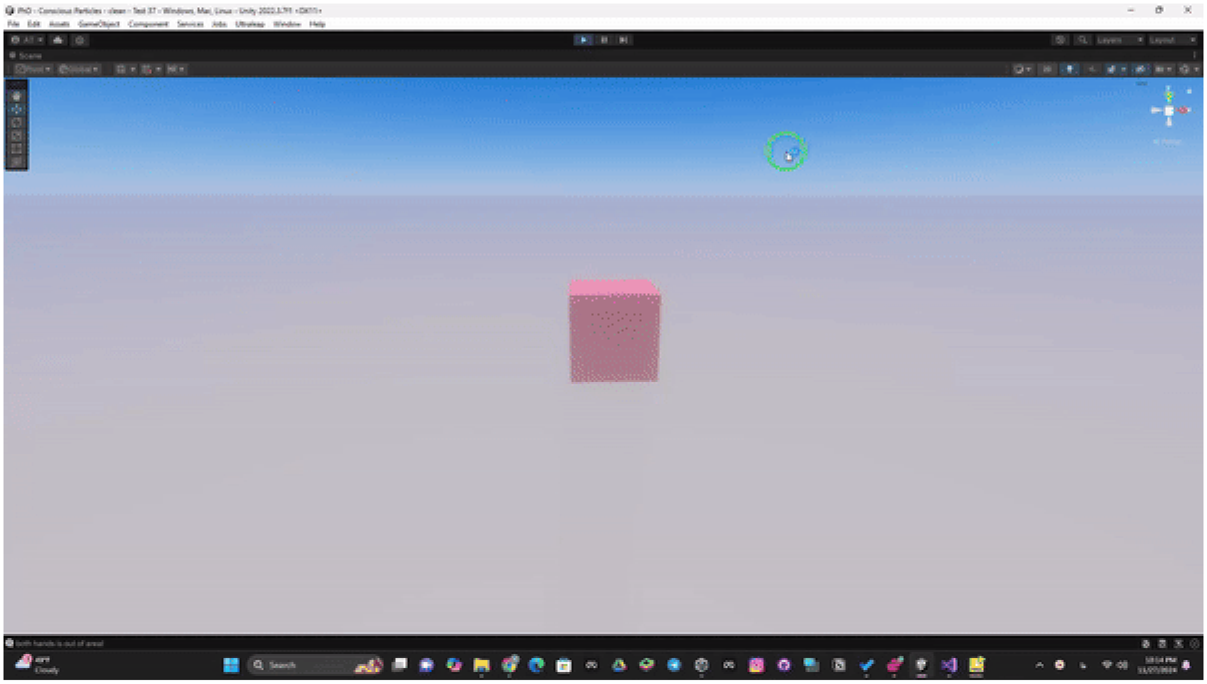
Appendix 6 - Technical Documentations

5.3.3 - Abstract Ideas for 4E+ Interaction Design - Smart Particles



Introduction

The objective of this project is to develop and implement a system for interacting with smart particles, utilising a combination of artificial intelligence and machine learning.

Leap Motion Clusters Particles

1. Introduction:

This document provides a step-by-step workflow guide for working with Clusters Project in Unity 2022.7.3. It's a particle system based on attractions and repulsions between colored dots. (Clusters use a unique algorithm that gives life-like behaviors to particle systems).

2. Importing Project to Unity

Follow these steps to run the project

- Clone https://github.com/leapmotion/Particles
- Launch Unity hub and add Cloned project
- Run the Cloned project

3. Testing the Project

- Open Particles Desktop Scene(Located at: Assets\ParticlesApp\Particles Desktop Scene.unity).
- Play and use mouse to move particles
- Use the Dev menu on the right to control the environment and clusters behavior.

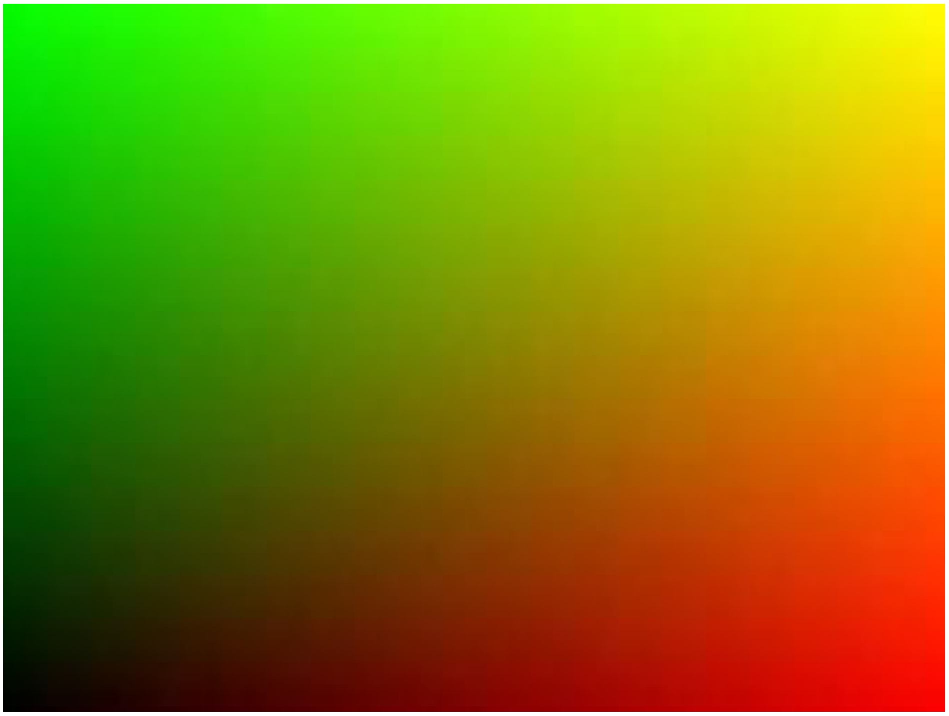
4. Information on this Unity git repo

A particle has 3 properties :

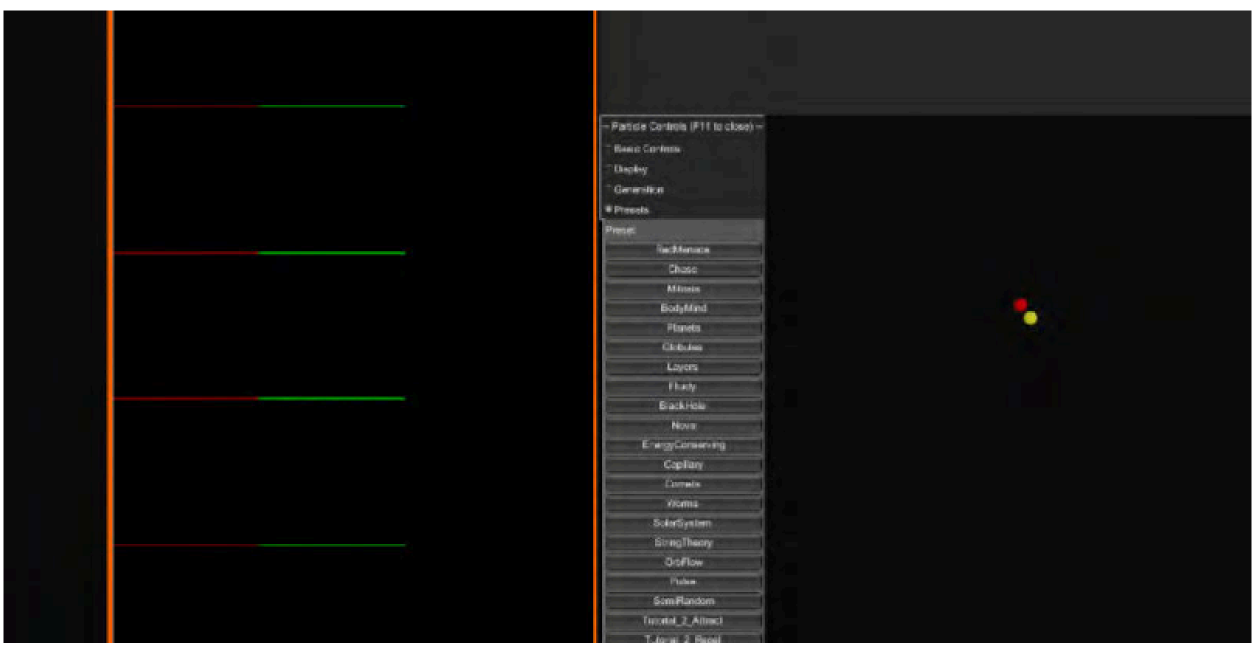
- Position
- Color
- Velocity

Particles can be Attracted to or Repelled by each other, this Depends on their Colors. Each particle has a circular region that can see other particles and cannot see beyond that region. Clusters Social and organism like behavior is computed in GPU.
The Shader Used for its Computing is “SimulationShader” located at:
Assets/ParticlesApp/ParticlesEngine/SimTexture/Shaders/SimulationShader.shader

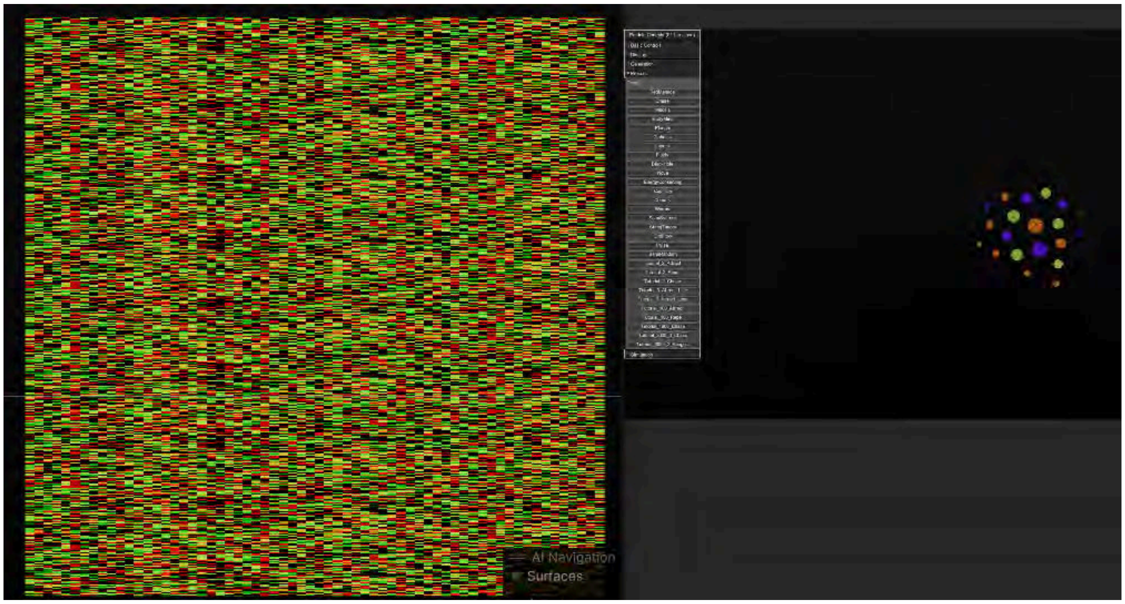
From previously hardcoded organisms, the project generates a Mesh which is used for computing particle behavior with the same or different species. Social forces and range is read from meshes UVS.



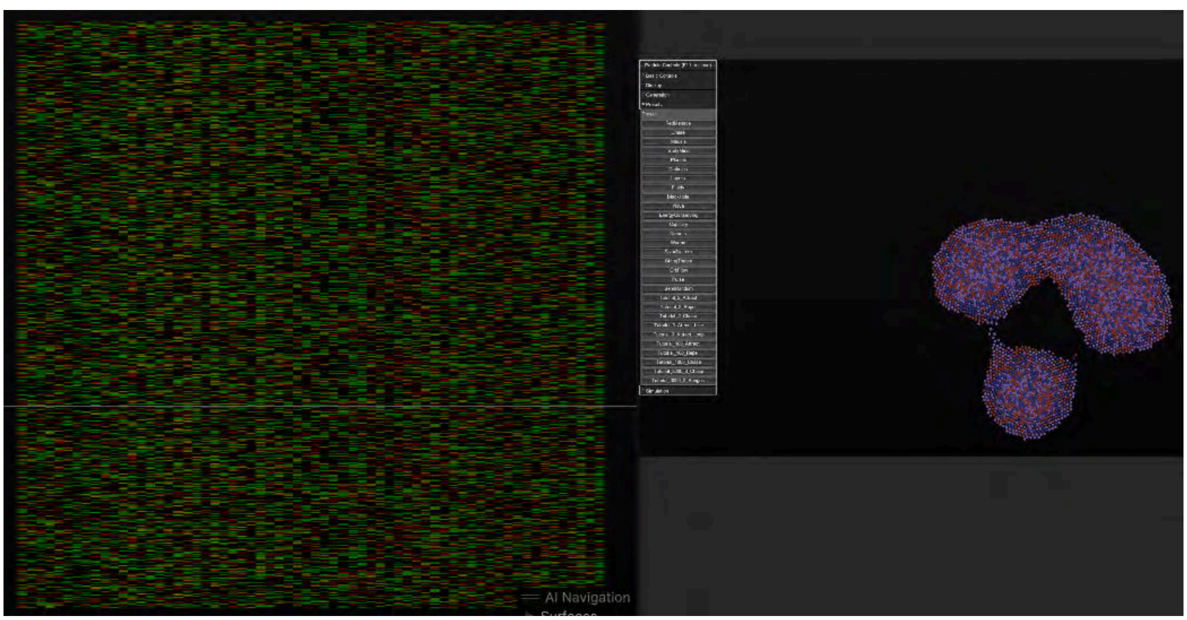
Forces toward a direction is shown in the pictures below:



As you can see , there are only 2 spots taken and it’s changing color based on each particle's direction of force. Yellow particle is forcing the red particle to the north west direction , which in the social behavior texture on the right is shown green, and vice versa.Social Behavior Texture of a semi active Organism:



Low socially active Organism Social Data:



Gravitation Towards Center

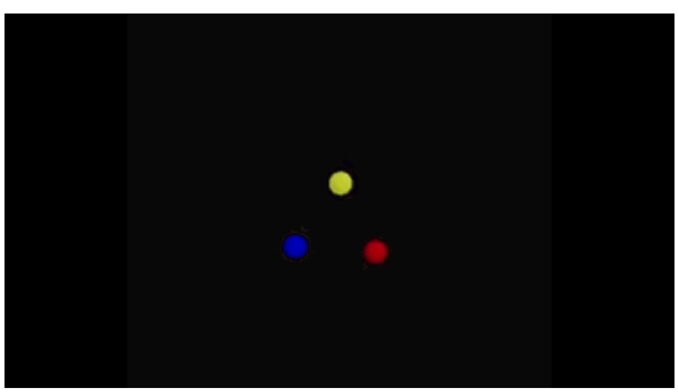
Clusters are Drawn to the Center with a Constant force :

```
half4 globalForces(v2f_p i) : SV_Target{
  half4 velocity = tex2Dlod0(_ParticleVelocities, i.uv.xy);
  half4 particle = tex2Dlod0(_ParticlePositions, i.uv.xy);

  //Attraction towards the origin
  half3 toFieldCenter = _FieldCenter - particle.xyz;
  half dist = length(toFieldCenter);
  if (dist > _FieldRadius) {
    velocity.xyz += toFieldCenter * _FieldForce;
  }
```

Social Organisms Presets

Presets are hardcoded to make a custom organism, you have to supply its color, social behavior and species data of each species. In the social data part, you can specify how each species behaves about other species. In the example above, there are 3 species in total. The first species that is red loves the second species which is yellow, meaning that it will chase yellow , while yellow hates red which means it's getting repelled from red, blue loves red and hates yellow.

```
} else if (preset == EcosystemPreset.Tutorial_3_Attract_Loop) {
  currentSimulationSpeciesCount = 3;
  particlesToSimulate = 3;

  int steps = 0;
  float drag = 0.1f;
  float collision = 0.02f;
  float epsilon = 0.0001f; //Alex: this is a bandaid for a side effect

  colors[0] = new Color(1.0f, 0.0f, 0.0f);
  colors[1] = new Color(1.0f, 1.0f, 0.0f);
  colors[2] = new Color(0.0f, 0.0f, 1.0f);

  for (int s = 0; s < currentSimulationSpeciesCount; s++)
  {
    speciesData[s] = new Vector3(drag, steps, collision);

    for (int o = 0; o < currentSimulationSpeciesCount; o++)
    {
      socialData[s, o] = new Vector2(0.0f, epsilon);
    }
  }

  float nextLove = 0.001f;
  float nextRange = 0.5f;

  socialData[0, 1] = new Vector2(nextLove, nextRange);
  socialData[1, 2] = new Vector2(nextLove, nextRange);
  socialData[2, 0] = new Vector2(nextLove, nextRange);

  particlePositions[0] = new Vector3(-0.2f, -0.17f, 0.0f);
  particlePositions[1] = new Vector3(0.2f, -0.17f, 0.0f);
  particlePositions[2] = new Vector3(0.0f, 0.20f, 0.0f);

  for (int p = 0; p < particlesToSimulate; p++) {
    particleSpecies[p] = p;
    particleVelocities[p] = Vector3.zero;
  }
```



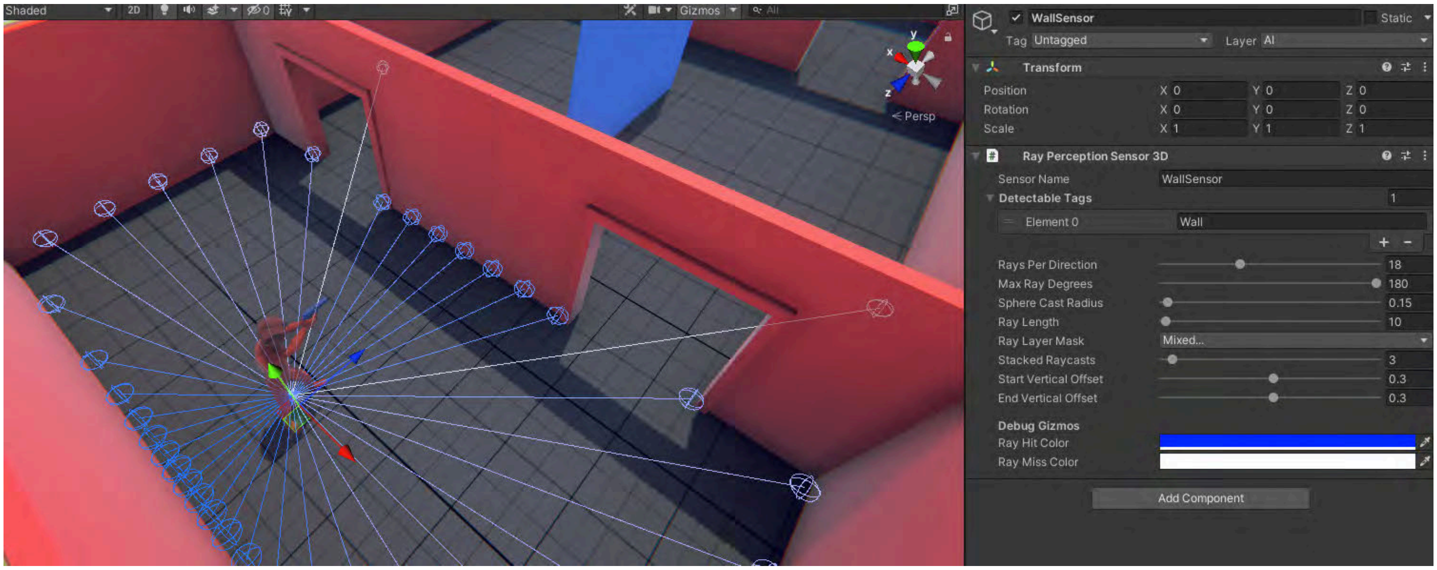
The math behind every particle behavior towards other particles:

```
half4 dampVelocities(Interpolator_p i) : SV_Target
{
    half4 velocity = tex2Dlod0(_ParticleVelocities, i.uv.xy);
    half4 particle = tex2Dlod0(_ParticlePositions, i.uv.xy);

    //Step offset for social forces
    i.uv.y = i.uv.y / MAX_FORCE_STEPS + i.uv.z / MAX_FORCE_STEPS;
    half4 socialForce = tex2Dlod0(_ParticleSocialForces, i.uv.xy);
    velocity.xyz += socialForce.xyz * 0.1 * lerp(0, 1, velocity.w);

    //Damping
    //velocity.xyz *= lerp(1, i.uv.w, velocity.w);
    float dampedUvw = lerp(i.uv.w, 0.95, _ResetPercent);
    velocity.xyz *= lerp(1,dampedUvw , velocity.w);

    return velocity;
}
```

Social force is a vector that its x axis is the social force and y axis the range of each particle view.
W in the damping section is drag.

General description of this PhD research version of the project

The overall project workflow involves a number of intelligent agents moving around specific targets. These intelligent agents have been developed using the ML Agents toolkit. Our main challenge pertains to the primary sensors of ML Agents, which are only capable of perceiving the surrounding environment in two dimensions, not three. This limitation poses significant issues for agents that need to navigate intelligently in all three axes. Initially, I attempted to address this problem using various techniques; however, these methods proved to be ineffective. For instance, rotating the agents around their own axes to analyze the entire surrounding environment did not yield the desired results.

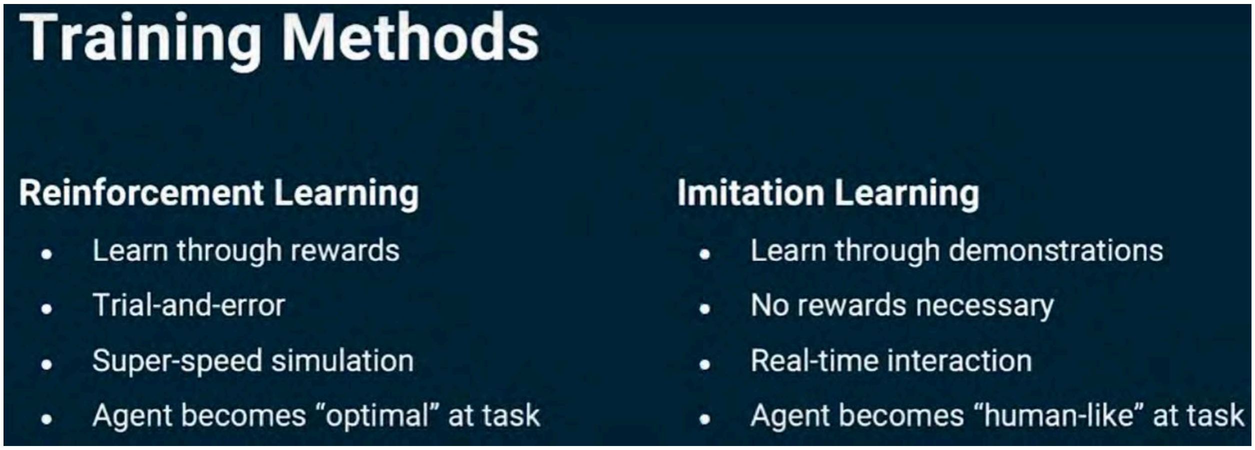


ML Agents

ML-Agents is an open-source project that enables games and simulations to serve as environments for training intelligent agents. It includes a C# SDK to set up a scene and define the agents within it, and a state-of-the-art machine learning library to train agents for 2D, 3D, and VR/AR environments. Unity ML Agents Toolkit can be found in the following git repo:
https://github.com/Unity-Technologies/ml-agents

Machine Learning is essentially any technique that instead of hard coding behaviors, the developer allows the machine to decide how to act, based on learning from data.

The 2 Most prominent Training Methods that unity provides:



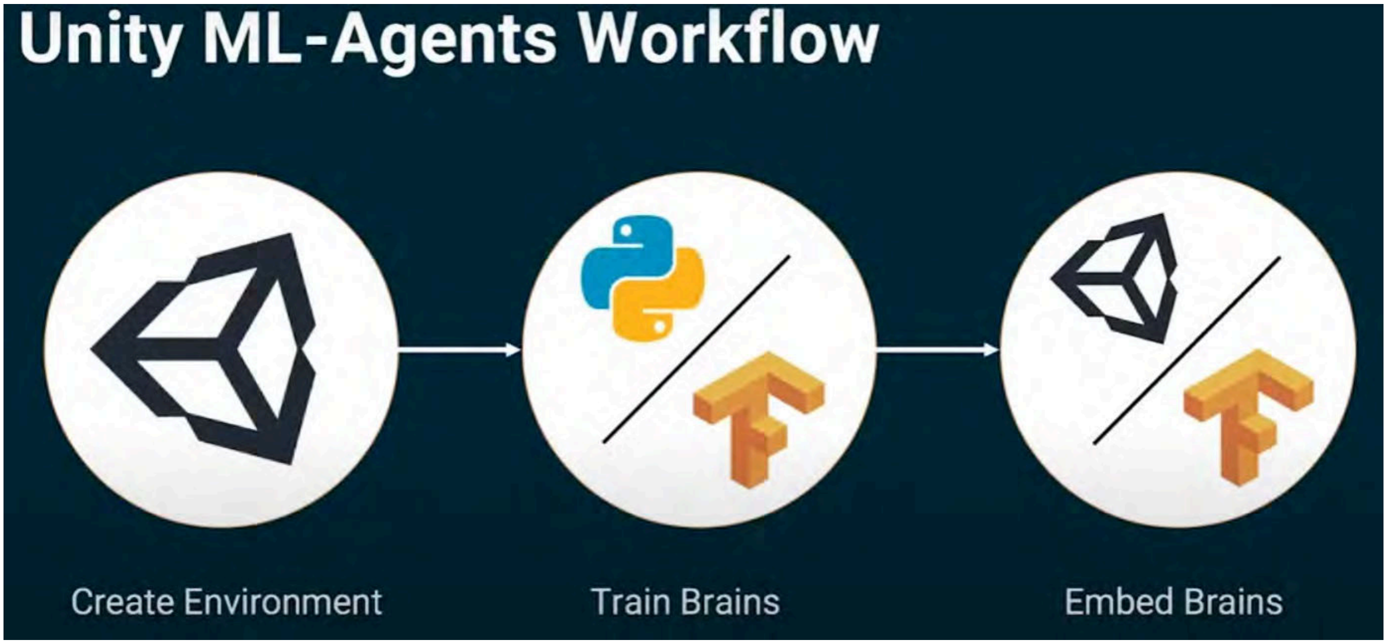
Reinforcement Learning

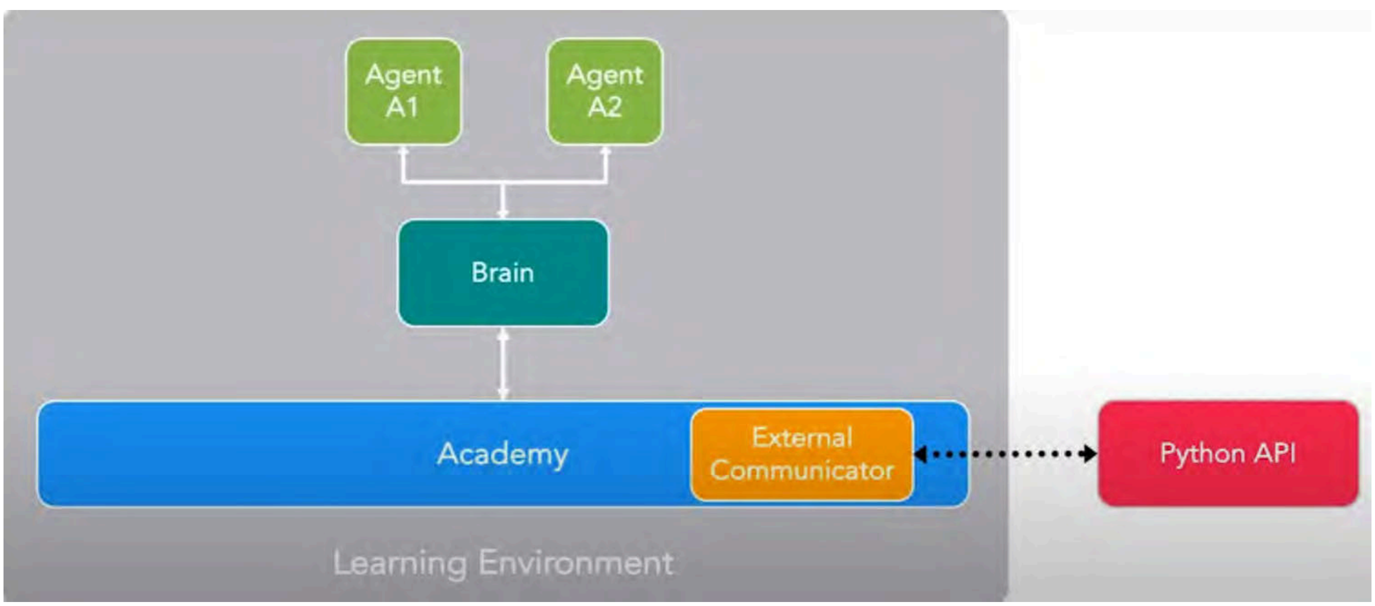
In reinforcement Learning, the primary learning Signal is Reward. This reward is a scalar value that can be provided to the agent at any time during the simulation. The developer has to choose what that reward is and when it's provided. The developer can Discourage or Encourage their behavior through positive and negative rewards .

Imitation Learning

Imitation Learning simply requires a set of demonstrations. These demonstrations are observation action pairs which can be recorded directly from a keyboard or gamepad. These observations can be provided by the player or developer by actually playing the game.

This is a good option in scenarios where the reward option is difficult to define by hand and it’s simpler to just show the agent what acting correctly looks like.


Unity ML-Agents Workflow
Create Environment
Train Brains
Embed Brains


Agent
A1
Agent
A2
Brain
Academy
External
Communicator
Python API
Learning Environment

The Academy

At the lowest level the academy is what allows everything to work together and allows unity to communicate with outside training frameworks.

The Brain

The brains are what actually make decisions and these can be thought of as our neural networks.

The Agents

With what the brain provides for the developer, the developer needs things to take these decisions and act on them in the world, these are our agents. Agents observe the world at any step of the simulation, and uses that observation via the brain to take actions in the world.

Notes: The developer can not increase the "Agent's Sensors" after Deep Learning has been done!

Tips for a Better Ai Agent

- Start Simple. Think of the simplest way to set up the AI and make the AI fail quickly and fail often.
- Work Carefully. Work slower, take your time, outline and design your code structure before waiting several hours just to see you made a tiny mistake.
- Be your own Tester, by using Player Brains you can pretend to be your ai and try everything and actually try to break your own system
- Human demonstrations.
- Shape Your Rewards Carefully.
- Adding a small penalty after each step(AddReward(-1/MaxSteps))

Adding custom Statistics to Tensor Board

Using the Stats Recorder (refer to https://docs.unity3d.com/Packages/com.unity.ml-agents@1.0/api/Unity.MLAgents.StatsRecorder.html), you can Add custom variables to the tensor board.

public void Add(string key, float value, StatAggregationMethod aggregationMethod = default(StatAggregationMethod))

By default, it averages all the values collected in the last 10/000 steps. You can change this default value by changing summary-freq: in the .yaml file.

Changing StatAggregationMethod to mostRecent, will get the last value like a high score.
When declaring a key, using / will make sub categories in the tensor board.

Imitation learning

Imitation learning is a training technique that the developer can use to train agents by example.

Imitation Learning Guide

Refere to the following document:
https://github.com/yosider/ml-agents-1/blob/master/docs/Training-Imitation-Learning.md

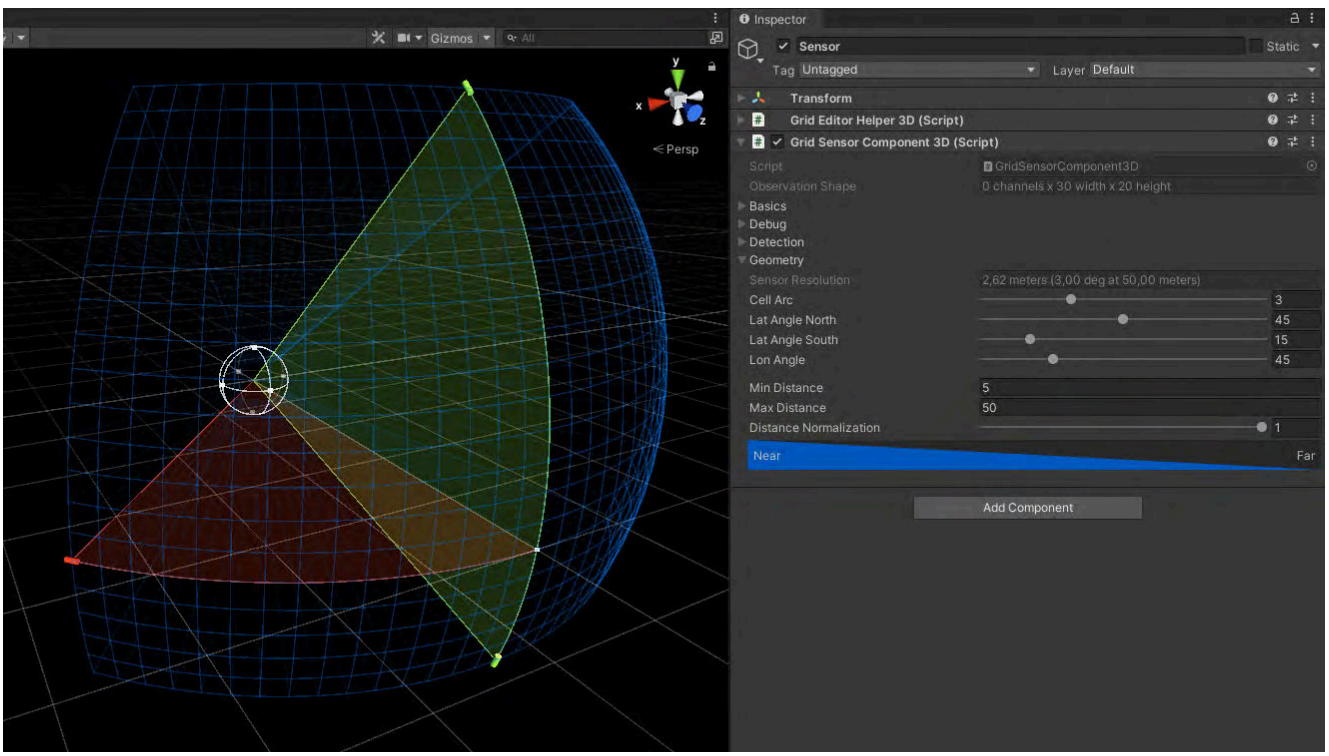
The ML-Agents toolkit provides two features that enable your agent to learn from demonstrations. In most scenarios, you should combine these two features :

- GAIL (Generative Adversarial Imitation Learning) uses an adversarial approach to reward your Agent for behaving similar to a set of demonstrations. To use GAIL, you can add the GAIL reward signal. GAIL can be used with or without environment rewards, and works well when there are a limited number of demonstrations.

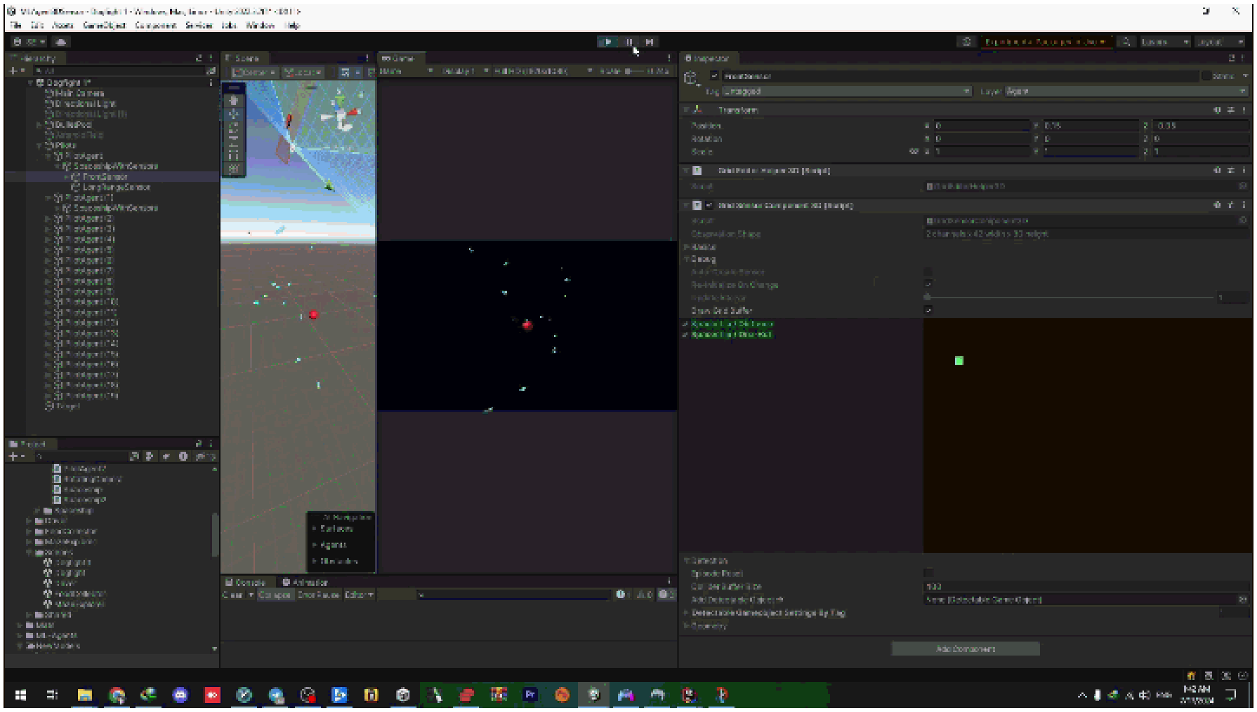
- Behavioral Cloning (BC) trains the Agent's neural network to exactly mimic the actions shown in a set of demonstrations. The BC feature can be enabled on the PPO or SAC trainer. BC tends to work best when there are a lot of demonstrations, or in conjunction with GAIL and/or an extrinsic reward.

ML Agent 3D Sensor

Grid Sensor Components for Unity ML-Agents



Custom 3d grid sensor in [MLAgent3DSensor.rar]() project :



As you can see, it shows us what the 3d sensor is seeing right now using a Grid Buffer, grid buffer is a 3D data structure for storing float values. It sees and detects any gameobject with the DetectableGameObject.cs Script component on it based on its Distance.

Getting Detected Game Objects of the 3d Sensor Based on a Specified Tag :

```
// Find targets in vicinity.
foreach (var target GameObject in m_SensorComponent.GetDetectedGameObjects(m_TargetTag))
{
    Vector3 delta = target.transform.position - pos;
    if (Vector3.Angle(fwd, delta) < m_TargetFollowAngle &&
        delta.sqrMagnitude < m_TargetFollowDistanceSqr)
    {
        m_Targets.Add(target);
    }
}
```

Trying to Punish agent if it Doesn't Move towards The Target :

```
// Speed towards target.
Vector3 deltaToTarget = targetTransform.transform.position - pos;
float speedTowardsTarget = Vector3.Dot(deltaToTarget.normalized, vlc);
AddReward(speedTowardsTarget * 0.01f);
if (speedTowardsTarget <= 0)
{
    AddReward(-0.01f);
}
```

Trying to punish agent if its Distance is more than Specified :

```
var distanceToTarget = Vector3.Distance(pos, targetTransform.position);
if (distanceToTarget > m_TargetFollowDistance)
{
    AddReward(distanceToTarget * -0.005f);

}
```

Trying to Simulate a Chase like Behaviour by Punishing chased agent :

```
Vector3 pos = m_Ship.transform.position;
Vector3 fwd = m_Ship.transform.forward;
Vector3 vlc = m_Ship.WorldVelocity;

foreach (var target in m_Targets)
{
    Vector3 delta = target.transform.position - pos;
    // Speed towards target.
    float speed = Vector3.Dot(delta.normalized, vlc);
    AddReward(speed * 0.01f);

    if (speed > 0)
    {
        // Penalize opponent for being followed.
        if(s_TargetCache.Count == 0){continue;}
        if(s_TargetCache.ContainsKey(target) == false){continue;}
        s_TargetCache[target].AddReward(speed * -0.005f);
    }

}
```

For each agent that the Chaser Agent sees, I decided to punish the Followed agent Like a dog fight situation.

Class RayPerceptionSensorComponent3D | ML Agents | 1.0.8
https://youtu.be/IiWdLrv8pY0

Setup ML Agents

Install anaconda:

- Download Anaconda Distribution and install it.(I do not recommend using CMD for working with this tool.)

- Why anaconda?
  - ❖ You can easily create and manage multiple virtual environments with different versions of Python and the required packages. This allows you to keep different projects with distinct configurations separate from each other.

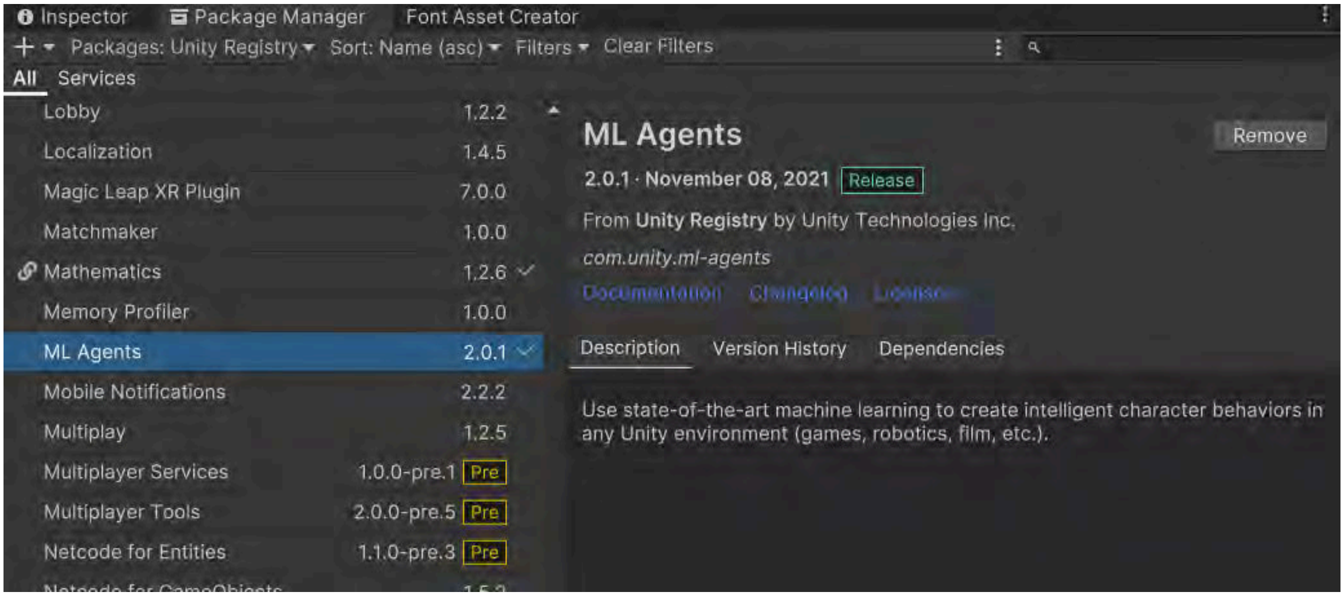
- It includes Conda, which simplifies the installation, updating, and removal of packages while managing dependencies. Additionally, many scientific and machine learning-related packages are available pre-built.
- It comes with a variety of tools like Jupyter Notebook, Spyder, and other scientific tools, which are very useful for developing and testing machine learning models.
- It ensures that packages and environments are compatible with each other, helping to reduce issues caused by version incompatibilities.

- Install points:
    - During installation, do not select the 'Add Anaconda to my PATH environment variable' option, and use Anaconda Navigator for managing environments.
    - After installation, open Anaconda Navigator to ensure that the installation was completed correctly.

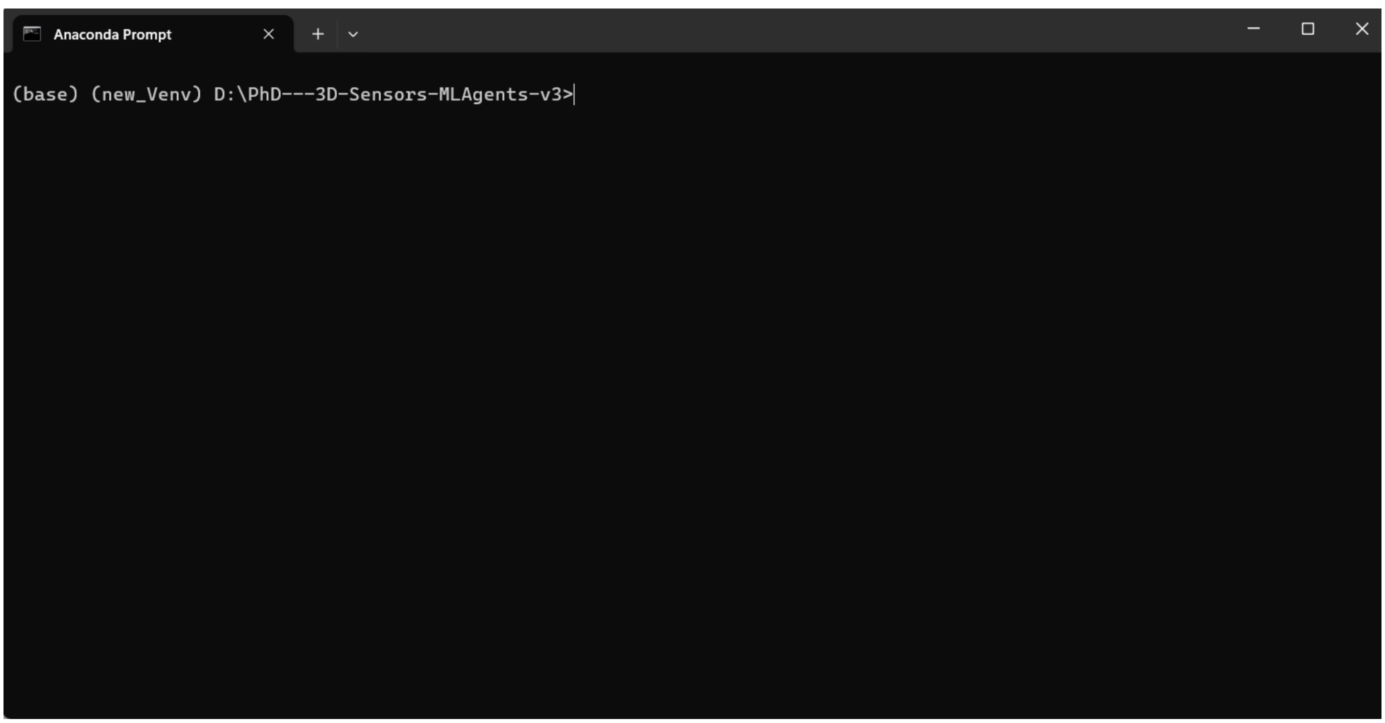
Setup project:

Please note that the recommended versions of the tools are for the present time (2023-2024), and in the future, it may be necessary to use more updated versions.

1. Install the ML-Agents asset in the project through the Package Manager.



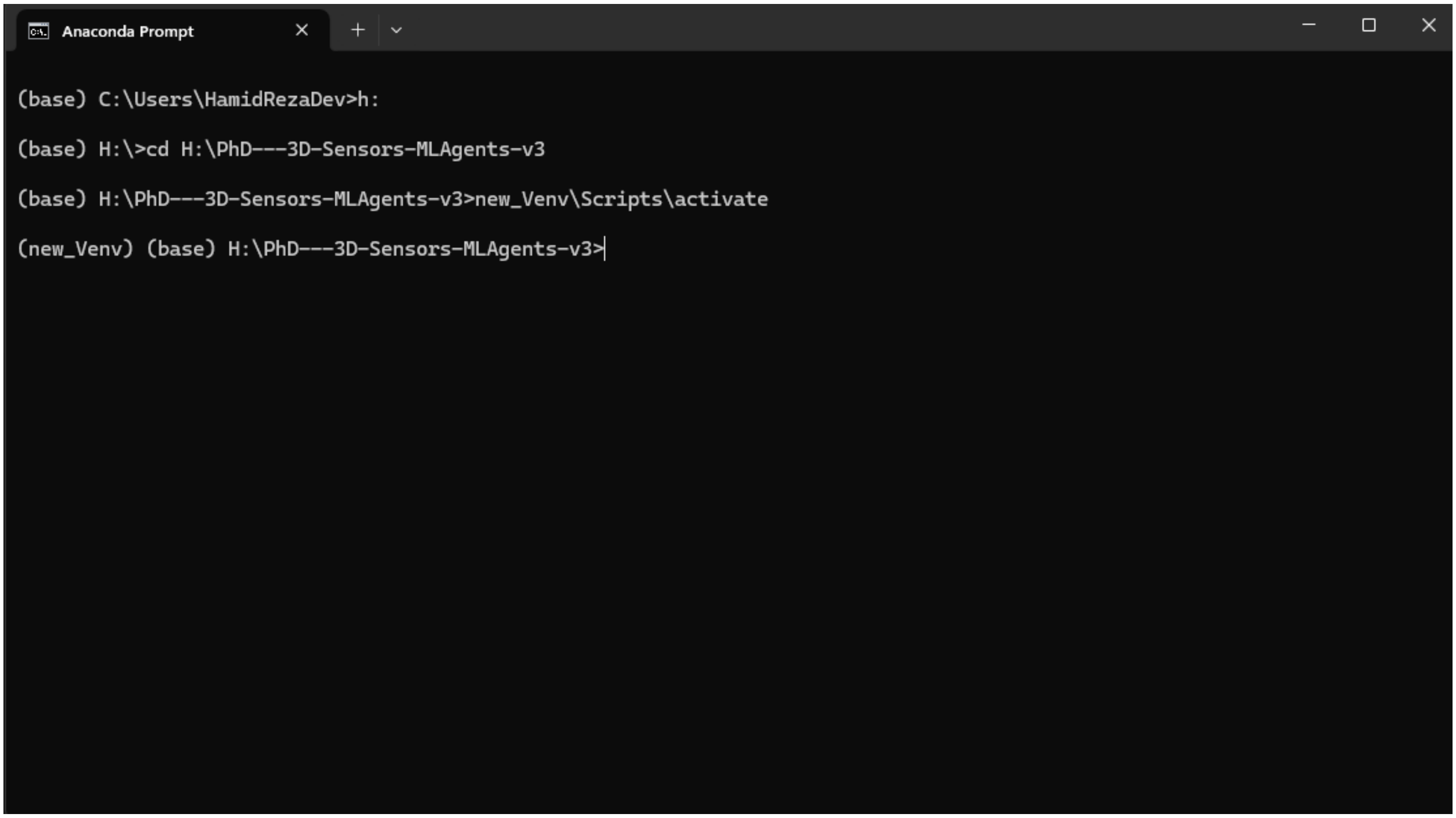
2. Open anaconda and set your project path.



3. Enter the commands

Enter the commands listed below in the console in order. Keep in mind that it is crucial for the different tool versions to be compatible, and note that current versions may become outdated in the future. Additionally, make sure that the process for executing each command is completed successfully and correctly. If you encounter any errors or issues, pay attention to the comment in the console and resolve the problem accordingly. Do not proceed to the next command until the issue is resolved!

- Currently, make sure to have Python version 3.9 installed on your system. Other versions, including newer ones, may cause issues or disrupt the process!
- Install python with this command “conda install python=3.9” and check the current version with this command “python --version”.
- Update pip with this command “pip install --upgrade pip”
- Install pytorch with this commnad “conda install pytorch torchvision torchaudio -c pytorch -c nvidia“
- Install mlagents with this command “pip install mlagents”
- Verify the installation of ML-Agents with this command “mlagents-learn --help”, After running this command, you should not encounter any errors. If you do, it means the installation process encountered an issue.
- Create an environment for training models with this command “conda create -n ml-agents-env python=3.9”
- Then, activate it with this command “conda activate ml-agents-env” or just enter activate file path “....\ml-agents-env\Scripts\activate”



Train Model:

1. After writing the code for the Agent and designing and setting up the environment in the engine, run the scene and execute this command in the console "**mlagents-learn -run-id="Enter a name" -train**"
2. To train the model more efficiently and systematically, use the YAML(YAML file) file for this purpose. For this purpose, enter the `train` command as follows " mlagents-learn "config file path" —run-id="Enter a name" —train —force"
3. Additionally, if the training process is interrupted and you want to resume it, enter the following command " mlagents-learn "config file path" —run-id="Enter a name" —train —resume"
4. Additionally, if you have already completed the training process and intend to start over with a new environment and settings, initiate the training process by

calling the model with the following command:“ mlagents-learn “config file path” —run-id=”Enter a name” —initialize-from=”last id name” --train”

YAML - “Yet Another Markup Language”

1. What is a YAML file?

YAML (YAML Ain't Markup Language) is a structured data format used for configuration settings. In ML-Agents, YAML files are used to define various training parameters such as hyperparameters, neural network structure, reward signals, and more.

```yaml
behaviors:
  JetAgent:
    trainer_type: ppo
    hyperparameters:
      batch_size: 1024
      buffer_size: 10240
      learning_rate: 3.0e-4
      beta: 5.0e-3
      epsilon: 0.2
      lambd: 0.95
      num_epoch: 3
    network_settings:
      normalize: false
      hidden_units: 128
      num_layers: 2
    reward_signals:
      extrinsic:
        gamma: 0.99
        strength: 1.0
    max_steps: 500000
    time_horizon: 64
    summary_freq: 10000
```

2. Role of the YAML file in ML-Agents

   The YAML file acts as a configuration file that defines various settings related to the model training process. This file allows the `mlagents-learn` tool to train the model using the specified configurations.

3. Structure and Key Sections of a YAML file:

   A YAML file in ML-Agents typically includes the following sections:

   - behaviors
     This section includes settings related to the various behaviors of Agents. Each behavior can have its own specific configurations
   - trainer_type
     Specifies the type of training algorithm. ML-Agents support various algorithms, such as PPO (Proximal Policy Optimization).
   - hyperparameters
     This section contains hyperparameters related to model training, which have a direct impact on the performance and speed of training:

       - **batch_size**: The number of samples used in each model update.
       - **buffer_size**: The size of the experience buffer from which the model learns.
       - **learning_rate**: Determines how quickly the model's weights are updated.
       - **beta**: A regularization coefficient to prevent overfitting.
       - **epsilon**: A parameter to control allowable changes in the model's policy.
       - **lambd**: GAE (Generalized Advantage Estimation) parameter used to estimate advantages.

- **num_epoch**: The number of times each data batch is used in an update.
- **learning_rate_schedule**: The schedule for adjusting the learning rate (e.g., linear, constant).

- network_settings
  Settings related to the model's neural network:

  - **normalize**: Whether to normalize the input data or not.
  - **hidden_units**: The number of hidden units in each layer.
  - **num_layers**: The number of hidden layers in the neural network.

- reward_signals
  Reward signals that the model uses to learn:

  - **extrinsic**: External rewards obtained from the environment.
  - **gamma**: The discount factor for future rewards.
  - **strength**: The strength of the reward signal.

- other settings
  - **keep_checkpoints**: The number of checkpoints to retain.
  - **max_steps**: The maximum number of training steps.
  - **num_sequences**: The number of temporal sequences the model uses.
  - **time_horizon**: The time duration before each model update.
  - **summary_freq**: The frequency of reporting training summaries.

4. Impact of YAML Settings on Model Training

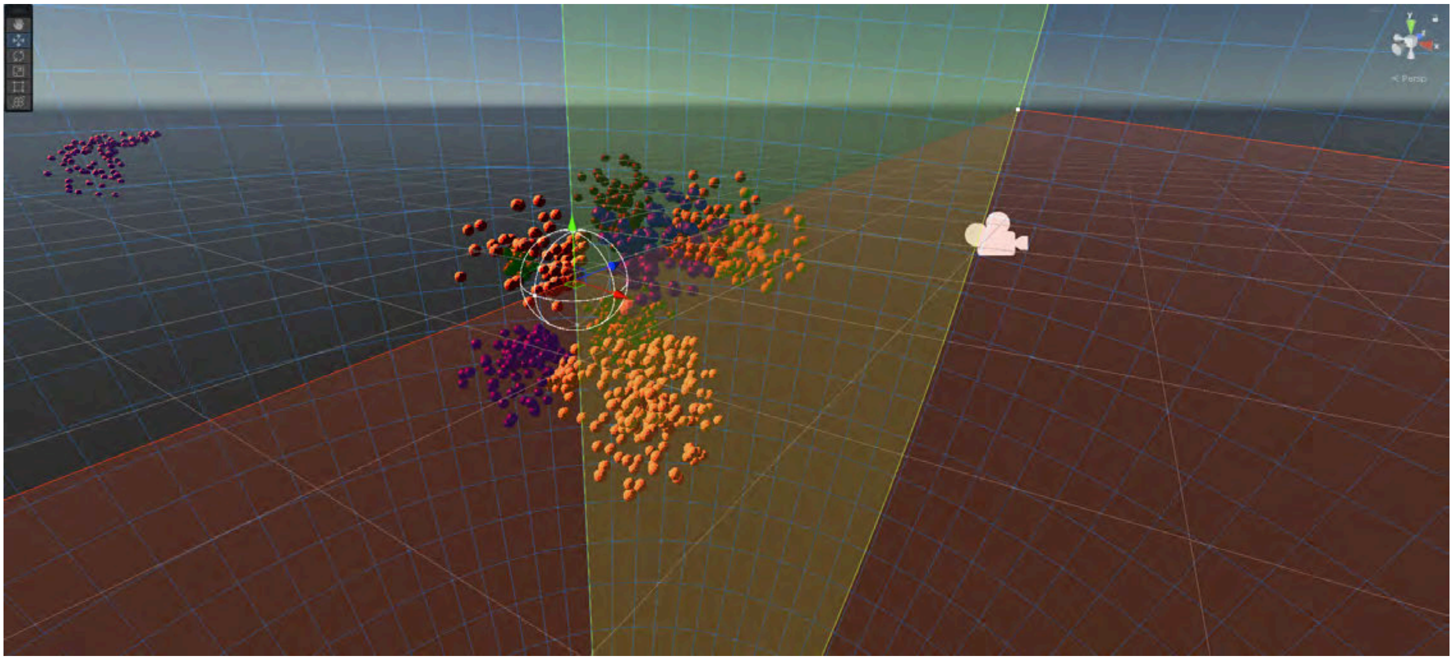
Various settings in the YAML file can significantly affect the performance, speed, and quality of model training:

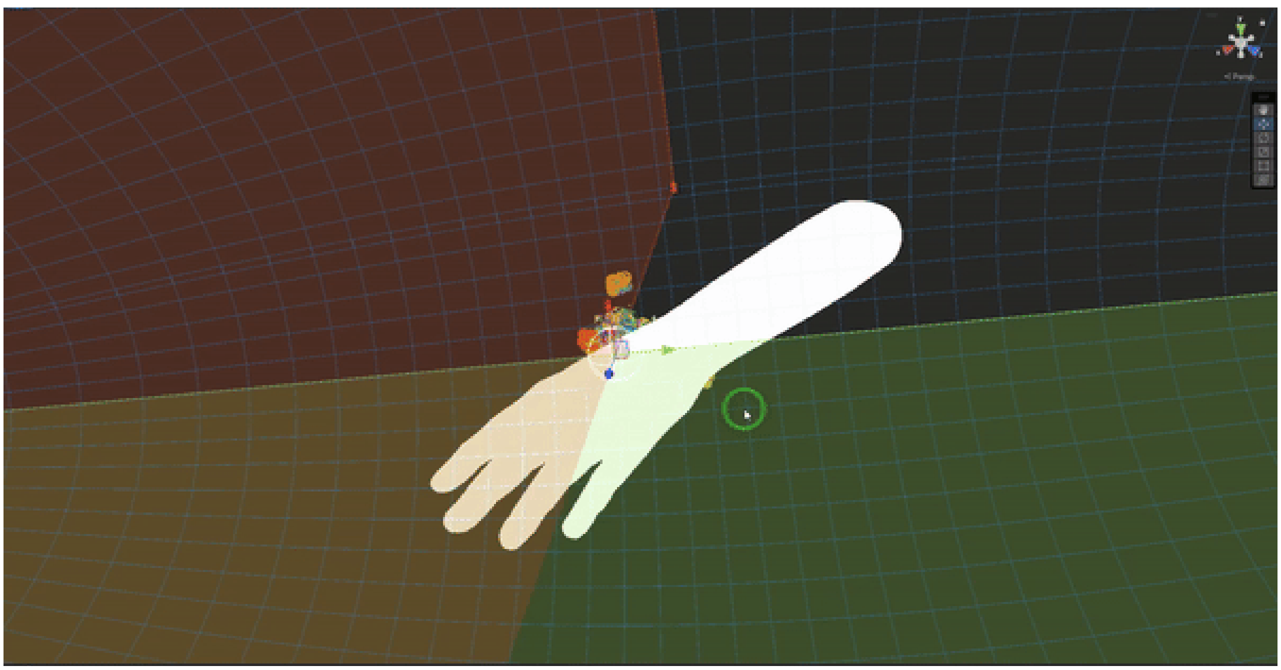
1. hyperparameters
    - **Learning Rate (learning_rate):** A higher learning rate can lead to faster convergence, but may result in fluctuations and instability. A lower learning rate may lead to more stable and precise convergence but requires more time.
    - **Batch Size (batch_size):** A larger batch size can lead to more stable learning and higher resource efficiency, but may require more memory. A smaller batch size can enable faster training with less memory, but may result in more fluctuations.
    - **Discount Factor (gamma):** This parameter determines how much future rewards are considered. A value close to 1 causes the model to consider distant rewards, while a lower value makes the model focus more on immediate rewards.
2. Neural Network Settings
    - **Number of Layers and Units (num_layers and hidden_units):** Increasing the number of layers and units allows the model to learn more complex features, but may increase training time and data requirements, as well as the likelihood of overfitting.
    - **Normalization (normalize):** Normalizing inputs can help improve the speed and stability of training.
3. Reward Signals
    - **Reward Signal Strength (strength):** Adjusting the strength of the reward signal can control the balance between learning different behaviors. Stronger reward signals can guide the model more quickly toward desirable behaviors.
    - **Type of Reward Signals:** Using multiple reward signals can help the model learn more complex and balanced behaviors.

5. Tips and Best Practices for Setting Up the YAML File
   - **Start with Default Settings:** It's best to begin with the default settings and gradually adjust the hyperparameters.
   - **Trial and Error:** Test different settings and evaluate their impact on the model's performance.
   - **Document Changes:** Keep a record of your changes so you can easily revert to previous settings if needed.
   - **Use Separate Files for Different Experiments:** Create a separate YAML file for each experiment to easily manage different configurations.
   - **Study Educational Resources and Research Papers:** Optimal hyperparameters and settings can vary for different problems, so studying relevant educational resources and research papers can be helpful.
   - **Use Monitoring Tools:** Tools like TensorBoard can help you visualize and monitor the impact of changes in the YAML file on model training.

3D Grid Sensor Components for Unity ML-Agents

Ultimately, to address this issue, I utilized a project named Grid-Sensor developed by mbaske · GitHub . This project enabled me to train intelligent agents capable of analyzing their surrounding environment in three dimensions. This is the link to the Git repo: https://github.com/mbaske/grid-sensor





The Grid Sensor project is a powerful plugin for Unity ML Agents that enables developers and AI researchers to easily implement grid-based sensors within their interactive environments. These sensors provide intelligent agents with structured environmental information in a grid format, enhancing their performance and decision-making capabilities.

Features:

- Simplified Grid Sensor Implementation: Grid Sensor allows developers to effortlessly create and configure grid-based sensors within Unity environments.
- Compatibility with Unity ML Agents: Fully integrated with the ML Agents system, providing essential data for machine learning processes.
- Support for Diverse Configurations: Configure grid dimensions, cell sizes, types of data each cell transmits, and other related parameters.
- Performance Optimization: Designed to deliver necessary information with minimal impact on game or simulation performance.
- Comprehensive Documentation and Practical Examples: Includes guides and code samples to facilitate usage and customization.

Initial Configuration

- Importing to Unity
- Adding the Grid Sensor to an agent in ML-Agent
- Grid Dimensions: Define the number of cells along each axis (X, Y, Z) for the sensor.
- Cell Size: Specify the size of each grid cell.
- Data Types: Determine the type of information each cell should transmit (e.g., color, height, object type, etc.).

Example Code

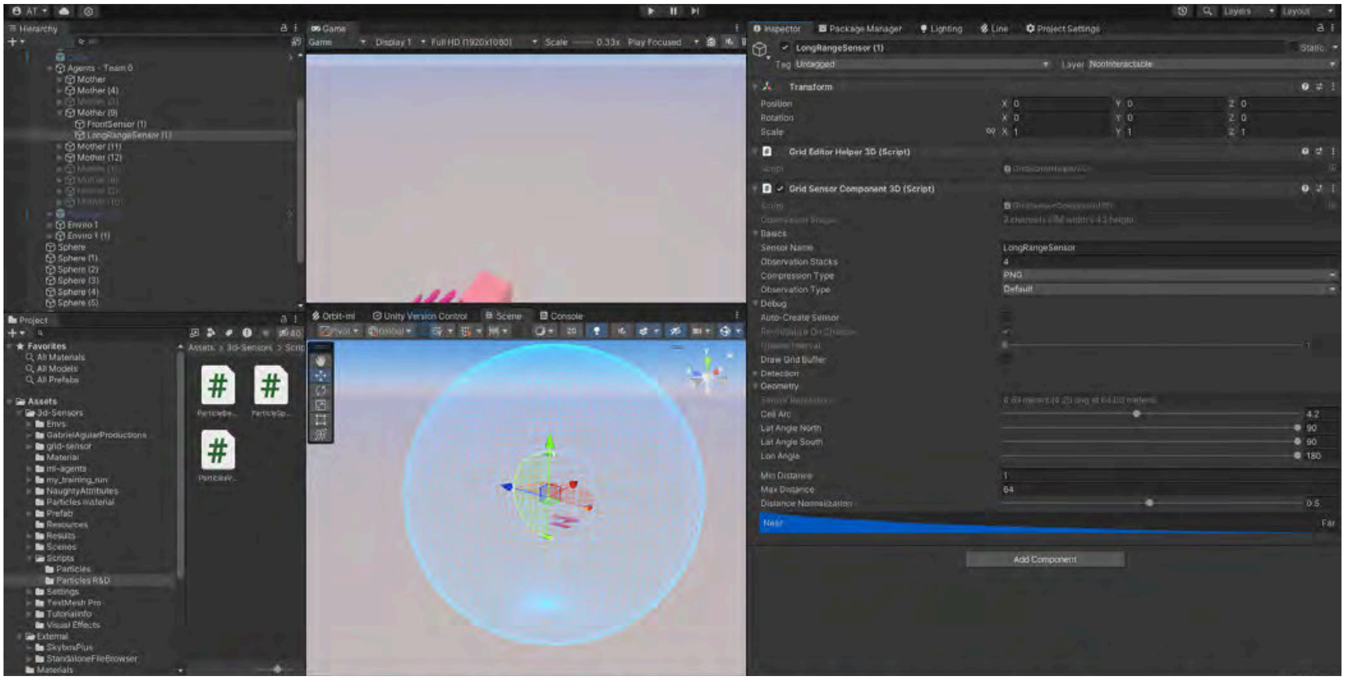
Below is an example of how to use Grid Sensor in a C# script:

—--

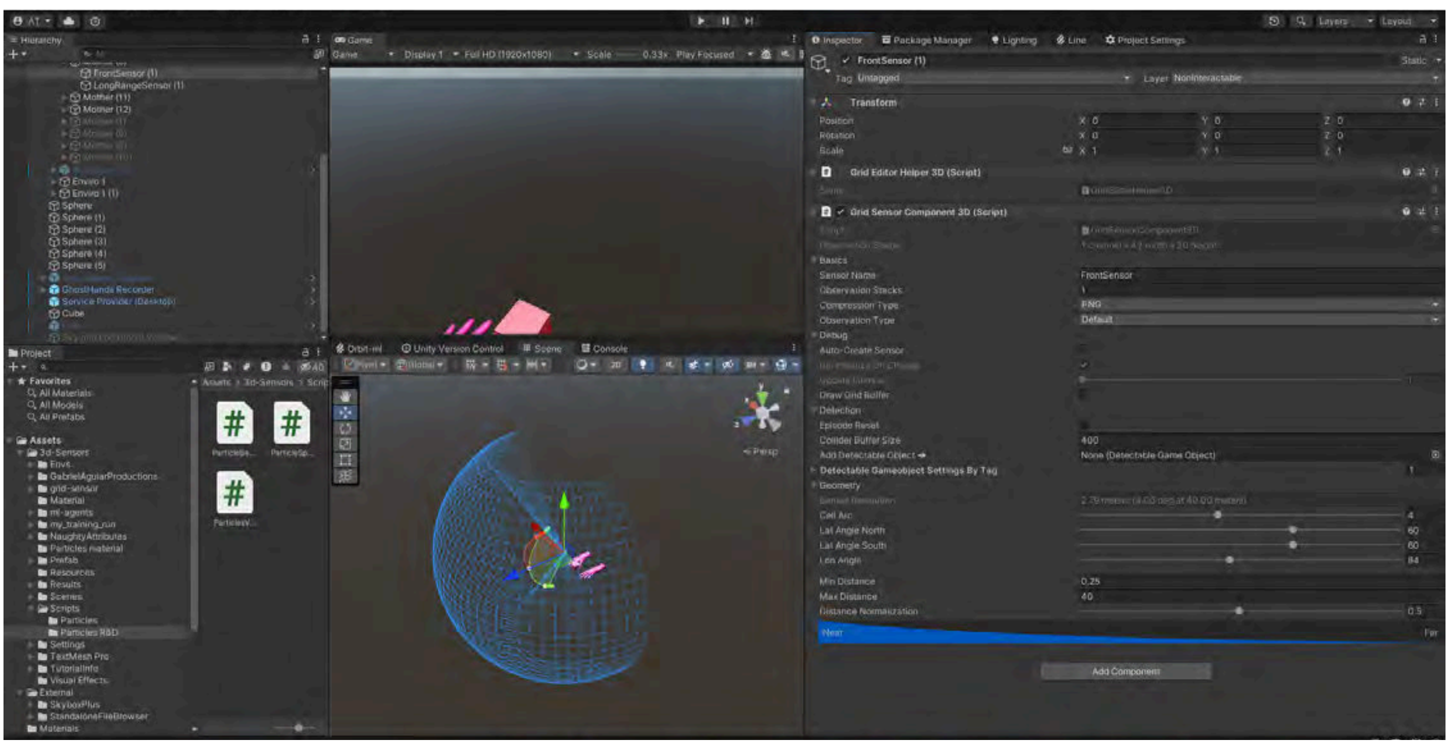
```
using Unity.MLAgents.Sensors;
using Unity.MLAgents;

public class GridAgent : Agent
{
```

```
    private GridSensorComponent3D gridSensor;

    public override void Initialize()
    {
        gridSensor = GetComponent<GridSensorComponent>();
        // Initial sensor settings
        gridSensor.SetGridDimensions(10, 10);
        gridSensor.SetCellSize(1.0f);
    }

    public override void CollectObservations(VectorSensor sensor)
    {
        // Utilize grid sensor data
        var gridData = gridSensor.GetGridData();
        foreach(var cell in gridData)
        {
            sensor.AddObservation(cell);
        }
    }

    public override void OnActionReceived(float[] vectorAction)
    {
        // Process agent actions
    }
}
```
—---

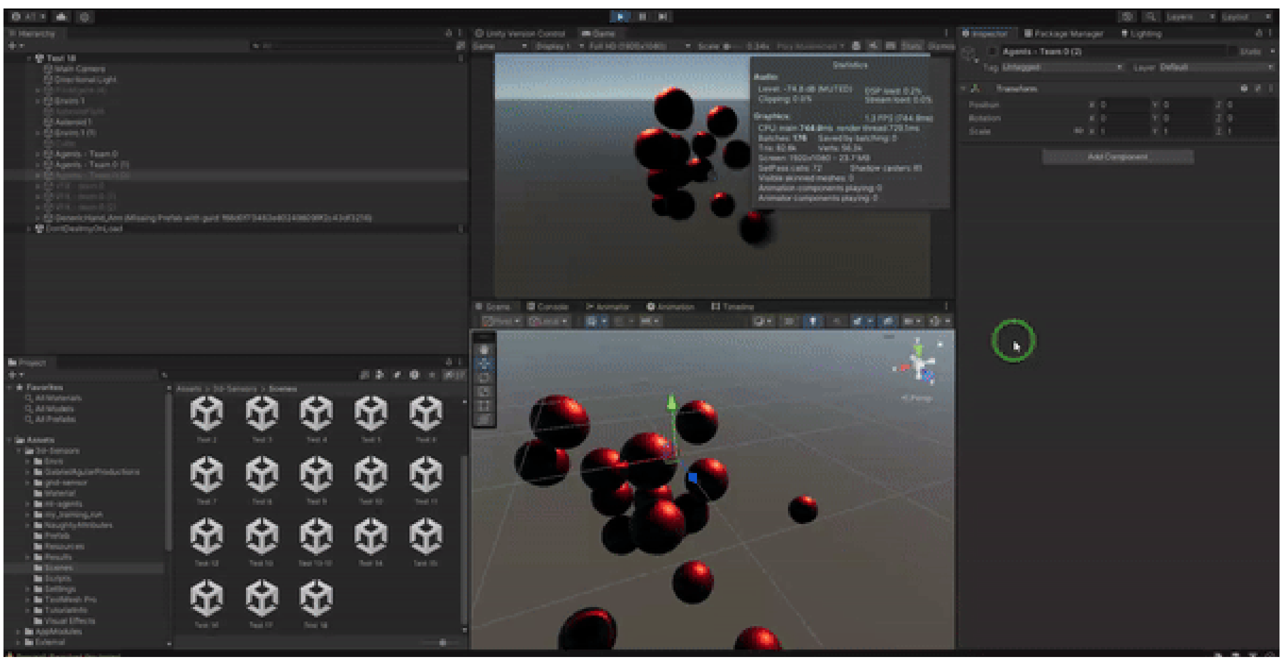
By utilising the "GridSensorComponent3D" component, I enabled agents to analyze their surrounding environment from all directions. Additionally, by configuring the parameters of this component, I was able to adjust the range, radius, and type of the sensor, allowing agents to operate more purposefully and effectively.



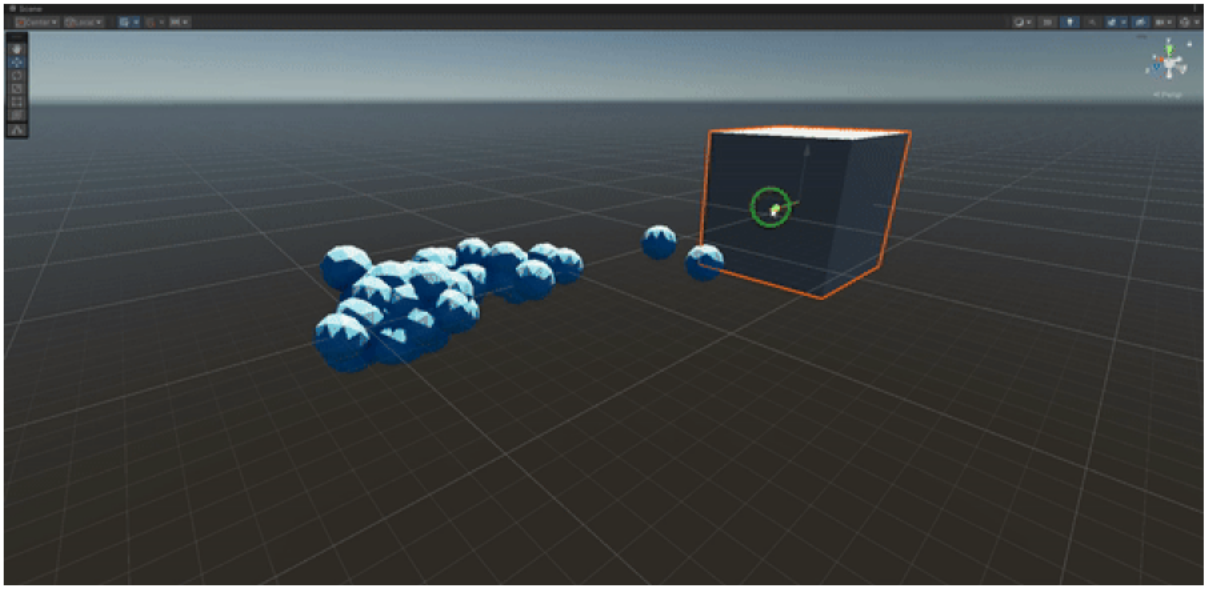
Additionally, if I aim to reduce the processing load in the future, I could limit the dimensions and coverage radius of the sensors.

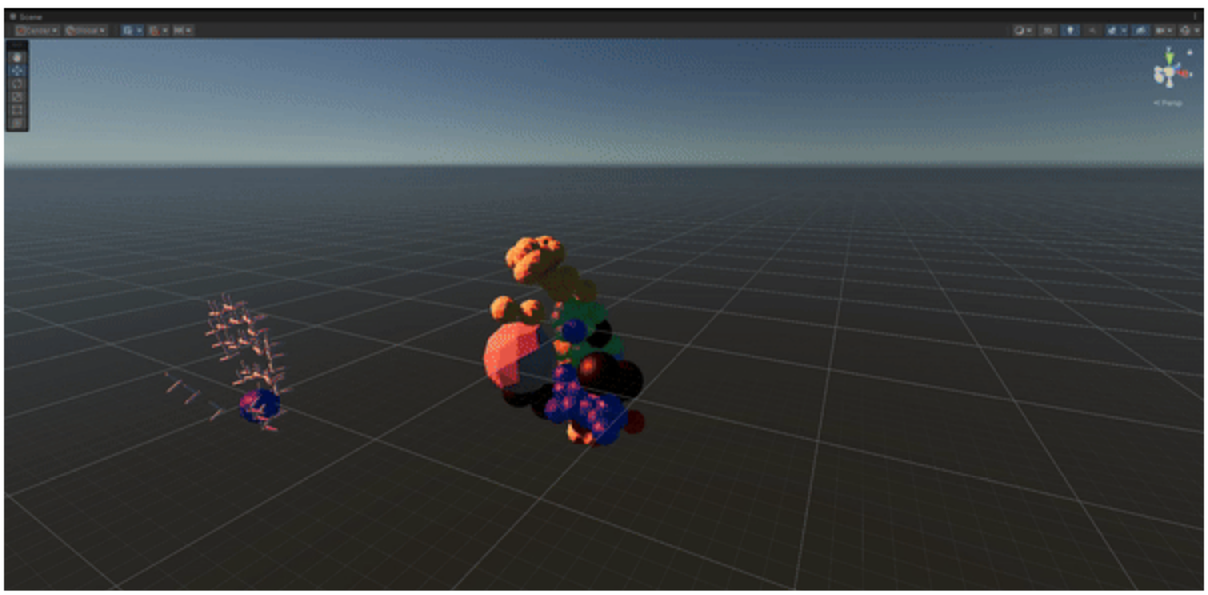


Initially, our primary strategy for training the models was to create intelligent agents that would move randomly toward a specified number of targets (which, in later stages, would be considered as part of the hand) while avoiding collisions with certain agents and not approaching others. Based on these considerations, I attempted to train several agents; however, the overall design of these agents led to the emergence of conflicts. For example, many agents did not move toward the targets to avoid obstacles, and in cases where the reward for reaching the targets outweighed the penalties, the agents struggled with target selection. Ultimately, I decided to design a relatively simpler system in which agents have a single objective and are also capable of following moving targets at any speed without deviating from them.

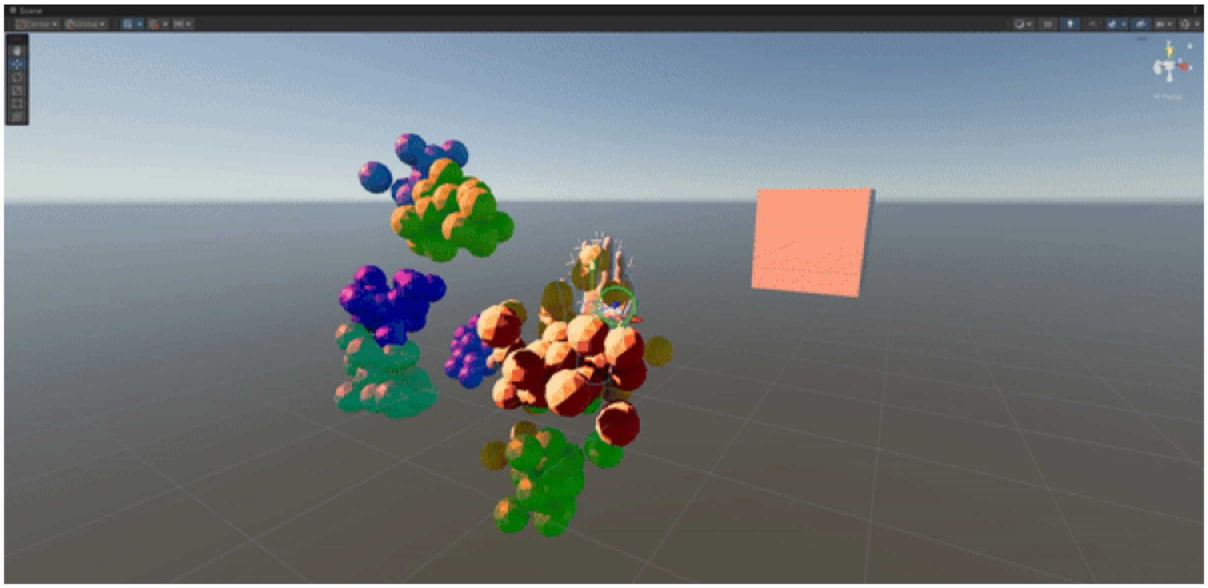


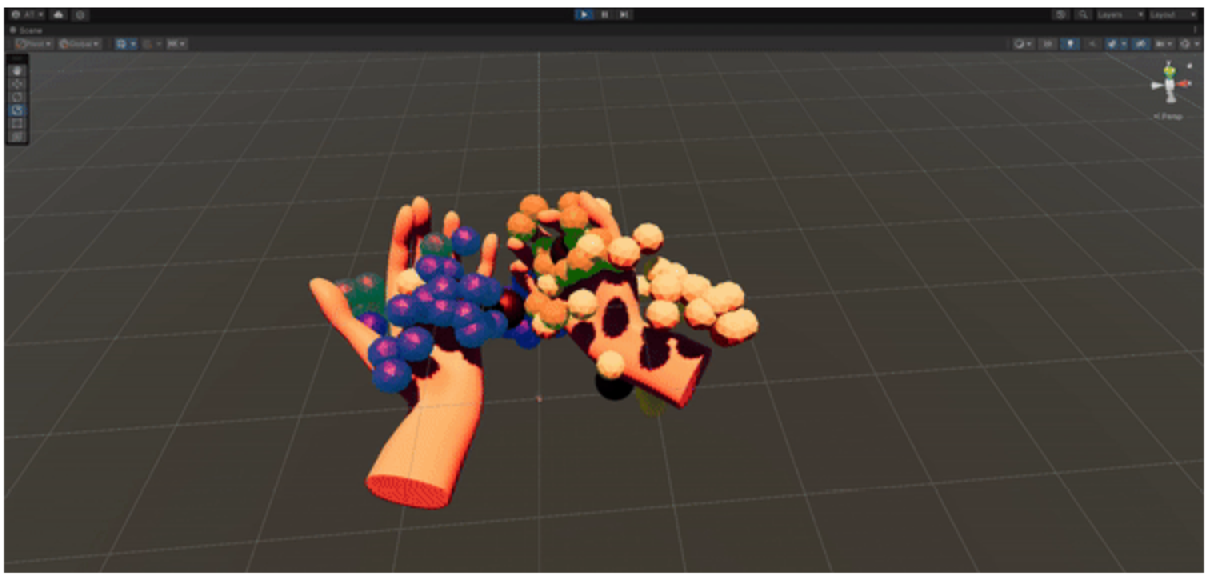
Since utilizing a large number of agents along with three-dimensional sensors requires substantial processing power, deploying numerous agents results in a decrease in frame rates. Consequently, I decided to develop a custom particle physics system that connects to these agents and can compensate for the limited number of agents. The reason for developing a separate system instead of using Unity's built-in particle system was that Unity's particle system lacks adequate physics for object collisions, and I needed to address this deficiency in some manner.

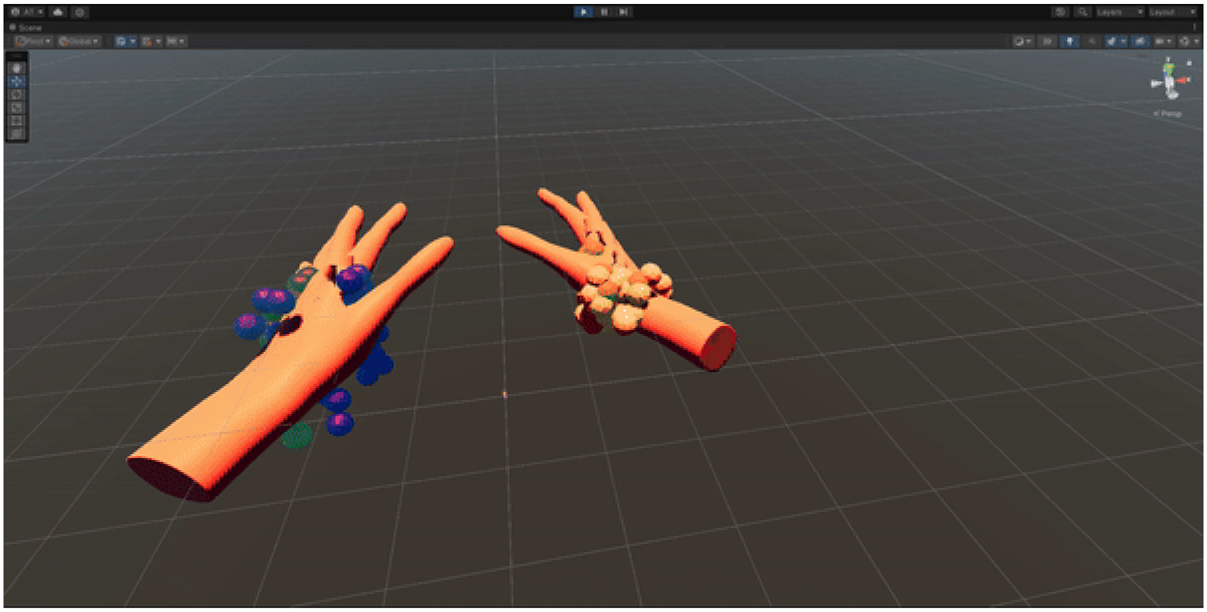




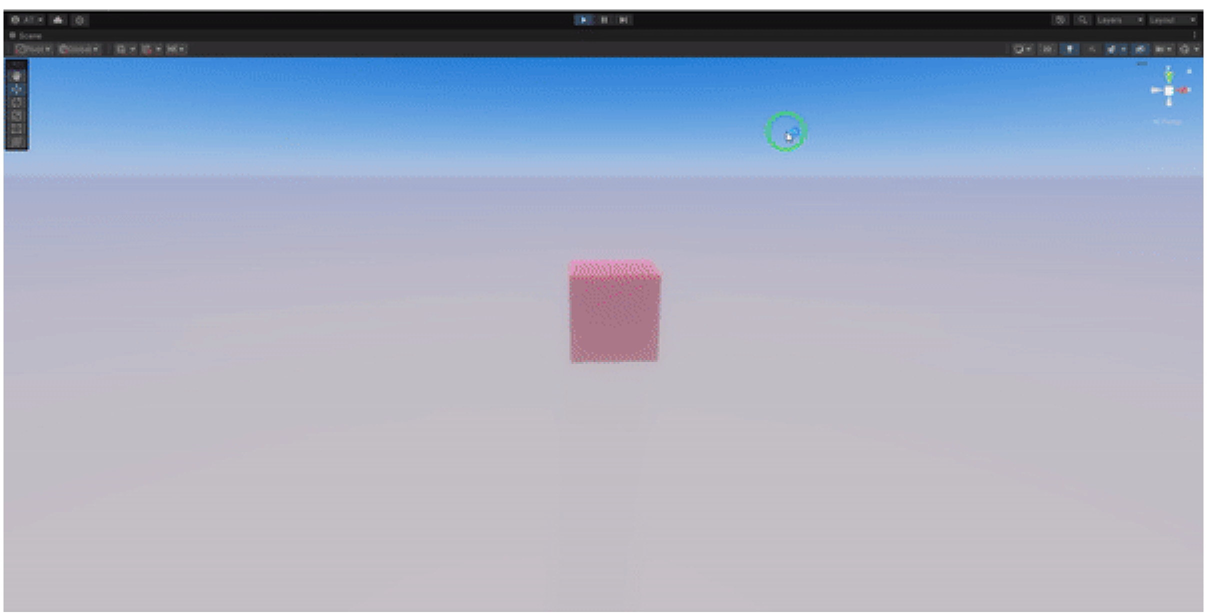
For example, in this scenario, six agents move around the hand, and the particles for which I have developed our own system are connected to each agent in separate groups.







The system for these agents is designed in such a way that they are stimulated and rewarded upon approaching a specified transform. The developer then will be responsible for defining these transforms; however, whether the agents move toward these transforms and how they navigate based on the training they have undergone is not under our direct control.



For example, in the latest prototype I have prepared, agents feed by being near a cube. When the hand interacts with the cube, some agents select the hand as their source of nourishment and detach from the cube. Other particles that are generated also move toward the agents based on the system I have designed and glide over the hands or the cube.

Resources

GitHub - Unity-Technologies/ml-agents: The Unity Machine Learning Agents Toolkit (ML-Agents) is an open-source project that enables games and simulations to serve as environments for training intelligent agents using deep reinforcement learning and imitation learning.

Grid Sensor Components for Unity ML-Agents

https://youtu.be/kpb8ZkMBFYs?si=4H35SwswVRW__cuuZv

Unity ML-Agents Toolkit Documentation

Interview with artist Jeffrey Ventrella

A Darwinist, Avatologist, & Algorithmic Artist (Jeffrey Ventrella Interview)

Particle Life Simulation Tutorial in JavaScript

Create Artificial Life - Tutorial In JavaScript Code - Particle Life Simulation

How particle Life Emerges from Simplicity

- How Particle Life emerges from simplicity

Power of Command Buffers

- The power of command buffers in Unity | JellyCar Worlds

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- Vectors & Dot Product • Math for Game Devs [Part 1]

Machine Learning Series from Unity:

- Machine Learning Agents - Introduction [1/10] Live 2018/4/4
- ML-Agents 1.0+ | Create your own A.I. | Full Walkthrough | Unity3D
- Unity ML-Agents - 5 things you didn't know about - Version 1.0+
- Unity ML-Agents 1.0 - A.I. Shooting Game (FULL WALKTHROUGH)
- Leverage Unity ML-Agents and Game Simulation | Unite Now 2020
- 5 Hacks to speed up ML-Agents Training in Unity3D