

MESTRADO

MULTIMÉDIA - ESPECIALIZAÇÃO EM TECNOLOGIAS INTERATIVAS E JOGOS
DIGITAIS

ENHANCING MUSEUM BRAND AWARENESS THROUGH IMMERSIVE TECHNOLOGIES: A CASE STUDY FOR MHNC-UP

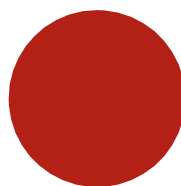
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**Enhancing Museum Brand Awareness through
Immersive Technologies:
A Case Study for MHNC-UP**

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2024

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Enhancing Museum Brand Awareness through Immersive Technologies: A Case Study for MHNC-UP

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Resumo

Os museus promovem experiências culturais através de suas exposições e das histórias que as acompanham. No entanto, no mundo digital de hoje, a maioria dos museus enfrenta dificuldades para atrair o público jovem. Neste estudo, procuramos descobrir como os museus estão adotando tecnologias imersivas, particularmente Realidade Virtual (VR), Realidade Aumentada (AR), Realidade Mista (MR) e tecnologias de motores de jogo (GE) para aumentar a conscientização sobre a marca. O principal objetivo do estudo é criar uma campanha de marketing aprimorada com realidade aumentada (AR) para o público jovem adulto do Museu de História Natural e Ciência da Universidade do Porto (MHNC-UP) em Portugal. Esta campanha utiliza cartazes interativos que envolvem os estudantes com modelos tridimensionais (3D) em AR, oferecendo insights científicos sobre as exposições do museu e incentivando uma exploração mais aprofundada através de visitas presenciais. Através do uso de tecnologias móveis interativas, a campanha visa aumentar a interação e a conscientização dos visitantes para o museu, ao mesmo tempo que destaca a importância do patrimônio cultural na era digital de hoje. Um total de 167 participantes foi inquirido, e foram realizadas 4 entrevistas de seguimento para obter insights detalhados que ajudaram a avaliar o impacto da campanha. Através das exposições de história natural no Museu MHNC-UP, a iniciativa também apoia o conhecimento e a apreciação da biodiversidade e sustentabilidade, alinhando-se com os Objetivos de Desenvolvimento Sustentável da ONU.

Palavras-chave: realidade mista, realidade aumentada, realidade virtual, tecnologia imersiva, tecnologia de motores de jogo, branding de museu, marketing experiencial, conscientização da marca, promoção da marca, jovens adultos, narrativa digital, experiência do usuário (UX), patrimônio cultural, sustentabilidade.

Objetivos de Desenvolvimento Sustentável (ODS) das Nações Unidas: ODS 4: Educação de Qualidade, ODS 11: Cidades e Comunidades Sustentáveis, ODS 15: Vida Terrestre.

Abstract

Museums foster cultural experiences through their displays and the stories that accompany them. However, in today's digital world, most museums struggle to attract young audiences. In this study, we aim to find out how museums are adopting immersive technologies, particularly Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) and Game Engine (GE) technologies to enhance brand awareness. The study's main goal is to create an augmented reality (AR) enhanced marketing campaign for young adult audiences for the Museum of Natural History and Science of the University of Porto (MHNC-UP) in Portugal. This campaign utilizes interactive posters that engage students with three-dimensional (3D) AR models, offering scientific insights into the museum's exhibits and encouraging further exploration by visiting in person. Through the use of mobile interactive technologies, the campaign aims to increase visitor interaction and awareness for the museum while highlighting the significance of cultural heritage in today's digital age. A total of 167 participants were surveyed, and 4 follow-up interviews were done to gain detailed insights that helped evaluate the campaign's impact. Through the natural history exhibitions at the MHNC-UP Museum, the initiative also supports the knowledge and appreciation of biodiversity and sustainability, which is in line with the UN Sustainable Development Goals.

Keywords: mixed reality, augmented reality, virtual reality, immersive technology, game engine technology, museum branding, experiential marketing, brand awareness, brand promotion, young adults, digital storytelling, user experience (UX), cultural heritage, sustainability.

United Nations Sustainable Development Goals (SDG): SDG 4: Quality Education, SDG 11: Sustainable Cities and Communities, SDG 15: Life on Land.

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Abbreviations and Symbols

AR	Augmented Reality
CAVE	Cave Automatic Virtual Environments
CH	Cultural Heritage
GE	Game Engine
HHDs	Hand-held devices
HDM	Head-Mounted Display
MR	Mixed Reality
MHNC-UP	Museu de História Natural e da Ciência da Universidade do Porto
SAR	Spatial Augmented Reality
VR	Virtual Reality

1. Introduction

As technology continues to advance, organizations are constantly seeking innovative ways to enhance their brand awareness. Over the past decade, the world has seen many examples of the use of Mixed Reality (MR), Virtual Reality (VR) and Augmented Reality (AR) technologies beyond their immediate and direct applications. Before delving deeper into the subject, it is critical to understand the two underlying technologies at the heart of this research. Mixed Reality (MR) technologies include a variety of immersive experiences that combine elements of both virtual reality (VR) and augmented reality (AR) (Wainman et al., 2019). The goal of MR technology is to produce a computer-generated reality that integrates smoothly with the real environment (Flavián et al., 2019). These technologies have found widespread application in a wide range of industries, including education, medical, manufacturing, construction, and entertainment.

To create immersive experiences with Mixed Reality there is a need for software platforms - which are the Game Engines. Game engines are a practical medium for audio-visual immersive experience creation. It is a framework that is sketched for the creation of video games which includes certain libraries and packages for developing interactive 2D or 3D games and simulations.

These immersive technologies, including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), have found their place in museums, enhancing the visitor experience. Some museums are integrating AR applications into interactive exhibits, while others are employing gamification and GE technologies to create immersive digital experiences within their physical spaces. These applications aim to enhance the museum's interactions with visitors, ultimately amplifying brand awareness.

In the context of branding, Augmented Reality (AR), a subset of Mixed Reality (MR), is gaining attention due to its potential to enhance advertising effectiveness. Studies have shown that ads with Augmented Reality evoke curiosity and attention, leading to increased engagement and memorability (Yang, Carlson, & Chen, 2020). In addition, augmented reality is better than conventional advertising at capturing customer attention and promoting brand engagement (Pozharliev, De Angelis, & Rossi, 2021).

Several studies have examined the use of Mixed Reality in brand advertising. These studies demonstrate the benefits of utilizing mixed reality, narrative elements, and immersive experiences in brand advertising campaigns. Such strategies can improve brand perception, engagement, and loyalty by creating immersive emotional experiences (Bae et al., 2020; Rauschnabel et al., 2019). Interactive stories using Mixed Reality can enhance the interaction between brands and consumers (Darzentas et al., 2018). According to Van Laer et al. (2019), storytelling in general has a significant impact on consumer attitudes and behaviors.

1.1 Context and Motivation

The motivation behind this study stems from a recognized gap in academic research regarding the use of immersive technologies specifically for museum branding, despite the extensive exploration of immersive technologies in brand marketing and museum visitor enhancement.

Besides there being a research gap on the stated topic, my motivation to explore it is also highly personal and started with my acquaintance with the advertising campaign for Paradoxe perfume from Prada, when I was at Amsterdam's airport on my way to start my Multimedia master's degree in the city of Porto. It was an advertisement inside a vibrant digital augmented reality universe, which could be accessed through a QR code on a branded blotter. Inside the universe, I could move through the rooms and explore the origins of the perfume's key ingredients, allowing me to virtually explore the landscapes where the scents were sourced, as well as the philosophy and history of fragrance. Moreover, I was also able to play an interactive memory card game related to individual notes and fragrance elements. I was inspired by this interactive and innovative storytelling approach to advertising the product, leaving not only a pleasant impression but also a personal connection with the product, making the experience both memorable and delightful.

Such decisions in the marketing of the luxury segment have been observed quite often lately, but at the same time, I have rarely heard of museums resorting to such solutions in their advertising. And then I became interested in combining my two interests in the form of museums and immersive technologies in branding and exploring the intersection of how cultural heritage objects can use these innovative techniques to increase their audience.

During my time at the University of Porto, both my creative projects and the majority of my coursework focused on Digital Games and interactive technologies. In my final year, I also

immersed myself in the study of media marketing to refresh my knowledge from my Bachelor's in Media Communications. Thus, exploring the topic of using game engines and mixed reality technologies in museum branding is a logical continuation and conclusion to my studies as a Multimedia Master at the University of Porto.

1.2 Project Overview

This dissertation seeks to integrate theoretical understanding with real-world applications, and it is situated within the larger framework of multimedia studies being undertaken at the University of Porto. Motivated by a personal interest in the connection between museums and innovative branding strategies, as well as the growing trend of immersive advertising in the market, it looks into how immersive (MR, VR, AR) and GE technologies can be used in museum branding to effectively connect cultural heritage with modern audiences.

1.3 Problem Statement, Objectives, and Research Questions

Our research aims to uncover the transformative potential contained in the use of immersive technologies in the context of cultural organizations and museums. In recent years these technologies have transformed the way we interact with cultural organizations and museums. This transformation becomes ever more critical in our digital age, where museums, to remain modern and connect with diverse audiences, are increasingly recognizing the importance of these technologies. This thesis addresses a major issue: how can museums use immersive technology to increase brand awareness among young adults audiences? The relevance of this subject lies in museums' ability to thrive in the twenty-first century, by opening doors for new interactions with visitors, redefining their brand, and successfully fostering a deeper connection between culture, history, and a new generation of museum-goers. This research uncovers transformative potential that goes beyond mere curiosity. This major question includes in itself several sub-questions: 1) how does immersive technology interest young adults to visit the museum?; 2) what is the influence of immersive technologies on museums in terms of brand awareness and brand engagement?; 3) do out-of-the-walls immersive, technology-based promotional campaigns for museums increase visitations?; 4) what are the perceptions of young adults on the potential of immersive technologies as a marketing tool for museums?

To solve this research questions, we identified the following research objectives:

- Take a comprehensive look at the applications, creative possibilities, challenges, and emerging trends of immersive technologies in the field of museum branding;
- Create a practical prototype integrating these technologies to increase brand awareness of a particular museum.

- Assess how the prototype will change the perception of users towards the chosen museum.

These objectives will lead us to a better understanding of how these technologies can help to develop an appealing and relevant museum brand ecosystem in the digital age. Despite the great potential of immersive technologies to improve museum branding, many institutions are struggling with acceptance, efficacy, and integrating innovations into current narratives (Bekele et al., 2018). These difficulties are serious and necessitate extensive investigation and analysis.

In response to these challenges, our research project focuses on exploring, analyzing, and contributing to the use of immersive technologies in museum branding to provide theoretical knowledge and a practical solution that can help museums and cultural institutions to engage young audiences and strengthen their brand identity. This project is not just theoretical but aims to create a practical prototype that combines these technologies to increase specific museum brand awareness.

1.4 Methodology of Research

The methodology of this research adopts a mixed-methods approach, focusing on the creation and evaluation of an AR-enhanced promotional campaign for the museum. This includes deploying AR-enhanced posters at locations outside the museum and analyzing the effectiveness of these tools in engaging the target audience — young adults, specifically university students aged between 18 and 25. The study combines quantitative data gathered through surveys with qualitative insights from semi-structured interviews. This dual approach enables a comprehensive analysis of how immersive technologies influence visitor interest, engagement levels, and actual visitation rates to museums. Additionally, a review of current literature helps contextualize these findings within the broader framework of digital innovation in museum marketing.

1.5 Dissertation Structure

The dissertation is organized into different sections after this introduction, starting with a review of the literature that establishes the background knowledge needed to comprehend the current status of MR, VR, AR and GE technologies in relation to museum branding. The study methodology, the prototype creation process, the data analysis, and the research's implications for future museum branding initiatives are covered in depth in the following chapters.

The dissertation follows the University of Porto's criteria by being structured this way, which guarantees a clear and concise flow that leads the reader through the complexities and advancements at this intersection of immersive technology and cultural heritage branding.

2. Bibliographic Review

2.1 Introduction

In this bibliographic review, we explore the complex relationship between immersive technology use and museum branding, providing a critical analysis based on the field of cultural heritage. It carefully investigates the complex dynamics of museum branding. The examination traverses the theoretical foundations of branding, from traditional ideas of branding to the subtle implementation of these concepts in museum environments. This includes the connection between business tactics and the maintenance of cultural integrity by critically analyzing the real-world implications of museum branding in addition to discussing its theoretical components.

The exploration extends to immersive technologies—AR, VR, and MR—highlighting their capacity to redefine museum experiences and brand interactions. The review highlights the creative application of these technologies to improve visitor contact and engagement through a variety of case studies, therefore boosting museum branding in the digital era. It offers a technological overview of the primary instruments and techniques used in the integration of immersive technologies into museum environments, such as sensor-based, GPS location-based, and marker-based systems.

The review highlights the advantages and challenges of adopting these technologies, emphasizing the potential for development by addressing implementation failures. It also advocates for future technology and methodology choices by critically analyzing existing work and highlighting knowledge gaps.

Serving as a foundational component of scholarly discourse on museum branding and immersive technologies, this review seeks to illuminate the ways in which these technologies can enhance museum branding and visitor engagement, setting the stage for future research and practical implementations in this dynamic intersection of culture, technology, and marketing.

2.2 Museum branding and brand awareness

In this section, we delve into the complex concept of museum branding, a multifaceted and sometimes controversial aspect of museum management and marketing. We start by going over the fundamental ideas of branding and brand identification as they relate to companies and organizations. After that, we go into detail about how these ideas are specifically applied to museums. The literature review is selected to cover a wide range of perspectives and methodologies, including the classic branding theories and the concepts of museum branding.

2.2.1 Branding Fundamentals

Before delving into the concept of branding in museums it is important to overview the literature about the classic brand and branding theories. The American Marketing Association (2008) and Kotler (1997) define a brand as a unique identifier, such as a name, design, or symbol, that distinguishes a company's products or services from competitors. Brands, according to Kotler and Keller (2012), have acted as a source of differentiation and a catalyst for financial value for organizations throughout the century. Eid et al. (2011) argue that brand elements go beyond mere words and are often manifested in the form of symbols or images called brand marks.

Branding in business is the process of creating a unique and recognizable identity for a product, service, or company (Belenioti, Z., & Vassiliadis, C.A., 2017). It involves developing a distinctive name, logo, design, and messaging that sets the company apart from competitors and helps create a positive perception and reputation among consumers. While some authors concentrate on the most visible components of a brand, including the logo, tagline, colors, or characters (Ward et al., 2020), brand identity encompasses much more. Certain models integrate elements from the outside of the company, like the relationship with various audiences, the image, or the brand message communication, with internal elements like the product, personality, organization, culture, and values, or the employees themselves. The evolution of a brand is more of a dynamic process (Essamri et al., 2019) than a static and fixed brand identity; it can adjust over time to changes in the environment, trends, and influences from customers (Da Silveira et al., 2019). Specifically, positioning, differentiation, competitive advantage, and unique value proposition are all defined by brand strategy, according to Wheeler (2009). The strategy serves as a road map to direct marketing initiatives, optimize the sales procedure, and give staff members direction and motivation. The power of branding is in its capacity to enhance a company's position in the market, attract and retain customers, and set it apart from the competition.

Branding is closely related to concepts such as brand identity and brand equity and includes a wide range of definitions ranging from the functional, rational, or tangible aspects of how a brand works to the more abstract, symbolic, or emotional elements that comprise what a brand represents (Kotler & Keller, 2012). According to Kotler and Keller, the core of effective branding is to distinguish oneself from other companies in a comparable category. Branding is a complicated process that incorporates brand definition, brand values, associations, and

Bibliographic Review

communication tactics to impact and differentiate consumer perceptions within the same product line.

These concepts define brand management as a dynamic and ongoing process of strategic brand construction that includes tactical and sequential actions that sustain and strengthen brand identity (Yoo et al., 2000; Aaker, 1992; Keller, 2001). This process reacts to shifting consumer trends, which have a direct impact on organizational performance. Wheeler (2009) expands on this topic by categorizing the branding process into five important stages: performing foundational research, defining and devising strategies, effectively advancing those strategies, building touchpoints for customers to connect with, and managing brand assets. This organized approach stresses branding as a disciplined technique geared not only toward growing brand awareness but also toward creating and expanding customer loyalty, thus strengthening the brand's presence in customers' thoughts and the market.

2.2.2 Conceptualising museum branding

Branding in museums has always been a controversial concept. It strongly depends on the funding of the museum, its direction, the politics in the country where it is located and the degree of traditionalism of museum managers. Several studies have demonstrated the benefits of brand-centric management, which can help not only increase visitor numbers but also increase awareness and loyalty (Ajana, 2015); connect with the community (Scott, 2007); generate trust to attract funding (Pusa & Uusitalo, 2014; Belenioti et al., 2017); improve internal museum management (Scott, 2007) and ensure sustainable development (Belenioti et al., 2017).

Massi & Harrison (2009) in their study identified and compared two approaches to branding in museums in Italy and Australia. The first is the Classical model (applied in Europe) and the second is the Modernist model (applied in Australia). Within the classical model, a cultural brand is mainly associated with the known history and heritage of a museum (Massi & Harrison, 2009). In this case, the brand is already established due to the unique heritage. Such museums perceive branding more as a secondary tool, as the museum experience is culture-oriented and not related to entertainment. On the contrary, the modernist model perceives branding as the second *raison d'être* of the museum (Massi & Harrison, 2009). Here, museums usually build their identity not on history, but on narrative.

However, researchers (Belenioti et al., 2016) concluded that regardless of the focus of a museum, managers still need to emphasize branding due to the fact that it is a driving force for museum sustainability and growth. A careful combination of commercial and curatorial perspectives can improve the museum experience and enhance museum identity, image and recognition. (Belenioti et al., 2017; Recuero Virto et al., 2017).

Museum branding is a complicated activity that includes different factors affecting how consumers perceive a museum. Pusa and Uusitalo (2014) discuss in detail the elements that contribute to creating a museum's brand. They elaborate on the components that contribute to building a museum's brand, noting that a museum's brand can be forged through several avenues, including its core products such as collections and exhibitions, the people associated with it such as artists or regular visitors, the use of symbols such as visual imagery, metaphors, the museum's name, architectural design, heritage, and the museum's overall organization. Values, professionalism, managerial approach, and network relationships are examples of the latter (Pusa & Uusitalo, 2014).

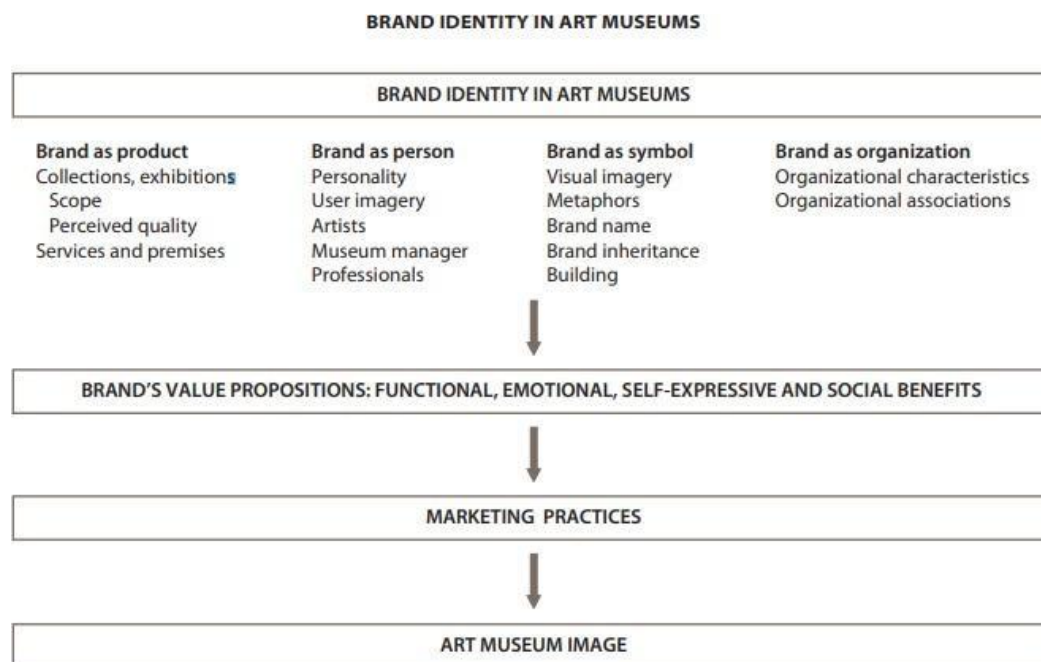


Figure 1. Aaker's model on brand identity in art museums (1996)

The concept of branding in the art market is intertwined with the perception of exhibition quality. Schroeder (2005) emphasizes the close relationship between artistic value and branding, especially in the art market sphere. In this context, the perception of exhibition quality is significantly influenced by the reputation of the artist - in essence, the artist acts as a brand, and their reputation has a profound impact on the assessment of artistic quality (Pusa & Uusitalo, 2014).

The cultural industry has suffered greatly as a result of the COVID-19 pandemic (Cecilia, 2021). In 2020, museums had to modify their admission methods to reflect the difficult medical limitations that had become a reality. They then had to concentrate on adjusting to a constantly shifting environment. Current research on museums primarily focuses on developments in the public and private sectors at the educational (Samaroudi et al., 2020), inclusive (Cecilia, 2021),

Bibliographic Review

economic (Antara & Sen, 2020), and digital levels—specifically regarding technological integration and digital engagement strategies (Choi & Kim, 2021; Crooke, 2020; Corona, 2021; Kist, 2020; Zollinger, 2021). Museums have had to reconsider their brand identification and mission communication in light of the pandemic.

Rosende E. F. (2022) analyzed the literature on the concept of brand identity over the past few decades and created a comparison table, which shows that researchers have shaped their propositions towards a more dynamic version (Figure 2).

Authors	Brand identity	Authors	Museum brand identity
Kapferer (1986)	Personality, Culture, Physique, Relationship, Reflection, Self-image	Caldwell (2000)	Customer satisfaction, Brand name awareness, Perceived quality, Brand name associations, Other proprietary brand assets.
Upshaw (1995)	Logo/graphic system, Product/Service performance, Brand name, Marketing communications, Promotion/merchandising, Selling strategies, Brand positioning	Ferreira (2012)	Aaker system (based): Artworks, customer's service, educational programmes, events, employees, social inclusion, environmental sustainability, commitment to technological innovations, brand personality, logo, tagline, meaningful heritage, distinctive architecture.
Aaker (1996)	Product, Person, Symbol, Organisation	Pusa & Uusitalo (2014)	Aaker system (based): Collections and exhibitions, Scope, Perceived Quality, Services and premises, Personality, User imagery, Artists, Museum manager, Professionals, Visual imagery, Metaphors, Brand name, Brand inheritance, Building, Organisational characteristics, Organisational associations
De Chernatony (2010)	Brand vision, Culture, Personality, Positioning, Relationships (staff to consumers; staff to stakeholders), Reflecting stakeholders	Ajana (2015)	Brand name, architecture, celebrity architect
Ghodeswar (2008)	Positioning the brand, Communicating the brand message, Delivering the brand performance and Leveraging the brand equity	Baumgarth <i>et al.</i> (2016)	Name, Logo, Livery, Architecture, Traditional and social media, Face-to-face interaction between staff and visitors, Communication, Exhibits, Venue's shop, Café
Coleman <i>et al.</i> (2011)	Human resource initiatives, Employee and client focus, Brand personality, Corporate visual identity, Consistent communications	Wallace (2016)	Collection, Exhibits, Website and social media, Educational programmes, Tours, Public relations, Events, Publications, Building, Marketing materials, Fundraising and membership initiatives, Core values, Store, Restaurant, Campus, E-mail, Partnerships, Stakeholders, Board and volunteers.
Urde (2013)	Position, Personality, Culture, Mission and vision, Value proposition, Expression, Relationships, Position	Ferreiro-Rosende <i>et al.</i> (2021)	Aaker system (based): Product, Person, Symbol, Organisation, Digital and Territory
Da Silveira <i>et al.</i> (2013)	Brand management, Encounters, Brand face, Consumer's face, Additional dimensions (competitor's actions, industry/environmental conditions, partner's actions).		
Mindrut <i>et al.</i> (2015)	Products and Packaging, Marketing Collaterals, Logo, Messages and Actions, Signage, Stationery and apparel.		
Ward <i>et al.</i> (2020)	Character, logo and logotype.		

Figure 2. Rosende's table on dimensions of brand identity and museum brand identity (2022).

The development of brand identity through collaboration between organizations and stakeholders — such as customers, employees, suppliers, investors, and the local community (Saraniemi & Komppula, 2017), has garnered scholarly attention recently. This has been noted in the works of Essamri *et al.* (2019), Ramaswamy & Ozcan (2018), and Helmi *et al.*, (2020). Still, the focus of these investigations is primarily on institutional internal components. Baumgarth *et al.* (2016) made a clear distinction between marketing and branding, suggesting that while marketing is outwardly focused on visitors, branding primarily adopts an inside-out

approach. This implies that the cornerstone of branding should be its internal attributes, which play a pivotal role in shaping management decisions and market communication strategies.

Several dimensions have been continuously investigated by scholars in branding literature. Among these are brand personality, which focuses on brand attributes and has been covered by Aaker (1996), De Chernatony (2010), Coleman et al. (2011), Kapferer (1986), and Urde (2013). Authors like Aaker (1996), Coleman et al. (2011), Kapferer (1986), Mindrut et al. (2015), Upshaw (1995), Urde (2013), and Ward et al. (2020) have all studied the visual dimensions, such as logos and design. Central themes in branding research also include other dimensions, like the product or service offering (Aaker, 1996; Ghodeswar, 2008; Mindrut et al., 2015; Upshaw, 1995); and the values associated with the organization (Aaker, 1996; Coleman et al., 2011; De Chernatony, 2010; Kapferer, 1986; Urde, 2013).

The onset of the COVID-19 pandemic has necessitated a shift in how museums interact with their audience, compelling them to modify their content and explore novel engagement methods. Corona (2021) notes the profound impact of technology on social communication, which has escalated digital adoption and markedly influenced the lives of millions, a sentiment echoed by Antara & Sen (2021). In response, museums have been focusing on digital content, engagement, and infrastructure enhancement. These efforts aimed to sustain operations, alleviate public isolation, bolster mental health, and fulfill creative and educational demands, as observed by Kist (2020) and Samaroudi et al. (2020). The digitalization process not only enhances visitor experiences and accessibility but also plays a crucial role in promoting the values held by museums, as identified by Choi and Kim (2021).

2.2.3 Role of branding in museums

Museums, often considered cultural sanctuaries, have evolved to employ unique branding strategies that extend their influence beyond their physical boundaries. This chapter explores the multifaceted role of branding in museums from historical, contemporary and ethical perspectives.

Beginning in the 1970s, many museums faced financial difficulties, which led to a change in branding strategy. The concept of branding, previously associated primarily with for-profit enterprises, has begun to be used by non-profit organizations, including museums (Kotler and Keller, 2012). This transition, driven by the need to create memorable brands with high equity, has allowed museums to become recognizable and respected organizations.

Branding in museums is not without controversy, with some voicing concerns about the commercialization of these institutions (Kylander & Stone, 2012). Critics raise ethical issues surrounding the marketing and branding of museums, fearing the risk of commodification and loss of their cultural integrity (Bradburne, 2001). However, many proponents argue that branding is a valuable asset that contributes to the ongoing cycle of brand development by creating partnership opportunities, increasing brand loyalty, and leveraging additional resources (Kylander & Stone, 2012).

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Museums have evolved significantly in reaction to economic challenges, changing financing dynamics, and customer behavior in the face of leisure industry rivalry (Belenioti & Vassiliadis, 2017). Museums strive to implement commercial strategies based on marketing concepts as they face financial constraints and intense competition from other leisure activities. This shift has ushered in a new era in the museum sector, one marked by a clear need for branding and marketing tactics to maintain its long-term viability and profitability (McLean, 1995; Kotler, 2008).

Given the current conditions of the impression economy (Gilmore and Pine, 1999), postmodern consumption, and declining interest in academic institutions, museum leaders are compelled to use an enhanced or expanded product to make museums more appealing to visitors. Augmented products can help museums increase their brand awareness, promote their uniqueness, and make progress toward their mission (Aalst and Boogaarts, 2002; Mclean, 2012). One way to offer an augmented product is to create museum stores with an assortment of merchandise that includes museum souvenirs (Mclean, 2012).

It has been suggested that using digital media is essential for drawing in and satisfying a larger spectrum of visitors (Light et al., 2016; Zollo et al., 2021). Because of the high levels of customer interaction created by networking, electronic communications, and word-of-mouth (eWOM), these media are increasingly popular, interactive, and accessible communication tools for museums (Li et al., 2021).

It is possible to significantly boost visitor engagement by utilizing digital communication technologies. Furthermore, according to Manna and Palumbo (2018), social media plays a significant role in visitor happiness and engagement as well as brand equity for museums. Through digital communications, these efforts will try to raise the museum's profile and attractiveness in addition to possibly increasing both in-person and online museum visits (Claes and Deltell, 2019).

2.2.4 Museum outside the Walls

Gavin Hogben highlights the concept of "the museum without walls" as a phenomenon where artists leave the building, focusing on erasing physical walls and freeing power within museums. Land art artists view nature and the public sphere as their "museum," allowing art to thrive in a free environment (Hogben, 2012). The concept of a "museum without walls" has been in the works since long before the advent of digital media in the twenty-first century. André Malraux, a French writer and politician, proposed the concept of an "imaginary museum" in the 20th century (Grasskamp & Elliott, 2016; Malraux, 1997). He believed that museums could be more than just beautiful props, and one of his ideas was to create photo albums to present museum collections, allowing artworks to be liberated from museums. This could then be compared to where the arts and museums are located today. For example, digital platforms like Google Arts are enabling the publication of various artworks and museum exhibitions on the internet, allowing global accessibility.

Museums also contribute to the broader brand identity of cities, especially those known for

their academic, cultural, or historical heritage (Gordin, 2011). The COVID-19 pandemic has further increased the need for museums to innovate. During this period, museums experimented with formats that extended beyond their walls. For example, The National Gallery in London looked to take the collections of the National Gallery, National Portrait Gallery, and Royal Academy of Arts beyond the walls of museums with an augmented reality experience. People walking on streets in central London could activate QR codes to visualize some of the museum's artworks (Augmented Reality Art Gallery, 2021). During this period, virtual exhibitions also gained a special wave of popularity. Due to quarantines and the inability of people to leave their homes, museums began to move their collections into virtual spaces, allowing people to visit exhibitions directly from home. For example, in Britain in 2020, the Royal Academy of Arts released a free virtual tour of the exhibition Tracey Emin/Edward Munch: The Loneliness of the Soul (Tracey Emin/Edward Munch: The Loneliness of the Soul at the Royal Academy of Arts, 2021).

2.3 Immersive technologies in the context of museum branding

The major and frequently exclusive focus of a museum's goal used to be on conserving, disseminating, and honoring local culture and memory; today, the focus is on providing enhanced visitor experiences (Trunfio et al., 2022). In recent years, museums have undergone a significant shift in how they engage with their visitors and increase brand awareness. The incorporation of immersive technology like virtual reality (VR) and augmented reality (AR) into exhibits and experiences is mostly to blame for this change. This chapter examines the use of immersive technologies by museums to boost visitor engagement and fortify their brand.

Augmented reality (AR) enhances the real world by overlaying digital information onto it, while virtual reality (VR) creates a completely immersive digital environment that replaces the physical world. Both AR and VR fall within the realm of immersive technologies (Lee et al., 2013), offering unique experiences by blending or substituting real-world elements with digital content (Flavián et al., 2019; Kozinets, 2023; Cesário & Nisi, 2022; Cesário, Olim, & Nisi, 2020; Cesário, Trindade, Olim, & Nisi, 2019). These technologies have gained widespread adoption due to their ability to create rich sensory experiences that allow visitors to interact with cultural artifacts and historical context in unprecedented ways (Kidd, 2014; Suh and Prophet, 2018; Pellas et al., 2021).

The term "mixed reality" (MR) describes the blending of the actual and virtual worlds to give users engaging and immersive experiences. According to Bae, Jung, Moorhouse, Suh, and Kwon (2020), it includes a variety of technological advancements, from augmented reality (AR) to virtual reality (VR). Advertising that uses storytelling elements, such as narratives, characters, plotlines, and emotional appeals, has been shown to capture consumers and convey brand messaging (Darzentas, Flintham, & Benford, 2018).

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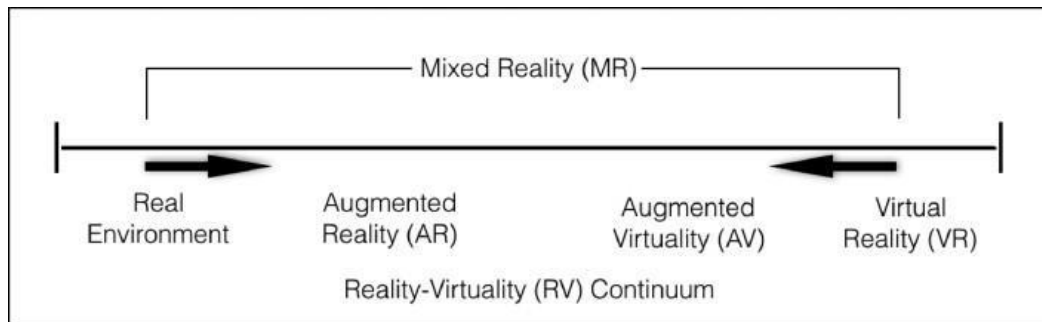


Figure 3. The reality-virtuality continuum, (Bekele et al., 2018).

The concept of a meta-universe is closely related to virtual and augmented reality technologies, as well as the Internet, mobile communications and artificial intelligence. The Cambridge Online Dictionary defines a meta-universe as "a virtual world in which people, such as avatars, interact with each other in a three-dimensional space that mimics reality" (Ianenko, M.B.; Ianenko, M.E.; Shevchuk, E.V., 2023., 18-25). From a marketing perspective, the concept of the metaverse represents a shift towards an enriched digital environment that enhances the sense of presence and broadens socio-economic interactions. As an avenue for innovative promotional technologies, the metaverse is envisioned as a virtual digital space that leverages augmented reality (AR), virtual reality (VR), social networking, and blockchain technologies. This combination aims to create a three-dimensional Internet realm that mirrors the real world, thereby extending the scope of user interactions (Dwivedi et al., 2022).

The application of mixed-reality storytelling in brand advertising has been the subject of several published research studies. These studies emphasize the advantages of using immersive experiences—defined as deeply engaging, sensory-enriched interactions that fully captivate the user's attention—along with narrative components and mixed reality in brand advertising efforts. By producing immersive and emotionally engaging experiences, these tactics can enhance brand perception, engagement, and loyalty (Bae et al., 2020; Rauschnabel et al., 2019). Interactive storytelling with mixed reality capabilities can improve communication between consumers and brands (Darzentas et al., 2018). Van Laer et al.'s (2019) research indicates that storytelling typically has a big impact on customer attitudes and behavior.

Immersive technologies have attracted much attention due to their potential to enhance brand advertising and engagement in museum activities. Research has shown that immersive experiences created through these technologies can play an important role in engaging younger generations (Z and Millennials) in the context of museum tourism (Robaina-Calderín et al., 2023). The study experimented with different immersive scenarios such as virtual reality headsets and mobile applications with virtual reality goggles. The results indicate a direct relationship between the level of immersive experience and young people's affective and cognitive scores. Higher levels of immersive experiences lead to higher affective and cognitive scores, especially for those who are culturally active.

AR, a subset of mixed reality, has garnered attention for its potential to enhance advertising effectiveness. Studies have shown that augmented reality advertisements evoke curiosity and attention, leading to increased consumer engagement and recall (Yang, Carlson, & Chen, 2020).

Furthermore, it has been discovered that augmented reality performs better than conventional advertising at grabbing customers' attention and encouraging brand engagement (Pozharliev, De Angelis, & Rossi, 2021). For example, back in 2013, a group of scientists from the American University of Beirut presented their project titled "International Augmented Med" (I AM). The project's goal was to develop tourism and cultural-historical connections in the Mediterranean countries of Europe and the Middle East using innovative technologies. The developers of "I AM" created a range of solutions based on virtual and augmented reality. Using special scanners, three-dimensional models of various objects were created, which could then be viewed on mobile devices. These objects ranged from small artifacts, such as vases, to large architectural structures, such as ancient amphitheaters. When a user, often a tourist, pointed their mobile device at one of these objects, a three-dimensional model of the object, along with additional information that could also be three-dimensional, was displayed. This could include tourist guides, sound, and light effects. This way, the tourist received various types of reference information without taking their eyes off the sight they were viewing. Such technology can be used both in museums and in open-air environments.

The inspiration model, as proposed by Rauschnabel et al. (2019), is a concept that has been applied to various industries, including the tourism and hospitality industry. The inspiration model, which includes utilitarian benefits, hedonic benefits, perceived augmented quality, and inspiration, can influence users' attitudes towards AR applications and brand attitudes. The physical process of AR can change people's perception and behavior, making it crucial to study its influence on museum visits (Chin-Hung, et. al., 2023). This approach can provide new insights into AR marketing and help businesses adapt to the changing landscape of the industry.

Several published studies have looked into the use of mixed-reality storytelling in brand advertising. These studies demonstrate the benefits of incorporating mixed reality, narrative elements, and immersive experiences into brand advertising campaigns. Such strategies can improve brand perception, engagement, and loyalty by creating immersive and emotionally captivating experiences (Bae et al., 2020; Rauschnabel et al., 2019). Mixed reality-enabled interactive storytelling can strengthen interactions between brands and consumers (Darzentas et al., 2018). According to research by Van Laer et al. (2019), storytelling generally has a considerable influence on consumer attitudes and behavior.

In the modern world, museums face difficulties in addressing the changing demands of a society that is evolving quickly in the twenty-first century. Digital technology is bringing about a new golden age in popular culture, according to Waldfogel, J. (2018). This has occurred because it has greatly reduced the costs of creation, distribution, and promotion, increasing access to cultural content. This period, which Waldfogel has dubbed the "digital renaissance," offers museums previously uncommon chances for cultural expression and communication via a variety

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of digital media. Immersive technologies transform interactions with museum collections. Websites enable virtual tours accessible globally. Serious games incorporate educational gameplay. Mixed Reality (MR) overlays digital information in physical spaces, enhancing perception. Virtual Reality (VR) immerses users in reconstructed or imaginary environments. Augmented Reality (AR) adds digital overlays to real-world views, enriching the learning experience. The early adoption of these technologies started in the 2000s, and a noticeable upsurge in developments has been occurring internationally since 2015 (Miyashita et al., 2008; Wojciechowski et al., 2004). The pandemic crisis, which lasted for two years, has further accelerated the digital transition that started in the 2000s (Sousa et al., 2022; Goodman, C., 2022).

To understand how immersive technologies contribute to museums' brand awareness, it is necessary to consider their impact on visitor experience and brand perception. According to Mclean (2012), augmented products, like immersive technologies, can raise brand awareness by making museums more distinctive and strengthening their purpose. According to (Bae et al., 2020), mixed reality—which is characterized by liveliness and interactivity—has a favorable impact on visitors' brand awareness, brand association, and brand loyalty when it comes to cultural heritage sites. Furthermore, Deng and colleagues (2023) underscore that virtual reality technology enhances digital museology by augmenting the inclination to visit a museum and favorably impacting brand recognition.

Immersive technology boosts brand awareness and equity by enhancing brand knowledge. Keller (1993) highlights the significance of brand knowledge in influencing consumer perception and how it influences product choice in low participation decision-making situations. Immersive experiences can enrich this knowledge by providing interactive and memorable encounters with the brand, thus affecting consumer choices more profoundly. Furthermore, it was found by Homburg et al. (2010) that brand awareness has a considerable impact on market performance, highlighting its significance for business success. Moreover, visitor experience and perceived value are linked to the effect of immersive technologies on brand awareness. Mixed reality elements affect visitors' emotional experiences, as shown by Bae et al. (2020), which raises brand recognition and loyalty. Similarly, Deng et al. (2023) demonstrate that engagement and immersion in a virtual museum contribute significantly to a sense of pleasure among visitors.

Museums are using immersive technologies in five areas: (1) VR and AR-enhanced heritage tourism, (2) VR and AR-enabled virtual museums, (3) interactive digital art education in immersive environments, (4) immersive storytelling in virtual heritage spaces, and (5) mobile AR heritage revival (Jingjing et al., 2023). Virtual museums and virtual worlds are digital representations of physical museums used for accurate or creative purposes. They also create special interesting places, such as archaeological, historical, religious, and architectural sites (Komianos, V., 2022).

Game engines significantly impact the development of virtual museums by providing ready-to-use functionalities that facilitate the creation of virtual environments, thus avoiding the time-consuming process of developing from scratch (Lepouras, G., & Vassilakis, C. 2004).

2.3.1 Case studies showcasing immersive technology use in museum branding

Digital technologies can be employed in a variety of ways in museums to improve the communication of cultural heritage, ranging from websites and virtual tours (Giannini, T., Bowen, J. P., 2022) to specific applications and installations for use on-site (Pagano et.al., 2021). Digital technologies are employed for cultural heritage communication in several contexts, including pre-visit preparation and site investigation, during the visit to facilitate and deepen comprehension, and even post-visit memory reconstruction (Kuflik et al., 2005). In this part we will look at historical examples of how museums have used immersive technologies, as well as newer examples of how museums are using them to advertise and promote their brands. These technologies go by the abbreviations VR, AR, and MR, which stand for virtual reality, augmented reality, and mixed technologies, respectively.

One of the first examples of museum-adapted immersive technology is the case of the Stedelijk Museum in Amsterdam. The ARTours project was initiated in 2010 and is being managed in conjunction with the design studio Fabrique, with funding provided by the Dutch Ministry of Culture. At the Lowlands Music Festival, the ARtotheque project allowed attendees to interact with AR reproductions of museum artworks (Blooloop., 2020). Visitors selected a digital artwork at a designated desk, positioned it anywhere on the festival grounds, and then others could view these pieces using their smartphones. This initiative was part of the museum's exploration of innovative ways to engage the public outside traditional settings.

In 2015, the Smithsonian National Museum of Natural History launched an AR application called Skin and Bones, which shows what the skeletons would have looked like while alive in the Bone Hall. The AR app provided visitors with a unique and interactive way to visualize the creatures' appearance (National Museum of Natural History., 2015).

In 2016 the Celtic Heritage Museum in Salzburg offers visitors the “Speaking Celt AR” application, where an animated 3D model of an ancient speaking Celt becomes the guide during the tour (Wikitude, 2016).

In the years that came next, there was a more noticeable shift in the application of immersive technology toward visitor interaction and educational outreach. The Cleveland Museum of Art combines the latest AR technologies and motion capture technologies for a spectacular demonstration of artworks and historical artifacts. They use interactive AR stands for pottery making, digital painting canvases, and offer the ability to paint a picture with hand movements using motion sensors (Cleveland Museum of Art, n.d.; Smithsonian, 2018; Blooloop, 2017). Furthermore, a virtual reality tour of Modigliani's studio was offered by Tate Modern in London, allowing visitors to immerse themselves in a digital recreation of the artist's workspace, while the Art Gallery of Ontario's 'ReBlink' AR project reinterpreted classic artworks in a modern context (Figure 3). This pattern persisted when the first video game made by a museum 'Father and Son' was released by the Archaeological Museum of Naples the year after, using narrative storytelling to connect historical themes (Father and Son., 2017).

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It was a novel narrative technique for museum collections in which the player's decisions during the game affected the outcome of the video game. The main character connects themes from the museum's permanent collections as he looks for signs of his father and travels through time to Ancient Rome, the Egyptians, and the Bourbon era.

"Mona Lisa: beyond the glass," the first virtual reality experience featuring the Mona Lisa, was introduced by the Louvre in France in 2019 and was accessible on smartphones as well. The virtual reality experience provided an in-depth look at Leonardo da Vinci's painting techniques and demonstrated how they gave his artwork life. The journey started in front of the Mona Lisa painting at the Salle des États, which is now part of the Louvre. After that, it transported guests back in time.

"The Ara As It Was" (2019) at Rome's Ara Pacis Museum introduces a mixed reality experience to enhance visitor engagement with the ancient monument, dating back to the 13th to 9th centuries BCE. Developed by ETT S.p.A., this project is the first in an Italian museum to extensively use Augmented Reality (AR) and Virtual Reality (VR) for an immersive historical exploration. The initiative employs advanced 3D tracking and computer vision to overlay digital enhancements directly onto the monument, offering a glimpse into its original colors. Equipped with Samsung Gear VR headsets and smartphones, visitors navigate through nine points of interest (POIs) featuring combined film, VR, and immersive technologies, starting with a contemporary 360° video before transitioning to a vivid, color-restored view of the monument.

Over the past few decades, serious gaming, VR, and AR experiences in museums have grown significantly (Graziano, T.; Privitera, D., 2020). Virtual reality and multimedia technologies, ranging from scientific to archaeological, are being developed by several institutions. The advent of the COVID-19 pandemic in 2020 saw museums like the National Gallery and Royal Academy of Arts in London pivot towards digital platforms, using AR and virtual exhibitions to maintain audience engagement during lockdowns (Figure 4). In 2020 The National Museum of the Republic of Mari El named after T. Evseev went beyond the museum's walls by implementing the idea of an AR guide for regional attractions and the museum itself. Using a smartphone application, visitors can choose a suitable tourist route with AR navigation and supplement the museum's printed presentation album with media materials (Ministry of Culture of the Republic of Mari El, 2021).

A growing interest in digital art markets and new audience engagement strategies was noted by The British Museum's NFT venture and The Cleveland Museum of Art's 2021 MR experience (Figure 4). In this note, in 2021, The Cleveland Museum of Art was showcasing the restoration of the 1,500-year-old stone sculpture, Krishna Lifting Mount Govardhan, from Cambodia. The exhibition features an immersive, mixed-reality HoloLens tour and is partnered with the National Museum of Cambodia and the Angkor Borei Museum. The sculpture highlights the impact of global changes on the discovery, disposition, and conservation of ancient Hindu sites in Southeast Asia.

The year 2022 saw further advancements, with the Louvre Museum collaborating with a 3D video game for a younger demographic and the Museo Nazionale Della Scienza e Della Tecnica

in Milan establishing a permanent VR cinema (Figure 3). The Museo Nazionale Della Scienza e Della Tecnica a Milano in partnership with Rai Cinema, is constructing a permanent VR area using Pico Interactive viewers. The VR Cinema featured short films, documentaries, and interviews with Italian and international cinema figures. The project is part of the museum's mission to use digital languages and technologies to enhance its heritage. The museum is the first in Italy to create a dedicated website and office for digital strategies and languages. The museum team is confident that digital tools and languages are strategically integrated into museums to enhance heritage, cultural offerings, public dialogue, institution reputation, and scientific culture, enhancing public understanding and interpretation (Rai Cinema, 2022).

Immersive experiences can extend to gift-giving strategies in a museum context. Spence (2022) discusses a unique approach in which visitors can turn a museum visit into a "gift" for a loved one by effectively weaving immersive elements into the museum experience. Such experiences can be created from photographs and audio recordings taken during a museum visit, turning museum objects into meaningful tokens of affection (Spence, J., 2022). A shift toward digital displays, holograms, and projections for narrative was demonstrated in the same year with immersive technology experiences at La Mostra di Leonardo in Rome and augmented reality experiences at Paris Montparnasse – Top of the City (Figure 4).

By 2023, a major step toward completely digital, interactive worlds where art and gaming collide was taken when the Metropolitan Museum of Art (MET) adopted the metaverse with a Roblox gaming experience, while the Pompidou Center's Web3 exhibition showcased the intersection of blockchain and art. (Figure 4). 2023 marked a significant turn towards the metaverse and Web3 technologies.

Country	Museum Name	Year	Technology Used	Key Points
Netherlands	Stedelijk Museum, Amsterdam	2010	AR (ARTours Project)	AR installations at Lowlands Music Festival, engagement outside traditional museum space
Netherlands	Rijksmuseum	2013	Live-streaming (Flashmob and Operation Night Watch)	Staged a flashmob of Rembrandt's "The Night Watch" for re-opening after renovation; included a viral campaign and live-streamed painting restoration.
USA	Frye Art Museum	2014	Co-creation in social media (#SocialMedium)	Exhibition showcasing most liked works on social media, demonstrating the power of crowdsourcing and social media engagement.
USA	Smithsonian National Museum of Natural History	2015	AR (Skin and Bones App)	Visualizes skeletons in Bone Hall as living creatures
UK	Museum of London	2016	Virtual World (in Minecraft)	To mark the 350th anniversary of the fire, rendered a virtual replica of the city of London before the blaze. Provided experiential way of learning plus provoked more interest in the public.
USA	Young Museum, San Francisco	2017	Virtual World (in Minecraft), 3D maps	An immersive experience in Minecraft for its temporary exhibition, Teotihuacan: City of Water, City of Fire. In the lead up to the exhibition, the museum produced also a free, downloadable three-dimensional map of the city.

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Canada	Art Gallery of Ontario	2017	AR (ReBlink)	Reimagines artworks, brings paintings to life using contemporary context
UK	Tate Modern, London	2017	VR (Modigliani's Exhibition)	VR tour of Modigliani's studio, enhances understanding of the artist's process
Italy	Archaeological Museum of Naples	2017	Video Game (Father and Son)	Narrative approach to museum collections, time travel elements, interactive storytelling
USA	Peterson Automotive Museum	2017	VR Experience with Microsoft HoloLens	Created a VR experience to interact with the Ford GT40, enhancing storytelling and visitor engagement.
USA	The Cleveland Museum of Art	2017	AR, Motion Capture	Uses the latest AR and motion capture technologies to enhance the demonstration of artworks and historical artifacts. Interactive AR stands and motion sensors allow visitors to create pottery and digital paintings.
Finland	The National Museum of Finland	2018	VR Exhibit	VR exhibit allowing visitors to explore R. W. Ekman's painting 'The Opening of the Diet 1863 by Alexander II' in a 3D environment.
UK	Natural History Museum	2018	Marketing Campaign in the city, including digital boards and posters	Featured a giant whale skeleton on a bus with the tagline "whale helloo there," used memes and internet language to appeal to younger generations, resulted in a significant increase in visitors.
USA	Smithsonian Institution	2018	VR ('No Spectators: The Art of Burning Man')	Incorporated VR to extend the life of the exhibition at the Renwick Gallery beyond its physical run.
UK	Natural History Museum, London	2018	VR Experience ('Hold the World')	Partnered with Sky to develop an educational VR experience featuring Sir David Attenborough, allowing interaction with rare museum specimens.
France	Louvre Museum	2019	VR (Mona Lisa: Beyond the Glass)	In-depth exploration of da Vinci's techniques, interactive experience with Mona Lisa
Italy	Ara Pacis Museum	2019	MR	The project combines history and technology to deliver an immersive, multi-sensory exploration of the Ara Pacis. It brings to life figures and scenes from ancient Rome and Emperor Augustus' family through 3D animations and color. Enhanced by computer graphics, virtual, and augmented reality since 20 January, the project offers a deeper engagement with the Ara Pacis' story.
UK	National Gallery, London	2020	AR (Augmented Reality Art Gallery)	QR codes in central London to view artworks from multiple galleries
UK	Royal Academy of Arts, London	2020	Virtual Exhibition (Tracey Emin/Edvard Munch: The Loneliness of the Soul)	Free virtual tour of the exhibition during COVID-19 pandemic
Russia	The National Museum of the Republic of Mari El named after T. Evseev	2020	AR Guide, Smartphone App	Implemented an AR guide for regional attractions and the museum itself. Visitors use a smartphone app for AR navigation and to supplement the museum's printed materials.
USA	Cleveland Museum of Art	2021	MR (HoloLens Tour)	Immersive MR experience showcasing the restoration of Krishna Lifting Mount Govardhan sculpture

UK	The British Museum	2021	NFTs (with digital Hokusai postcards)	The British Museum's venture into NFTs with LaCollection involves digitizing and selling more than 200 NFT artworks of Hokusai, coinciding with the "Hokusai, The Great Picture Book of Everything" exhibition. This initiative marks the museum's entry into the digital art market, aiming to engage new audiences and adapt to emerging digital trends.
Italy	Museo Nazionale Della Scienza e Della Tecnica, Milan	2022	VR (VR Cinema)	Permanent VR area with films and documentaries, integration of digital strategies
France	Louvre Museum	2022	3D Video Game (Collaboration with Time Princess: Story Traveller Game)	Teamed up with a 3D dress-up game to bring collections online, appealing to a younger audience.
Italy	La Mostra di Leonardo, Rome	2022	Immersive Technology Experience (holograms, projections, screens)	Used digital screens, holograms, and projections to immerse audiences in Leonardo Da Vinci's works.
France	Paris Montparnasse – Top of the City	2022	AR Experience	Augmented Reality used for multimedia storytelling and insights from the observation deck in the city.
UK	Victoria and Albert Museum, London	2022	TikTok Marketing	Used TikTok to digitally vandalise famous works of art, appealing to younger audiences.
Ukraine	Kharkiv Art Museum	2022	NFT collection	The collection and auction proceeds are to be donated to the museum in order to support its operations and preservation of Ukraine's cultural heritage.
USA	Metropolitan Museum of Art (MET)	2023	Metaverse gaming experience (via Roblox)	Gamified experience, allowing users to embody avatars within the immersive world of Roblox, alongside timeless works of art.
UK	The British Museum	2023	Metaverse gaming experience (via Sandbox)	Intends to provide NFT collectibles and create an interactive area within the Ethereum-based universe. The museum aims to share its rich cultural heritage and reach new audiences through this innovative digital platform.
France	Pompidou Center, Paris	2023	Web3 exhibition ("Policies of the Immaterial: From Certificate to Blockch")	Showcasing the intersection of blockchain and art, featuring CryptoPunk #110 and various digital art forms, including crypto, generative, and pixel art. Concurrently, The Sandbox announced an in-game museum dedicated to the World of Women NFT project, highlighting the center's engagement with digital and blockchain-based art.

Figure 4. Authors table on the museum usage of immersive technologies through years.

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2.3.2 Benefits and challenges of immersive technologies in museum branding

Immersive technologies have drastically changed the way that museums interact with their visitors, providing potential for creative branding as well as increased engagement. Since these technologies were first used for innovative purposes (Pence, 2010; Geroimenko, 2012), they have evolved to provide contextually rich experiences that increase visitor engagement (Hammady et al., 2020; Fan et al., 2022). Along with developments in VR and AR, the integration of AI and Digital Twins has produced immersive, interactive environments that greatly improve the visitor experience (Dwivedi et al., 2022; Eswaran & Bahubalendruni, 2023).

The educational value that immersive technology offers is one of its main advantages. Programs such as the Marine Learning project have demonstrated enhanced participation and information acquisition, especially for children who have performed less well academically (Lu & Liu, 2015). Furthermore, the AR-enhanced literary museum tour focused on Italo Svevo shows how these technologies have increased accessibility (Fenu & Pittarello, 2018).

Nevertheless, there are challenges to using immersive technologies, such as the requirement for regular technology upgrades and striking a balance between real-world and virtual experiences. Stationary VR systems in museums face challenges like secure cables, potential damage, loss, and theft. TPCast can stream image data wirelessly from a PC to the HMD over the 60 Ghz frequency band, but it requires a sender near the PC and a receiver attached to the HMD (Plecher, D. A., Wandinger, M., & Klinker, G., 2019). Additionally, hygiene concerns arise due to the HMDs becoming dirty quickly, increasing infection risk. Despite their superior field of view and graphics quality, these systems may not be suitable for museums or other cultural institutions.

2.4 Technological frameworks

The application of AR and VR technologies in tourism and cultural heritage enhances the tourist experience through various innovative means. These include GPS-based navigation aids, image recognition of historical landmarks, and the use of QR codes that reveal detailed narratives of historical events (Tom Dieck & Jung, 2017). Such advances emphasize the transformative, interactive role in the visitor journey. Moreover, AR and VR facilitate the fusion of digital content with the physical environment of museum cultural heritage, creating an enriched layer of experiences. This integration not only deepens the interaction between visitors and the organizational aspects of the museum, but also significantly increases visitor satisfaction, as exemplified by the implementation at the Ara Pacis Museum in Rome as discussed earlier (Trunfio, Mariapina et al., 2018).

AR systems are differentiated by their operational settings (indoor vs. outdoor), while VR systems are classified by the degree of immersion (non-immersive, semi-immersive, fully immersive). Each type employs specific tracking methods, displays, and interfaces to enhance the

user experience in the cultural heritage domain, aiming to provide an intuitive and engaging exploration of cultural heritage (Carmigniani et al., 2011; Pietroni et al., 2013; Gaitatzes et al., 2001).

The main purpose of AR is to show a computer model online in real space to establish the interaction between the user in real space and the 3D model in virtual space (Shepiliev et al., 2021). AR systems differentiate between indoor and outdoor environments. Indoor augmented reality (AR) uses technologies such as see-through head-mounted displays (HMDs) and marker-based or markerless tracking, which are appropriate for situations when GPS is not required. Two notable examples are the British Museum's AR Tour (Figure 5) with markerless interior tour system and Choudary et al. (2009) project with the use of visual tracking and a handheld display to enhance CH discovery (Figure 6). As demonstrated by research by Vlahakis et al. (2001), outdoor augmented reality, on the other hand, depends more on markerless and hybrid tracking, using portable and physical interfaces.

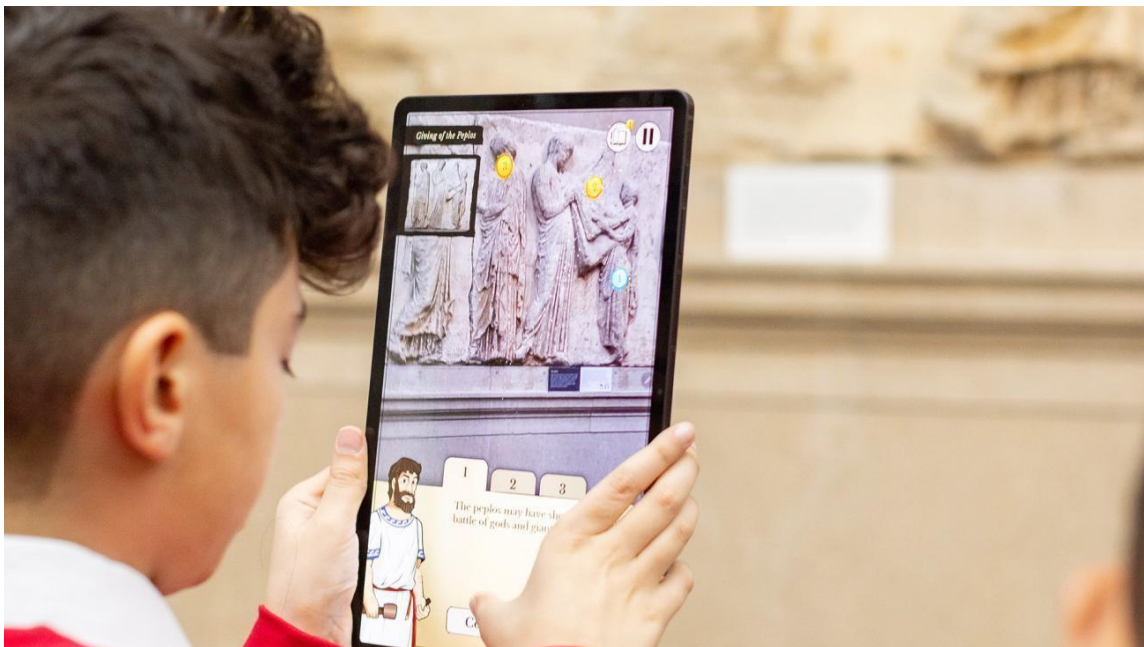


Figure 5. Free tour of a British Museum gallery with Samsung tablets (source: <https://www.britishmuseum.org/learn/schools/samsung-digital-discovery-centre/tablet-tours>)

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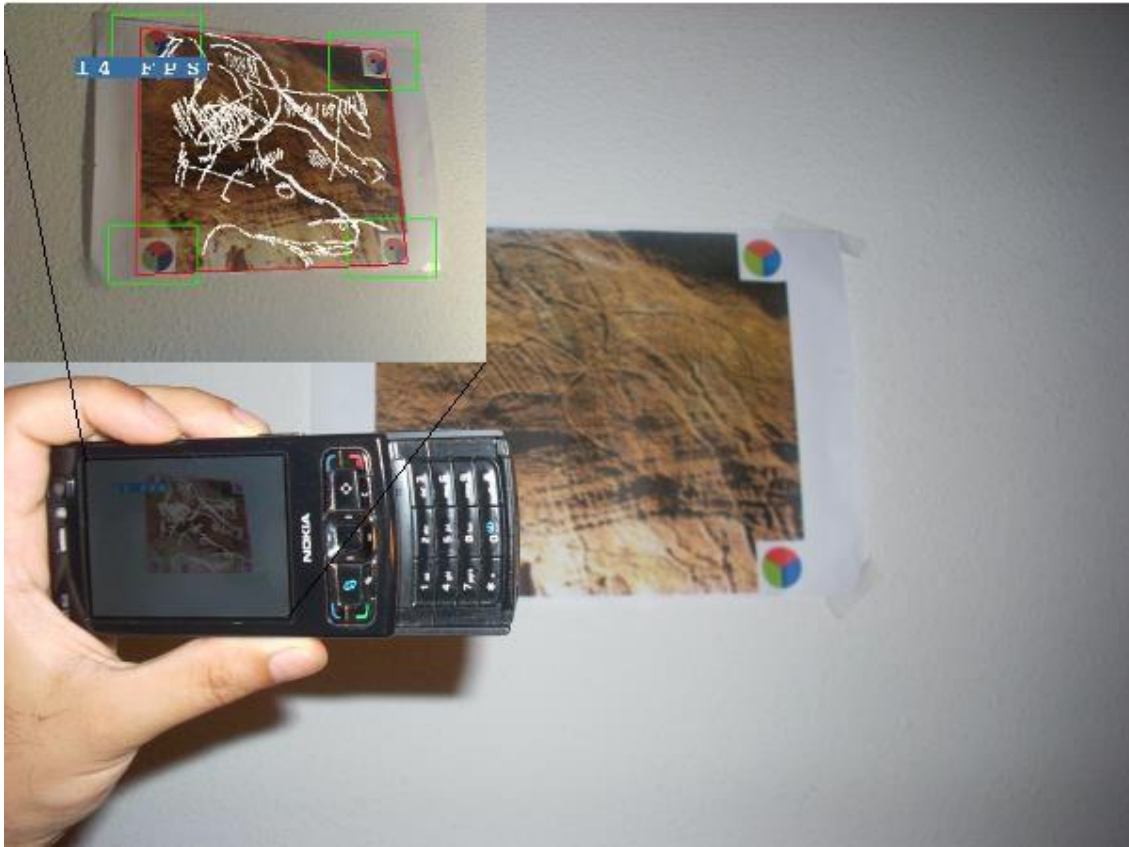


Figure 6. A snapshot of MARCH in a museum-like environment (Choudary et al., 2009)

Differentiating VR systems is done by level of immersion. With the goal of minimizing the user's presence in the virtual world, non-immersive VR offers a basic virtual environment interaction through desktop or mobile displays without the requirement for position tracking. According to Pietroni et al. (2013), semi-immersive VR is perfect for museum settings where large groups of people may be engaged at once. It works similarly to flight simulators or movie theaters, using enormous displays or projections to provide an improved but not entirely immersive experience. The ultimate in virtual reality is fully immersive VR, or telepresence, which places people inside a virtual world through the use of head-mounted displays (HMDs) or CAVE systems. This allows for intensive interaction and a heightened sensation of presence. The aforementioned level of immersion is demonstrated in the research conducted by Gaitatzes et al. (2001), whereby the use of hybrid and multimodal interfaces enables smooth interaction with virtual information.

Simply put, AR uses computer graphics that can add a layer to your mobile device that can interact with the physical world around you. AR can be used with markers, without markers, with sensors, or with GPS location. We will consider these methods in more detail below

2.4.1 Marker-based system

A marker is defined as an object in the surrounding space that is located and analyzed by special software before drawing virtual objects (Katiyar, A., Kalra, K., Garg, C., 2015). Based on the information about the marker's position in space, the program can accurately project a virtual object onto it, giving the impression of its physical presence in space. These markers can be passive, like printed symbols, or active, such as those emitting infrared (IR) light.

The virtual object can become almost real and difficult to distinguish from the rest of the interior or exterior elements by using additional graphic filters and high-quality models. A sheet of paper with a special image on it is frequently used as a marker. The type of drawing can vary greatly depending on image recognition algorithms. In general, the variety of markers is sufficient: they can be geometric shapes of simple shapes (e.g., circles, squares), objects in the shape of a rectangular parallelepiped, and even human eyes and faces.

Although marker tracking is technically feasible and cost-effective for indoor applications such as cultural heritage (CH) sites, it faces challenges (Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., Gain, J., 2018).

Marker detection requires good lighting, which can be provided indoors, but problems can arise. A significant concern at cultural heritage sites is the potential damage to historic sites as a result of marker attachment, which limits its use despite its technical simplicity and low cost.

One of examples of marker-based AR application in museum is the Speaking Celt App for the Museum of Celtic Heritage in Salzburg (Figure 7). The augmented celt, appearing when users scan targets, serves as a museum guide, sharing stories about his lifestyle, explaining museum elements, and engaging with visitors.

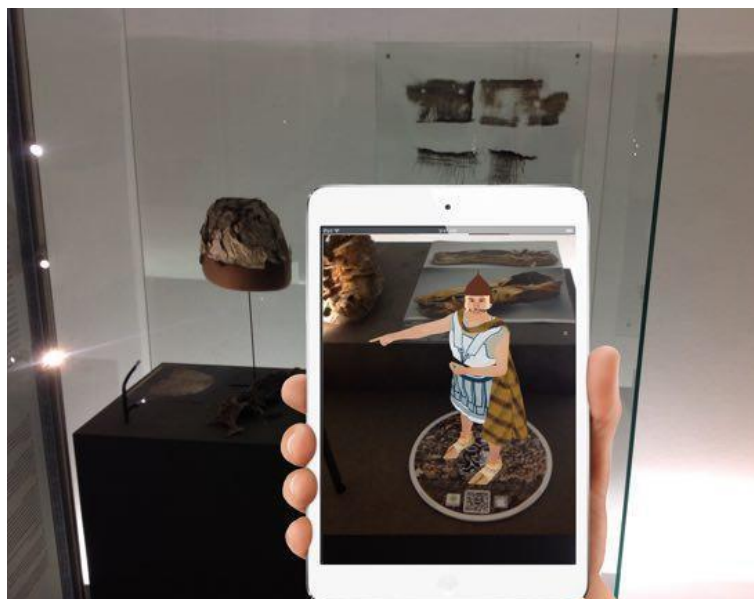


Figure 7. “The Speaking Celt” app (source: <https://www.wikitudo.com/showcase/speaking-celt-museum-experience/>)

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2.4.2 Markerless system

Markerless tracking, or vision-based tracking, works by identifying geometric features in the real environment to match the coordinates of the 3D world with those of the 2D image, allowing realistic and real-time tracking of the camera position (Bekele, M. K., Pierdicca, R., Frontoni, E., Malinvernì, E. S., Gain, J., 2018). However, because of the extensive processing involved, this approach may cause virtual object rendering to lag (Papagiannakis et al., 2008). In contrast to marker-based techniques, which depend on pre-established markers, markerless tracking makes use of the surroundings' natural characteristics, including building corners and edges.

In AR without markers, images captured over the Internet are displayed at any specific location. found using GPS. No marker is required to display content in the app. This is a more interactive approach than marker-based animation (Katiyar, A., Kalra, K., Garg, C., 2015).

Indoor and outdoor use of markerless tracking is possible, however it presents difficulties in situations with few distinguishing elements. A robust picture collection with various perspectives of every real-world item is necessary for model-based tracking. Additionally, it is more prone to malfunction in high-motion situations when geometric characteristics may not be reliably identified, resulting in inaccurate placement of virtual objects. However, technology is not standing still and this problem is gradually being addressed. For example, technologies such as Kinect and Leap Motion have shown promise in improving markerless tracking by utilizing depth and image data to accurately determine camera position, demonstrating the usefulness of this technique both indoors and outdoors if an appropriate image database is available (Bostanci et al., 2015).

In the study by Sdegno et al. (2015), Paolo Veronese's painted building was brought to life with the use of 3D reconstruction (Figure 8), while in the study by Pierdicca et al. (2015), the well-known painting "La Citta Ideale" was enhanced with digital data without the use of artificial markers (Figure 9). The cultural and museum sectors are seeing a rise in the usage of mobile devices and an increase in the quantity of applications available on stores like Google Play and the Apple Store. Many of these apps for museums are excellent instances of how technology and experience design can be integrated.



Figure 8. The virtual model of the scene using Augmented Reality algorithm (Sdegno et al., 2015).



Figure 9. Virtual content visualized in front of "La Citta Ideale"(Pierdicca et al., 2015)

2.4.2.1 GPS location-based AR

Smartphones and tablets provide access to high-speed wireless networks, which emphasizes the importance of content and its context. This allows relevant information to be delivered to the right people at the optimal time and place. One of the fascinating examples of a location-based AR application is the game Ingress Prime, from the creators of Pokémon Go (Figure 10). It is a multiplayer online game where players compete against Enlightened and Resistance factions to capture portals in culturally significant locations, using data from Google Maps on iOS and Android.

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Figure 10. Ingress Prime (source: https://ingress.fandom.com/zh/wiki/Portal_History)

Another widely used application that utilizes GPS is the Sky Guide, which displays the current star constellation overhead (Figure 11). By moving the phone to scan the night sky, users can discover and learn about different constellations, with the information presented changing depending on the specific time and location of the user.



Figure 11. Sky Guide (source: <https://www.fifthstarlabs.com/sky-guide>)

2.4.2.2 Sensor-based AR

Sensor-based augmented reality relies entirely on sensor technology, offering a more sophisticated approach than previously available markerless solutions. As an example, Snapchat has pioneered the use of this technology. As shown in Figure 12, the app determines the coordinates of the user's face using sensors, which allows the application of augmented reality effects. Brands are increasingly adopting this technology, sponsoring apps such as Snapchat and Instagram that use it to engage and enthuse their audiences.

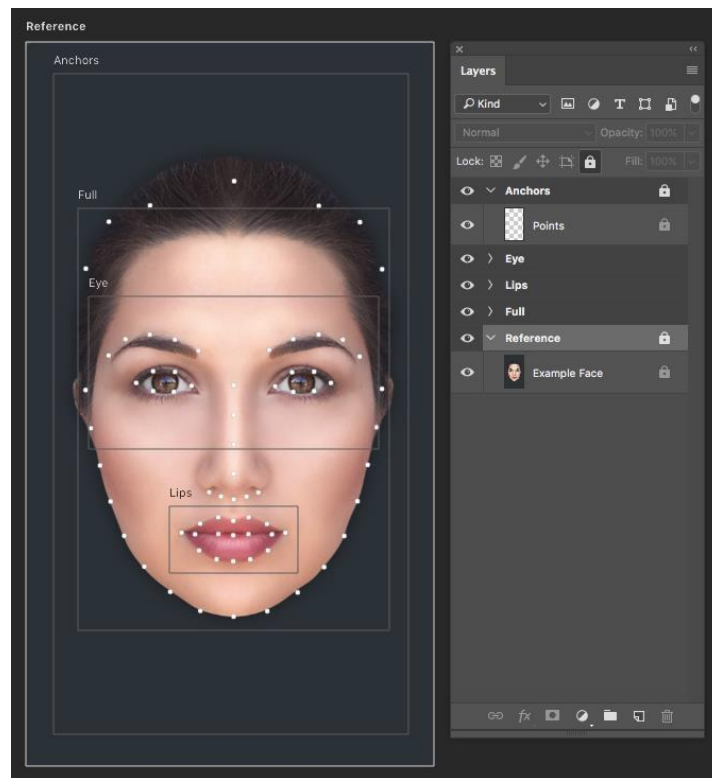


Figure 12. Snapchat mask development process (source: <https://docs.snap.com/lens-studio/references/guides/lens-features/tracking/face/face-effects/face-mask#face-mask-helper-files>)

2.4.3 Mixed Reality approach

Given that mixed reality (MR) falls somewhere in the immersive technology spectrum between augmented reality (AR) and virtual reality (VR), it is important to understand the differences between these three terms. Because both MR and AR connect with real-world settings, they are comparable technologies. As an illustration, Snapchat filters (Figure 7) augment reality by overlaying virtual components on it; yet, they prohibit direct contact with these components. The primary distinction is in the degree of interaction: in MR, if there is a box virtually placed on the table - the user may interact with this box by opening it, whereas in AR, the user can only view a virtual 3D box placed on a physical table. Therefore, the equipment needed for these methods differs: while MR usually calls for a more sophisticated headgear, like the HoloLens,

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AR can only be utilized with a portable device, like a smartphone, that has a camera and screen (Koontz, M.L., Gibson, I.E., 2002). In order to link museum cultural heritage displays with digital and virtual information, MR devices combine sophisticated visualization techniques like 3D, holograms, spatial mapping, and sensors with a variety of hardware, software, and mobile computing components (Trunfio et. al., 2022). This difference is also reflected in the cost of using these technologies, since due to the need for additional equipment, MR requires additional costs. One of the examples of using MR in museum is the 'The Ara as It Was' (Figure 13), an innovative project enhancing the value of the Italian masterpiece, the Ara Pacis Museum, which has been explored in the work by Trunfio et. al. (2020). One of the latest examples is "MR Museum in Kyoto", created by Hakuhodo-VRAR. It is a mixed reality experience for visitors of Kyoto's Kennin-ji, the oldest Zen temple in Japan. In partnership with the Kyoto National Museum, the "MR Museum in Kyoto" uses the immersive technology to explore Tawaraya Sotatsu's sacred artwork, The Folding Screen of Fujin and Raijin (Figure 14).



Figure 13. "MR Museum in Kyoto" (source: <https://www.vi-mm.eu/2018/02/25/mr-museum-in-kyoto-japan-national-treasure-meets-mixed-reality/>)



Figure 14. ‘The Ara as It Was’ (source: <https://www.tgtourism.tv/2016/10/ara-comera-un-racconto-in-realta-aumentata-del-museo-dellara-pacis-20321>)

2.4.4 Modeling Methods in AR, VR, and MR for Cultural Heritage

Digital modeling in cultural heritage utilizes advanced techniques to accurately represent historical artifacts and environments in augmented, virtual, and mixed reality platforms, incorporating factual, mathematical, and artificial measurements (Bekele et al., 2018). Measurements like 3D scanning are used for documenting ancient Egyptian artifacts, while mathematical models simulate environments, and artificial designs create fictional environments, with factual and mathematical methods being preferred for accuracy (Bostanci et al., 2015).

Modeling techniques in VR and MR for cultural heritage are important for creating immersive experiences that mimic historical artifacts and environments. Bekele et al. (2018) classify these methods based on sensory experiences - visual, auditory and haptic - and object modeling into scene appearance, physics-based behavior and combined real-virtual simulation. The latter is particularly important for cultural heritage: Digital simulations are combined with real environments to enhance authenticity and immersive virtual exploration.

The choice of appropriate modeling techniques depends on the complexity of historical objects, the desired sensory interaction and accuracy requirements. Often a combination of methods is used to achieve the required detail and realism.

MR uniquely facilitates the superimposition of contemporary and historical perspectives by using "real-virtual" modeling to create an integrated view of cultural sites. This synthesis of contemporary and historical data provides a richer and more engaging user experience in cultural heritage applications.

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2.4.5 Devices for AR, VR and MR.

The development of mixed reality (MR), virtual reality (VR), and augmented reality (AR) technology has fundamentally changed how people engage with and experience cultural heritage and museums. Bekele et al. (2018) offer a thorough description of the components that make up these immersive systems, classifying them as input mechanisms, computers, tracking devices, and displays. Each of these components is essential to providing enhanced sensory experiences.

Virtual material is presented primarily through displays, which come in different configurations to accommodate haptic, visual, and audio feedback. The Head-Mounted Display (HMD), which may be used in AR, VR, and MR contexts, is the most prominent of them. HMDs come in two varieties: video-see-through, which combines virtual features with live video, and optical-see-through, which enhances real-world views with digital overlays in augmented reality. Hand-held devices (HHDs) and spatial augmented reality (SAR) provide for augmented experiences by projecting virtual data onto real-world surfaces or through portable screens, respectively. While projection systems and desktop displays provide semi-immersive experiences, Cave Automatic Virtual Environments (CAVE) completely submerge users in a virtual 3D realm.

Computing devices have evolved from laptops to mobiles, combining high-resolution displays and advanced capabilities for outdoor AR applications. Tracking devices and cameras are crucial for accurate user movement capture, enhancing AR and MR experiences. They can range from marker-based systems to sophisticated sensor arrays embedded in smartphones. Input devices have transitioned from graphical to intuitive interfaces such as gestures, speech and gaze interaction supported by wearable technologies and motion sensors, allowing natural and immersive interactions with virtual content.

Smartphones with iOS (11 and above running iPhone and iPad) and Android (7.0 and above) are the most common device types for AR. For web browsers such as Google Chrome and Mozilla Firefox, AR is applicable if they support WebRTC and WebGL (Mozilla, 2021).

2.4.6 Interfaces for AR, VR and MR.

In the following, we consider various interaction interfaces that facilitate user engagement with virtual information in immersive reality systems such as AR, VR, and MR. These interfaces are crucial for enabling intuitive and natural interaction in digital environments, significantly affecting users' sense of presence - the feeling of being physically present in a non-physical world (Billinghurst et al., 2008; Carmigniani et al., 2011; Hürst & Van Wezel, 2013; Liarokapis et al., 2005; Vlahakis et al., 2001).

Interfaces are broadly categorized into six main types, each with their own unique contribution to immersion:

- Tangible interfaces (TUI): combine physical interaction with digital content, allowing users to manipulate virtual information through direct contact with physical objects.
- Collaborative interfaces: facilitate the sharing of experiences by allowing multiple users to simultaneously interact with virtual content in both co-located and remote settings.
- Device-based interfaces: Use traditional input devices and graphical user interfaces (GUIs) to navigate and interact in virtual spaces.
- Touch Interfaces: Use touch technologies to capture the user's natural movements and commands, offering an intuitive, hands-free method of interaction.
- Hybrid interfaces: Combine elements from different types of interfaces to support a wide range of devices and interaction methods to meet dynamic user needs.
- Multimodal Interfaces: Integrate multiple natural interaction modes such as gesture, speech, and gaze to enrich the immersive experience by processing multiple sensory inputs.

Particularly in cultural heritage applications, where users may explore and engage with historical knowledge in compelling and meaningful ways, these diverse interaction interfaces are essential to augmenting the realism and immersion of virtual reality. Enhancing the sensation of presence in virtual environments—giving users the impression that they are a part of a distinct, genuine world—is the ultimate objective of these interfaces. These interfaces are developing further as technology does, indicating even more intricate and immersive experiences to come.

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2.4.7 Development tools for AR, VR and MR.

In their work, Bekele et al. (2018) present a number of software frameworks created specifically to support the development of immersive reality that are more suitable for the CH field (Figures 15, 16).

SDK	Purpose	Tracking	Platforms	Graphics	Cloud, Computing	Tracking Sensors	License
Wikitude	Indoor, Outdoor	Inertial, Markerless, Model based	iOS, Android	3DUnity support, 2D images, text, 3D Models (proprietary format)	yes	Camera, GPS, IMU	free and commercial
Layar	Mainly for Outdoor	Inertial	iOS, Android	2D images 3D models (proprietary format)	yes	GPS, IMU	commercial
Vuforia	Indoor	Markerless Model based	iOS, Android	3DUnity, OpenGL 3D models	yes	Camera	free and commercial
PanicAR	Only outdoor	Inertial	iOS	2DImaged Labels	no	GPS, IMU	for free
DroidAR	Only outdoor	Inertial	Android	2D Images Labels	no	GPS, IMU	free
ARToolKit	2Dimages, Markers	Marker Markerless	iOS, Android	3DUnity, Android	no	Camera	GPL

Figure 15. A comparison between the most commonly-adopted AR frameworks in the field of CH (Bekele et al., 2018).

There are two types of frameworks available for AR development: open-source and commercial. Prominent enterprise platforms such as Wikitude, Layar, and Vuforia provide strong functionalities for location- and vision-based tracking; Vuforia is especially valued for its Unity3D integration, which enables fine-grained 3D modeling and cross-platform development (Caggianese et al., 2014; Haugstvedt & Krogstie, 2012). Conversely, open-source substitutes like ARToolkit, PanicAR, and DroidAR provide affordable options; ARToolkit is appropriate for PC-based apps, while DroidAR is made for the Android platform (Choudary et al., 2009).

SDK	License	Dev.Platform	Mobile Platform	Visual Editor	VR Target
Unity 3D	Proprietary	Windows, OSX, eucalyptus	Windows Phone, iOS, Android, Tizen	Yes	Oculus Rift, Gear VR
OpenSceneGraph	Open Source	Linux, Windows	-	No	-
Unreal	free and commercial	Windows, Mac OS X, Linux	iOS, Android	Yes	HTC Vive, Oculus Rift, Google VR, Samsung Gear VR
CryENGINE	free and commercial	Windows, Mac OS X, Linux	iOS; Android	Yes	PlayStation, XBox, HTC Vive, Oculus Rift, Google VR, Samsung Gear VR

Figure 16. A comparison between the most commonly adopted VR game engines in the field of CH (Bekele et al., 2018).

In the VR landscape, the accessibility of devices like Google Cardboard and HTC Vive has popularized game engines as the primary development platforms. Unity 3D stands out for its user-friendly interface and comprehensive cross-platform support, albeit with limitations in real-time modeling. Unreal Engine 4 and CryENGINE are recognized for their high-quality graphical capabilities and realistic rendering features, making them ideal for creating immersive VR experiences that require detailed visual effects (Bruno et al., 2010).

Not so long ago, web-AR technology became widespread. It was considered to be a high-quality libraries of computer vision, image recognition and monitoring (ARToolKit and its web-version JSARToolKit5), as well as knowledge of HTML, CSS and JavaScript programming languages are the key to designing WebAR software (Shepiliev et al., 2021). However, with the development of artificial intelligence and machine learning technologies in recent years, more and more automated universal applications have started to appear, allowing to create webAR without any programming knowledge and access to third-party libraries. One such application is Zapworks. It offers a suite of tools that enable users to build interactive and immersive experiences without the need for extensive programming knowledge. It includes tools like Zapworks Designer, a no-code solution allowing users to build AR experiences using a visual browser editor. This tool supports various tracking types, such as world tracking, image tracking, and face tracking, making it versatile for different projects. Zapworks Studio offers more advanced capabilities, enabling complex interactions and scripting for users with programming knowledge. Additionally, Universal AR SDKs allow developers to integrate Zappar's AR capabilities into their own applications across web, iOS, and Android platforms, facilitating seamless and customized AR experiences (Zappar, 2022).

3. Methodology

3.1 Research Design

State-of-the-art analysis provides a foundation for further elaborating areas where more profound research is still necessary. This mixed-methods study is designed to determine the response of the museum visitor to Augmented Reality through the measurement of changing levels of brand awareness, engagement, and qualitative perception of the potential of different immersive technologies within the realm of museum promotion. In particular, the concern is for young adults. The following will be the research questions, more detailed than the problem statements of the previous sections:

1. How does immersive technology interest young adults to visit the museum?
2. What is the influence of immersive technologies on museums in terms of brand awareness and brand engagement?
3. Do out-of-the-walls immersive, technology-based promotional campaigns for museums increase visitations?
4. What are the perceptions of young adults on the potential of immersive technologies as a marketing tool for museums?

These questions will be addressed by developing a prototype of an AR-enhanced promotional campaign that will be tested in collaboration with the MHNC-UP museum team. The next chapter will describe the research design for developing the prototype and the data collection techniques and analysis procedures.

3.1.1 Development of Prototype

The prototype development is composed of a set of AR-enhanced posters produced for the promotion of the MHNC-UP museum. These posters are intended to attract university students by incorporating AR educational and interactive content on the exhibits made available in the museum. Here's what it consists of:

- Conceptualization and design: first thinking, sketching layouts, and defining educational and interactive features of posters.

- AR feature integration: Use ZapWorks Designer to integrate AR features such as 3D models and animations.
- Iterative feedback and Refinement: working with the museum team to further refine the posters based on any comments made to ensure that they align with the standards of the museum and its goals.
- Finalization and deployment: printing good quality posters for viral marketing in some strategic points in the university campuses.

3.1.2 Survey Method

The quantitative survey is designed to measure the impact of AR-enhanced posters on brand awareness, engagement levels, and perceptions of immersive technologies by people who will be using the product. This has been inspired by the work of Damala et al. (2008) and Trunfio and Campana (2019), who advocate for user studies within the AR application space. The survey was structured into four sections. The first one covers socio-demographic information. The second one concerns the use of AR in previous experiences. The third one identifies three sections of questions, with a five-point Likert scale, for each variable of the users' experience model for augmented reality in the museum promotion we describe more detailed later (see Figure 32, p. 54), covering the user interaction with the AR posters, awareness and perception of the museum and intention to visit the museum. The fourth part identifies the effects of the experience (increasing interest on immersive technologies, their potential as a marketing tool for museums). The survey in the form of a questionnaire has been split into the following sections:

- Demographics: Gather the essential information, which includes the participant's background.
- Prior Experience with AR Technologies: Participants' past exposure and use of AR technologies are determined.
- User Interaction with the AR Posters: Analyzing the user interaction of ease and engagement, as well as the attention span while using AR features.
- Awareness and Perception of the Museum: Measuring how the AR posters would have influenced the general knowledge and perception of the museum by individuals.
- Intention to Visit the Museum: Measurement of the effect AR posters have had on the intention respondents have about visiting the museum.
- General Feedback on AR Experience: Gathering qualitative feedback of strengths and areas needing improvement of AR posters.
- Perceptions of Immersive Technologies: Measuring the participants' views on the effectiveness of AR in marketing for museums.

The complete survey questions are listed in Appendix B.~

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3.1.3 Semi-Structured Interviews

In addition to the quantitative survey data, the qualitative insights are further described through semi-structured interviews. A 15-minute follow-up interview was conducted on a sample of 4 of the experimental participants, who revealed interest and agreement in the conversation. Questions were designed to get more deep answers on the topics of the research questions. The first interview questions served as a warm-up and included general questions about the experience of interacting with immersive technologies and visiting museums, while the second part was devoted to visitors' impressions of interacting with AR posters, as well as their changes in perception of the museum and their opinion about the prospects for the development of museum promotion using immersive technologies. The interviews focus on the following:

- Personal experiences: understand the participants' interaction with AR Posters.
- Museum interest: AR posters helped in creating interest within the museum and in participation.
- Effectiveness of AR as a marketing tool: the perspectives on the potentiality of the marketing effectiveness of the museum with the help of AR.
- Suggestions for improvement: gathering ideas for improvements or any future prospects associated with AR.

The complete interview questions and answers are listed in Appendix A. This follow up method allowed us to get deeper qualitative insights. The interview guide includes open-ended questions, framing themes of the literature review, and survey responses.

3.1.4 Data Collection and Analysis

Data will be collected by administering the survey to participants engaging with the AR-enhanced posters and conducting follow-up semi-structured interviews with a sample of these participants. The analysis will attempt to unveil trends and correlations through description and inference of the quantitative data obtained. Qualitative data from interviews will be coded and thematically analyzed, meaning that it will be drawn on for further conclusions related to user experiences and perceptions. Moreover, the AR-development tool, Zapworks Designer, that will be used to create the prototype, has an integrated analytics function. It will help to get even more detailed quantitative data on user experiences with the posters (including: total views, unique users, average time spent, country, devices and more).

This research combines quantitative and qualitative data to afford a comprehensive understanding of how successful AR-enhanced promotional campaigns are at elevating museum brand awareness, visitor engagements, and perceptions of immersive technologies. The results will benefit museums that wish to employ immersive technologies in their marketing strategy.

3.2 Prototype Development

This chapter describes the iterative design process and technological aspects of the AR-enhanced posters utilized in the study. It highlights the conception phase, during which initial concepts were developed based on stakeholder feedback, as well as the subsequent development phases, which transformed these ideas into functioning AR experiences. The section also discusses the obstacles encountered throughout development and the solutions adopted to solve these concerns, giving a detailed picture of the project's journey from concept to realization.

3.2.1 Project background

An important research location for investigating the incorporation of immersive technology in museum settings is the Museu de História Natural e da Ciência da Universidade do Porto (MHNC-UP). The rationale behind choosing MHNC-UP for this thesis is based on a number of discrete but connected elements that support the overarching goals of improving visitor engagement and museum branding via creative technology solutions. These include the museum's close association with the principles of 'citizen science', allowing individual citizens to contribute to the growth and development of the museum, its role as an institution within the University of Porto where I study, and its active participation in innovative and interactive exhibitions, which creates an ideal contribution to the discussion of the impact of immersive technologies on museum branding within my research. It provides a framework through which the development of an environment in which the interaction of academic research, technological innovation, and public education could be brought into contact. MHNC-UP absolutely represents a prime setting for an exploration of how augmented reality can transform a museum promotion from one in which the user is passively observing to one in which an active role is taken.

Established in 2015 through the fusion of two historical units — the University of Porto Museum of Natural History and Science —, MHNC-UP has rapidly become one of the greatest cultural institutions dedicated to the preservation, study, and dissemination of heritage across the natural, exact, and human sciences. This broad mission represents the extension of more than two centuries of teaching and research at the University of Porto. However, in this way, MHNC-UP is much more than an institution of care with a repository function; it represents an active space for the present and the current debate of the science of contemporary learning (MHNC-UP, 2023).

Its structural and conceptual design evidently supports the museum's robust mission, bifurcated into the Core Pole located in the Historic Building of the Rectory (Figure 17a) and the Hall of Biodiversity at Porto's Botanical Garden (17b). This bipartite arrangement facilitates a multidimensional approach to museum education featuring traditional strategies of exhibition with an addition of interactive display mechanisms. Noteworthy, the integration of immersive technologies at the Hall of Biodiversity has seen the museum blend physical and digital interactive features to further the interest of the learner. For instance, through science-centered hands-on exposures and digital interactivity, the museum has successfully introduced interactive scientific

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modules that help visitors experience and understand diverse biological forms in action, engage with digital representations of the history of the Earth's evolutionary past, and explore personalized experiences on the human diversity theme (MHNC-UP, 2023).



Figure 17a-17b: The University of Porto Museum of Natural History and Science
(source: <https://portugalvisitor.com/portugal-museums/mhncup>)

One of the areas in MHNC-UP where this innovative approach is being expressed is in the Biodiversity Hall exhibition space. However, to make the experience rich, it is in the use of technology and interactive media. For instance, modules in the hall, such as the "Diversity of Shapes," are expositions presented in digital and tactile interaction manners through which the human being can talk to the content of the displays shaped into a dynamic visualization of biological diversity. A second way to interact is through a digital sphere showing the main moments in the evolution of Earth, by which users may see complex ecological and geographical transformations using user-controlled digital projections (Figure 18a, 18b).

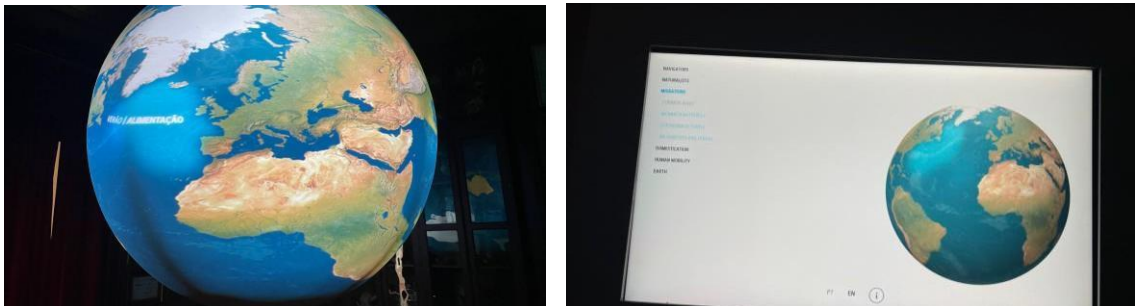


Figure 18a-18b: Exhibition in the Hall of Biodiversity of MHNC-UP.

The most engaging exhibit in the Hall of Biodiversity, for me, was the one about genetic diversity. The exhibit situated within the hall includes a large screen that makes the experience interactive and literally fantastic with the visitor's image echoed on the screen (Figure 19a, 19b). Visitors can also send the resulting image of themselves to their email, when leaving the museum (Figure 19c). This personalizes not just the experience of the visitor but, in a way, subconsciously even teaches a thing or two about the concept of genetic variability and biodiversity.

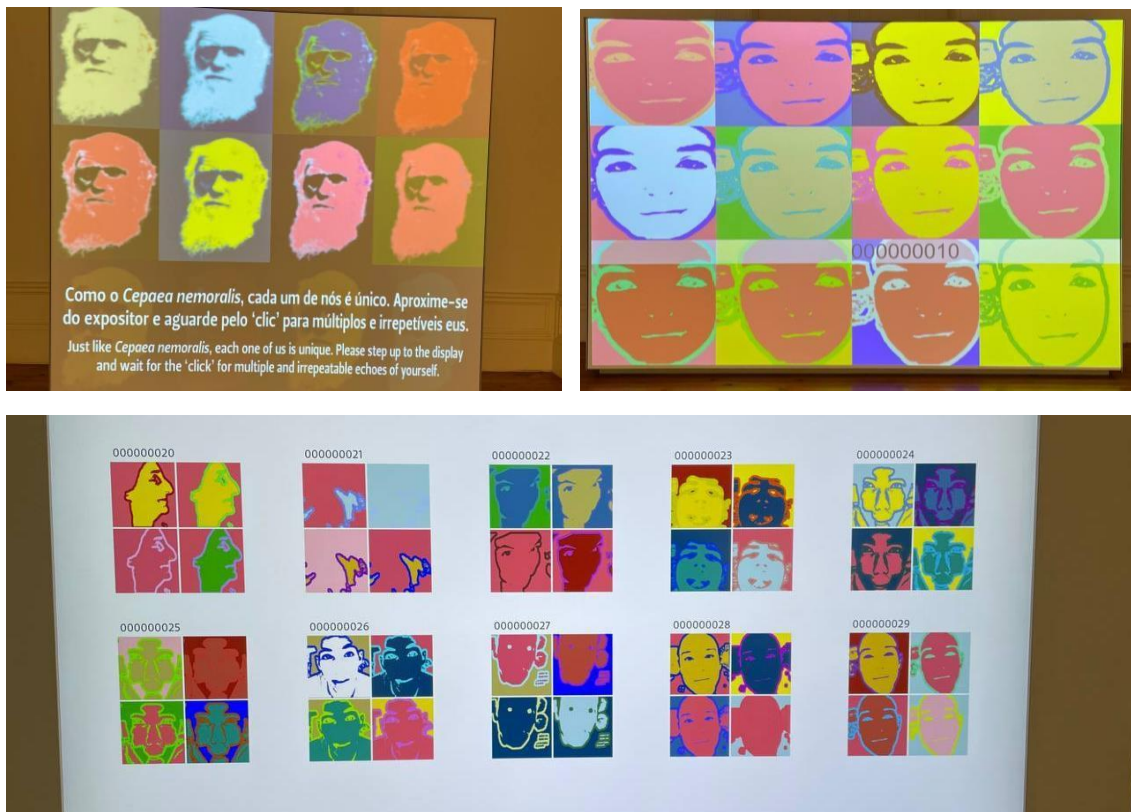


Figure 19a-19c: Exhibition in the Hall of Biodiversity of MHNC-UP.

While traditionally conservative in its advertising strategies, MHNC-UP has recently begun experimenting with more dynamic promotional tools. Promotionally, MHNC-UP is rather conservative and depends a lot on its educational and cultural activities, which go out through conservative media—social sites, scientific papers—and directly through society, along with schools and local institutions. At times, the museum tries to go for broader promotion events. For example, the hosting of the National Geographic Photo Ark exhibition in 2017 brought a very important increase in its visitation because of a large-scale video advertising in the streets (MHNC-UP, 2017). This shows a signal that there might be openness to accept novel promotion means based on up-to-date technology.

Another outstanding dimension of the generalized readiness of MHNC-UP for the integration of new technological paradigms is the recent experiment with AR-enhanced posters. By scanning the QR-code on the poster, users can virtually plant animated carnations wherever they want in the real world (Figure 20). This commemorative project, which honored the Portuguese Carnation Revolution, demonstrated the museum's ability to develop and adjust to new forms of communication, while also acting as a test project for incorporating augmented reality technology into its promotional toolset. This dimension of adaptability is crucial for the present thesis as it seeks to explore how such immersive technology might bring a new level of appeal to the museum, particularly for a younger demographic (aged 18-25), such as the students of Faculty of Engineering of the University of Porto (FEUP).

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Figure 20. "A Ciência saiu à rua num dia assim..." poster (source: <https://www.cienciaviva.pt/50-anos-25-abril/>).

In terms of branding, MHNC-UP has a comprehensive brand guideline, which was shared with me by the museum's team. The guidebook focuses on the rules for using the logo, fonts and core colors. The museum does not have any other patterns, branded visual elements or strict templates. The museum's website is similarly restrained and has no specific branding elements at the moment. Thus, observing a few rules, the designer can have the freedom to create visual design for the museum's expositions, which is the case with most of the posters. The museum team warned me that within my academic work, I also have artistic freedom, but that the formal language and status of the museum must be kept in mind.

The overall visual language of the museum is classic and formal. The basic concepts are culture, art and science. The red represents the passion for these concepts. The stylized "M" represents a museum with its doors open to the community and the world (Figure 21).



Figure 21. MHNC-UP design manual.

Museum branding includes two main colors - red (#E40429) and black (#000000). And two fonts - FreightDisp Pro (Semibold) and Open Sans (Regular and Bold). While the first one is only used in the logo and notes and never in text or titles, the second one is used in printed or digital texts and titles.

This collaboration with the MHNC-UP for this dissertation offers a great opportunity to enquire how AR might optimally increase the appeal of the museum and its accompanying educational impact, with special reference to a younger demographic of university students. By bringing AR technologies together with the interactivity and educational missions of the museum, the project will pioneer new methods of engagement that could serve as a paradigm for other museums globally. This is in the interest not just of MHNC-UP but also of the wider interest of academic debate where the use of immersive technologies in cultural institutions is of value in providing insight for future developments in museum practice.

3.2.2 Design and content creation

As part of this study, we decided to create a prototype advertising campaign for the MHNC-UP Museum using immersive and interactive technologies, particularly webAR. Developing a brand campaign is a lengthy process. It consists of gathering information and conducting interviews with the museum team, analyzing the obtained information, brainstorming, creating demo versions, making adjustments, conducting tests, and finally, creating the final version and subsequent analysis.

The objective was to create two AR-enhanced posters to advertise the two main venues of the museum - The Core Pole and The Hall of Biodiversity with the Botanical Garden. The posters should reflect the main themes of these two spaces and the museum as a whole, while also giving users the opportunity to interact with the educational content of the museum, inviting them to learn more by visiting the museum in person.

The conceptual foundation for the project was based on interviews with the museum team, self-observation of the exhibitions, and analysis of the content on the museum's website (described in the previous chapter). As a result, a unified theme for the posters was created, along with sub-themes for each poster that reflect the main exhibitions held in the two areas of the museum.

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Unified theme of both posters: ***The Earth***.

This ties both posters together under the concept of exploring different aspects of Earth — from its core substances to its living surfaces. Promoting two main venues of the museum - the Core Pole and the Hall of Biodiversity. Also, posters have a specific focus on the native Portuguese biodiversity.

Key topics of each venue were identified during self-observations:

- The Core Pole - Laboratory, Chemistry, Gems, Crystals, Minerals, Mineralogy, Paleontology, Geology.
- The Hall of Biodiversity and Botanical Garden - Botanical Garden, Diversity of Forms, The Art of Appearing Something Else, The Invisible Stillness, To Eat and Not Be Eaten, Analogy and Homology, Theatre of the Senses, Genetic Diversity, Human Diversity, herbs, green diversity, features by land, sea, and air.

Concept of Poster #1: “The building blocks of Earth” (Figure 22a).

Due to the fact that the main building is partially under renovation, only two permanent exhibitions are currently open, the Gems, Crystals and Minerals exhibition and the Ferreira da Silva laboratory. During discussions with the museum team, it was decided to focus on Mineralogy, Paleontology and Geology and to link the poster to the “Gems, Crystals, Minerals” exhibition.

Therefore, the poster emphasizes the fundamental nature of minerals as both the literal and metaphorical foundations of our planet. It encourages students to delve into the scientific basis of minerals and their impact on various environmental and technological aspects of our lives. Poster specifically focuses on the minerals that are mined in Portugal (Apatite, Siderite, Quarts, Fluorite) (Fabre Minerals, n.d.).

By interacting with the poster in AR, the user will be able to learn educational information about each of the presented minerals, as well as examine them in detail in 3D.

The Call to Action (instruction designed to encourage the user to take a specific action) will invite the user to visit the Core Pole of MHNC-UP to learn more.

Concept of Poster #2: “The breath of Earth” (Figure 22b).

Current poster represents the Hall of Biodiversity and the Botanical Garden. It reflects on the life that grows from the building blocks—the flora and fauna that are the living, breathing parts of Earth's systems.

The Botanical Garden and The Hall of Biodiversity offer insights into Earth's complex ecosystems. This poster, when scanned, displays a video of the botanical garden faced on the *Quercus robur*, a tree significant to Portugal (Museu de História Natural e da Ciência da Universidade do Porto, 2024). The oak's leaf-shaped “window” enhances the video with 3D animations of insects and animals like moths, deer, rabbits, and snails—species that inhabit or are associated with the oak tree and also are presented in the museum. Additional educational content about the *Quercus robur* and surrounding flora will be accessible.

Both posters have a minimalist design, since the main visual load is transferred to the AR

layer. One of the two main colors of the museum brand was used – black #000000, as well as the museum logo in white and the museum’s corporate font - Open Sans. Color contrast was used to also make the QR code easier to read. Full final versions of the posters are available for try in the Appendix C.

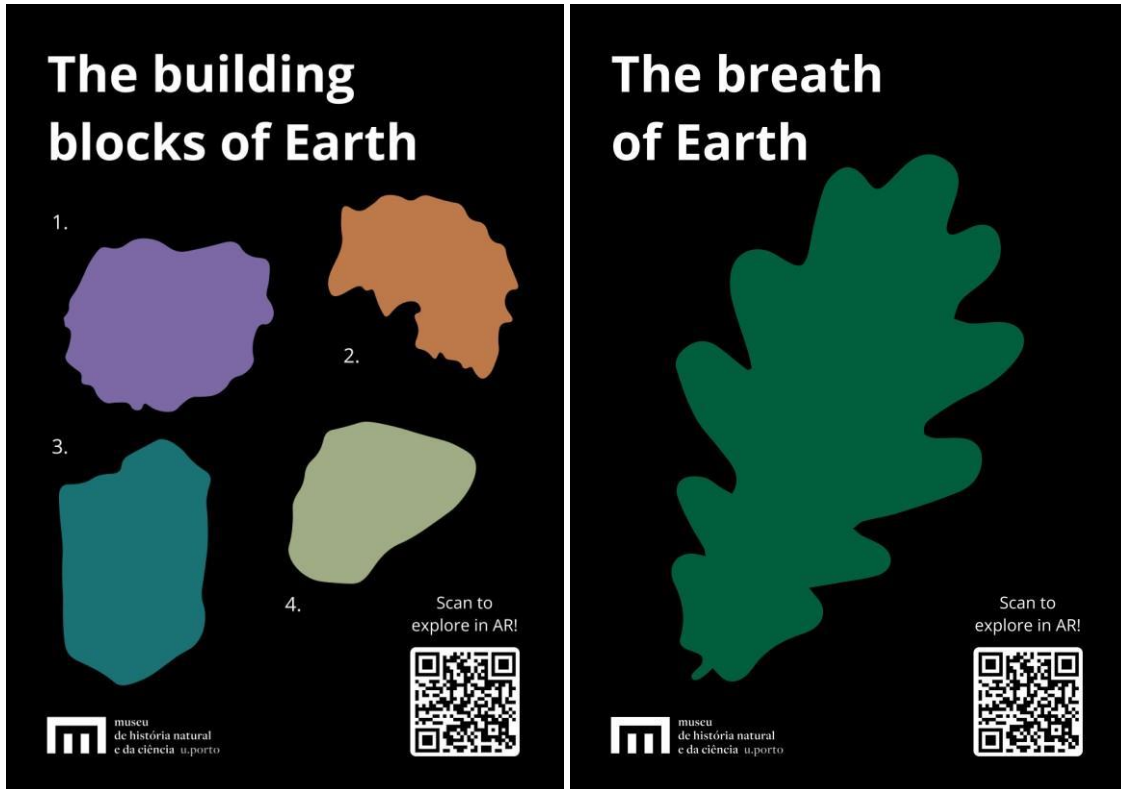


Figure 22. a) Poster #1, b) Poster #2.

3.2.3 Project Architecture

During the development process, it was decided to employ Zapworks tools, notably their browser-based studio, Zapworks Designer. This application allows you to create interactive experiences without the requirement for programming skills. Because I worked alone on both the development and design of the project, this application was the best fit for creating the project without extensive programming knowledge. Another benefit of Zapworks Designer is that users do not need to download third-party applications to interact with the projects; all interactions take place directly in the mobile device's browser, simplifying the user experience.

Augmented Reality (AR) typically delivers its experience to users through a video display in real-time. This process involves tracking marker to accurately place virtual objects. According to Barone Rodrigues et al. (2017), the assembly of an AR scenario on a handheld device, such as a smartphone, includes a series of tasks that enable this process, as you can see on Figure 23 (Barone Rodrigues et al., 2017).

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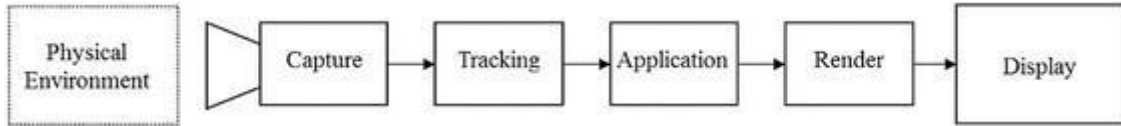


Figure 23. Sequence of events to assemble an AR scenario on a handheld device (Barone Rodrigues et al. (2017).

Zapworks allows to create three types of augmented reality: World Tracking, Face Tracking, and Image Tracking, as well as combinations of the three. For the work with the two posters, the major tool chosen was Image Tracking, which allows printed posters to serve as markers for the AR layer. World Tracking was then added to one of the posters to improve the interactive aspect of the experience. Thus, the two posters' architectures are similar but slightly distinct.

Poster #1 is more interactive, because it allows the user to click on each one of the four 3D models of the minerals, read educational cards and then try the 3D models in the World Tracking mode. Moreover, when clicking on the social media icons – user will be redirected on the museum webpages (Figure 24).

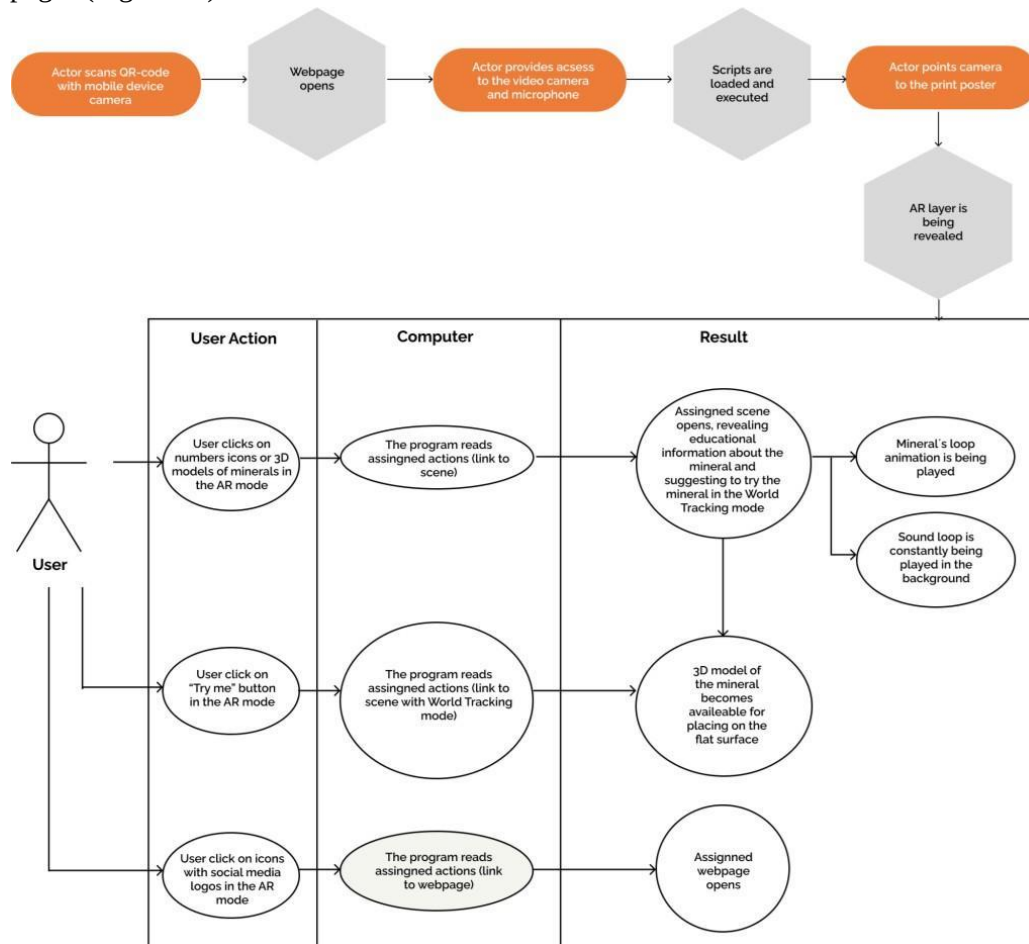


Figure 24. Diagram of the poster #1.

AR features of the poster #1 include: 3D Mineral Models, Educational Cards, 'Try Me' Feature, Social Media Links and Call to Action. More detailed description is in Figure 25.

Feature	Description	User Interaction	Educational Value
3D Mineral Models	Interactive 3D models of Apatite, Siderite, Quartz, and Fluorite.	Users can place the 3D model on a flat surface, walk around, and explore it.	Provides a detailed, visual understanding of the minerals' structures.
Educational Cards	Information cards appear when clicking on numbers.	Users click on the numbers to reveal facts about each mineral.	Delivers scientific insights and interesting facts about the minerals mined in Portugal.
'Try Me' Feature	Interactive exploration of 3D models.	Clicking 'Try Me' allows users to place and interact with the 3D mineral models in their environment.	Enhances engagement through hands-on interaction, reinforcing learning.
Social Media Links	Icons linking to the museum's webpages.	Users click on social media icons to visit the museum's social media pages.	Promotes further engagement with the museum's digital content and social media presence.
Call to Action	Text encouraging further exploration at the museum.	"Discover more about minerals, crystals, and gems at the Core Pole of MHNC-UP"	Invites users to visit the museum for more in-depth exploration.

Figure 25. AR features of poster #1.

The poster #2 includes the function of displayed video and animated background, therefore less interaction is being performed. Similar to poster #1, users can click on the number icons and read educational cards about the plants, as well as click on the social media icons to be redirected on the museum webpages (Figure 26).

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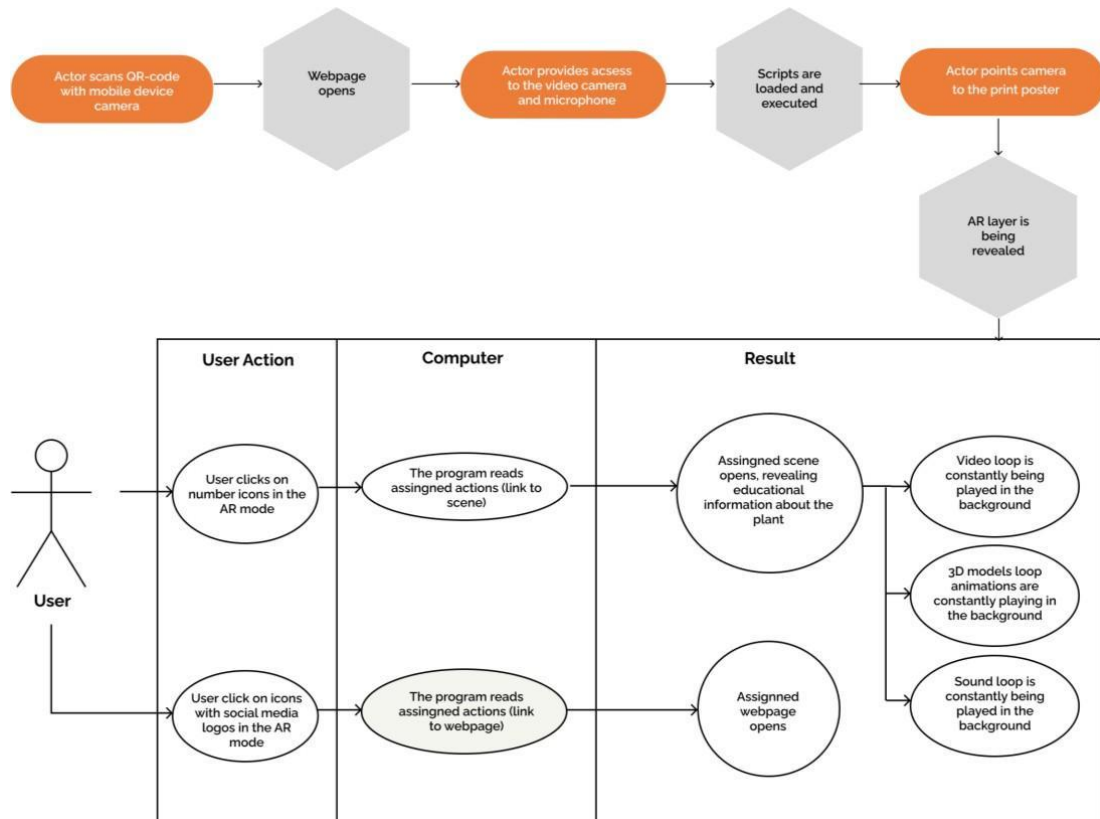


Figure 26. Diagram of the poster #2 algorithm.

AR features of the poster #2 include: Static Botanical Garden Video, 3D Animated Species, Educational Cards, Social Media Links and Call to Action. More detailed description is in Figure 27.

Feature	Description	User Interaction	Educational Value
Static Botanical Garden Video	Video of the botanical garden featuring <i>Quercus robur</i> .	Appears inside the oak leaf-shaped window when scanned.	Provides a visual and contextual understanding of the botanical garden's ecosystem.
3D Animated Species	Animations of moths, butterflies, deer, rabbits, and snails.	Users see animated species interacting with the video.	Highlights the biodiversity associated with the oak tree and educates about species found in the museum.

Educational Cards	Information cards about plants featured on the video.	Clicking on number icons reveals facts about the showcased plants.	Enhances learning with detailed information about the flora and fauna associated with <i>Quercus robur</i> .
Social Media Links	Icons linking to the museum's webpages.	Users click on social media icons to visit the museum's social media pages.	Encourages continued engagement with the museum's digital content and social media presence.
Call to Action	Text encouraging further exploration at the museum.	"Discover the ecosystems of Earth in the Hall of Biodiversity of MHNC-UP"	Invites users to visit the museum for more in-depth exploration.

Figure 27. AR-features of poster #2.

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3.2.4 Project Realization

The production of the AR-augmented poster campaign for the MHNC-UP Museum took place in several stages, beginning with design process, AR-feature and technical development, technical realization, implementation, and further improvement. Described in this chapter will be practical steps from concept design up to project completion, ensuring maximum objectives toward enhancements of museum brand awareness and increasing engagement of young adult audiences. The first phase of the design was starting with the conceptualization, brainstorming of ideas, and the first sketches of the layout, topics, and interactive features for the posters. The focus was mainly to ensure that the visual complements the educational content and guidelines of the museum brand. Mock-ups of the posters were presented to the MHNC-UP team for feedback. Such iterations followed feedback, ensuring that the posters were made to meet the museum standards and achieve the intent use. The feedback iterations helped make the design more effective considering the intended audience. The final agreed layouts of the printed posters are illustrated in Figure 28.

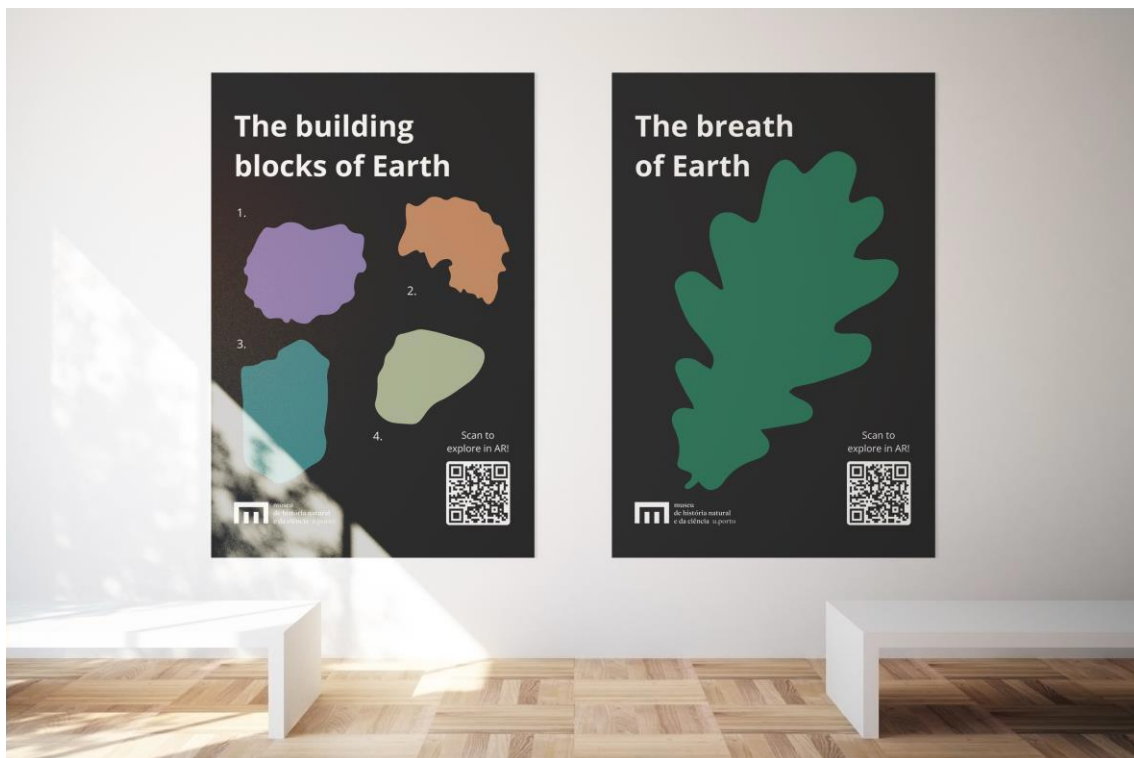


Figure 28. Mockup of the posters.

One of the most critical areas in the project was the creation of AR functionality. ZapWorks Designer offers a user-friendly interface for building highly interactive AR experiences that do

not require profound programming knowledge. The initial steps in this phase were to find 3D models and animate the minerals for Poster 1 (Figure 29a-29c), while for Poster 2, the content selection involved filming the appropriate video and finding 3D models of species with animation (Figure 30a-30b). This was entailed by searching for assets in the free open-source 3D modeling stock and then imported into ZapWorks.

The integration of these 3D models and animations into the AR layer involved setting up interactions such as clickable elements that display educational cards and social media icons that direct users to the museum's webpages. Multiple rounds of testing were conducted to ensure that the AR features functioned smoothly and were intuitive for users. Feedback from test users was used to refine the AR elements and improve the overall user experience.

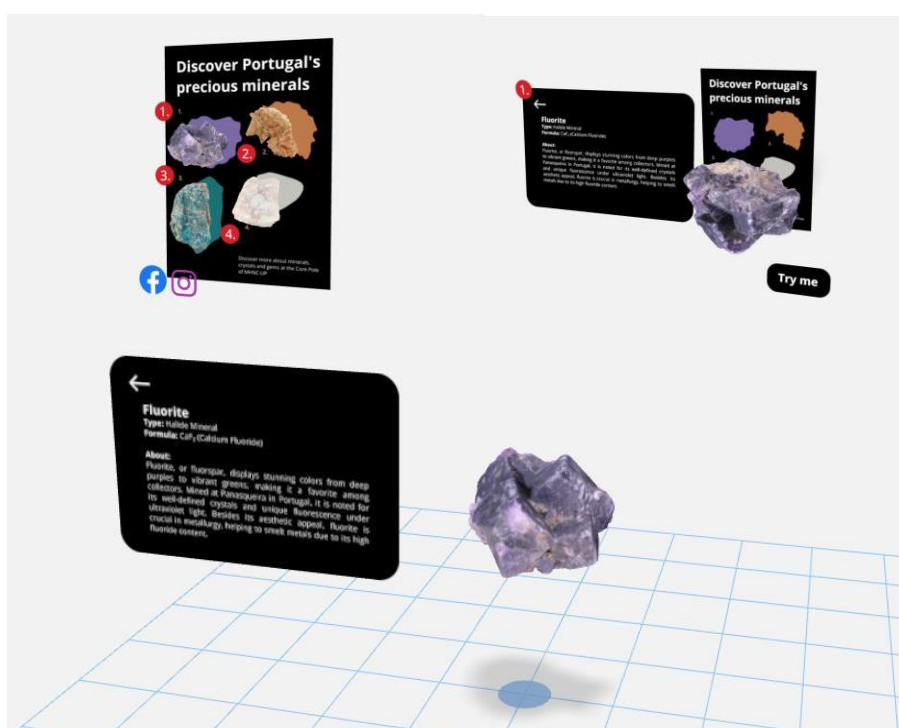


Figure 29a-29c: Poster#1 AR-view

On the technical side, setting up image tracking in ZapWorks Designer primarily involved ensuring high contrast on the printed posters to facilitate accurate scanning and AR content overlay. Additionally, Poster 1 was fitted with world tracking to enable users to place and look for interactions with 3D mineral models running AR in their environment. Therefore, optimizing the AR experience on mobile devices entailed keeping in mind loading times, responsiveness, and compatibility for as many smartphone models as possible.

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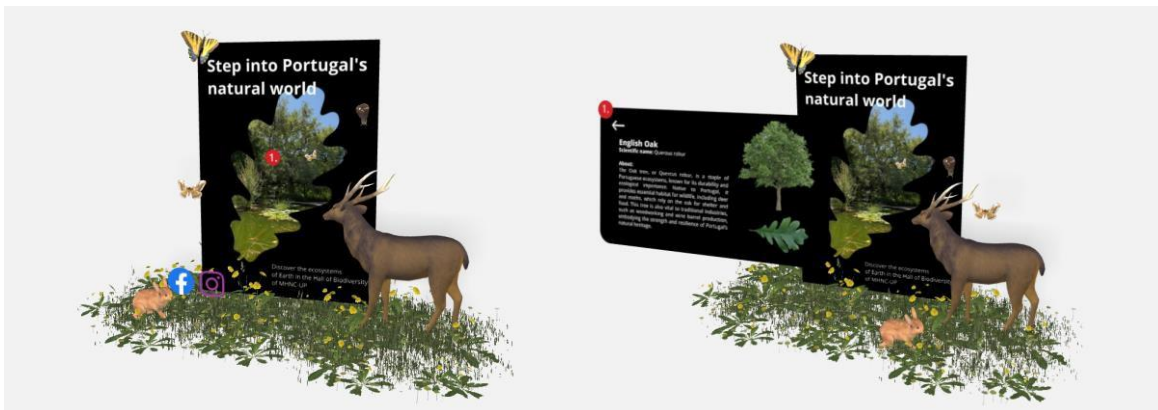


Figure 30a-30b: Poster#2 AR-view

After the development phase, the posters were meant to be rolled out to intended locations on the university campus. This could entail printing high-quality posters and strategically placing them around the campus to maximize visibility. Alternatively, because of the work schedule changes - the posters were presented to the participants in the online format. Final tests were also conducted online to ensure the AR features performed correctly in their environment. Mechanisms for user feedback collection included links leading to online survey and invitation to semi-structured interviews.

3.3 Data Collection and Analysis

This section explains into the data collection and analysis procedures used to assess the impact of AR-enhanced posters on museum brand awareness. The emphasis is on a mixed method that incorporates both quantitative and qualitative data, resulting in a strong framework for assessing user interactions and perceptions of the immersive poster campaign.

3.3.1 Sample and data collection

The sample consisted of 167 participants who interacted with AR-enhanced posters advertising the MHNC-UP. In the course of the research the practical part underwent some changes, in particular: a) due to the complicated schedule and inaccessibility of the museum team, the implementation of posters was postponed to the end of July; as a consequence, conducting a face-to-face survey and hanging posters in the halls of the university became inexpedient, as students went on holiday; b) the experiment was transferred to the online format.

The current study had data collection carried out over a 1,5-month period between July 2024 - August 2024 through the administration of questionnaires immediately after the participants experienced the experiment online and semi-structured interviews conducted with 5 survey participants afterwards. The five-point Likert scale was used in the questionnaires to measure the disagreement and agreement level with the items to determine the project's effect. Open-ended questions were used in the interviews to get deeper insights on the user experiences and opinions on the museum perception and immersive technologies used in museum brand promotion.

The study provides a conceptual model for capturing the effect of augmented reality on users' museum perception and intention to visit the museum. Its design is based on Damala et al.'s (2008) approach for designing and evaluating a mobile AR guide for museum visits, as well as Trunfio, M., and Campana, S.'s (2019) visitors' experience model for mixed reality at the museum (Figure 31). Damala et al. (2008) argued that AR application research based on user studies is insufficient, so they used qualitative methods such as directly observing visitors interacting with the paintings and with the AR application, as well as conducting semi-structured interviews afterwards. In our research, we decided to also combine quantitative survey data and qualitative data from semi-structured interviews, after interacting with AR enhanced posters to gain a deeper understanding of users' perceptions of the museum brand and the potential of immersive technologies in promoting museums.

Dimensions	Variables
Museum information	● Exhibition ● Services ● Historical period ● City attraction
Customization	● Personalized information ● Multiple language capability
Format	● Audio ● Images and video ● Accessible through own mobile device ● Touch
Usability	● Comfort ● Clever alternative to access information ● Easy to use
Information saving	● On personal devices ● On museum platforms

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Interaction	• Museum servicescape • Multimedia elements • Other technologies
Experience	• Heritage valorization • Educational • Entertainment • Socialization • Escape

Figure 31. The visitors' experience model for mixed reality in the museum (Trunfio, M., and Campana, S.'s (2019).

The user experience model (Figure 31) developed by Trunfio, M., and Campana, S.'s (2019) was redesigned to include new dimensions and variables measuring the experience of users' interaction with museum promotional posters in an augmented reality environment. Some of Trunfio, M., and Campana, S.'s (2019) variables specific to mixed reality and the experiential environment within the museum were excluded (e.g., Touch, Information Saving, Socialization, Escape, and others); others were redesigned with a focus on brand perception and/or combined into single variables. As a result, an augmented reality model of users' experience with museum advertising posters was developed with 9 dimensions and 18 variables (Figure 32).

Dimensions	Variables
Museum information	• Exhibition
Familiarity	• Familiarity with AR technologies
Format	• Images and Video • Audio
Usability	• Comfort • Easy to use • Attention span
Interaction	• Multimedia elements • Engagement
Experience	• Educational • Entertainment

Brand Perception	• Brand awareness • Perception improvement
Intention to Visit	• Desire to visit • Likelihood of visiting • Following the museum on social media
Opinions	• Marketing potential

Figure 32. The users' experience model for augmented reality in the museum promotion.

A small group of four participants, who had previously left their contact details on surveys and showed interest in further discussion, were chosen for a detailed follow-up. These 15-minute interviews aimed to delve deeper into their personal experiences. The interview was divided into two segments: an initial set of general questions about their interactions with immersive technologies and museum visits, followed by more specific questions about their specific experiences with AR posters, any changes in their perceptions of the museum, and their views on the future of immersive technologies in museum marketing. This method yielded comprehensive qualitative information.

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3.3.2 Data analysis

This chapter presents an analysis of the data obtained from a study on the effectiveness of AR-technology posters for the promotion of the Museum of Natural History and Science at the University of Porto. The analysis uses both quantitative and qualitative data from 167 respondents, focusing on how AR technologies affect the museum's brand awareness and visitor engagement.

Participants for the study were gathered by distributing an online survey, which included digital copies of the AR posters, across various university-related chat groups. The study employed a mixed-methods approach, analyzing quantitative data from Likert-scale responses and qualitative data from open-ended responses. Correlation analysis was used to explore relationships between AR familiarity and factors like usability and brand perception, while regression analysis assessed how usability and interaction influence brand perception and visit intention. We organized the analysis based on the user experience for augmented reality in the museum promotion model we developed earlier (Figure 32), analyzing each dimension systematically:

1. Museum Information
2. Familiarity
3. Format
4. Usability
5. Interaction
6. Experience
7. Brand Perception
8. Intention to Visit
9. Opinions

First section of the questions were about demographics. The majority of the survey participants were young adults, which is indicative of the typical university student body: most of the respondents are between 18-24 years (41.3%) and 25-34 years: (37.7%), lesser amount is between 35-44 years (14.4%), when 45-54 years and above were not represented. In gender distribution we see a slight female predominance (50.9%), while male are 47.3%. Since the surveys were distributed between the university-related chat groups, there is a significant internal reach within the university, the majority of respondents were from FEUP (48.5%), and 42.5% from other faculties. Only a few respondents are from different universities.

To provide a foundational understanding of the collected data, descriptive statistics were calculated. These statistics included measures of central tendency and dispersion such as the mean, standard deviation, and median, as well as the range of responses (minimum to maximum). This statistical approach helps to elucidate the general trends and variability within the data. Below is a detailed descriptive analysis of key survey variables (Figure 33):

Variable	Mean	Std Dev	Min	25th Pctl	Median	75th Pctl	Max
Familiar with AR	2.78	1.08	1	2	3	3	5
Ease of Use	3.62	1.24	1	3	4	5	5
Attention Hold	3.34	1.26	1	2	4	4	5
Engagement	3.66	1.13	1	3	4	5	5
Interaction Effectiveness	3.56	1.24	1	2.5	4	5	5
Comfort Using AR	3.31	1.25	1	2	4	4	5
Image Quality	3.90	1.11	1	3	4	5	5
Audio Quality	3.71	1.22	1	3	4	5	5
Understanding of Promotion	3.79	1.15	1	3	4	5	5
Perception Improvement	3.75	1.15	1	3	4	5	5
Increase Desire to Visit	3.90	1.16	1	3	4	5	5
Likely to Visit	3.02	1.23	1	2	3	4	5
Follow Social Media	3.34	1.28	1	2	3	4	5
Believe in AR Potential	3.61	1.23	1	3	4	5	5

Figure 33. Descriptive statistics for survey variables.

The initial analysis of the survey data reveals important insights into the respondents' experience with the AR-enhanced posters and their perceptions regarding the museum. The average score of 2.78 suggests a moderate level of familiarity among respondents, indicating that while many are aware of AR technologies, they might not have extensive experience. The high mean score of 3.62 suggests that respondents generally found the AR posters easy to use. The lower mean score of 3.31 indicates some issues with comfort, suggesting room for improvements. Engagement and Attention Hold variables both scored above 3.3, indicating that the AR posters were engaging and capable of holding the attention of viewers. Image and Audio Quality variables high scores (3.89 and 3.71, respectively) suggest that the technical quality of the AR posters was well-received.

For the correlation analysis, the technique used is called Pearson Correlation Coefficient calculation. It is calculated as the covariance of the two variables divided by the product of their standard

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deviations. Mathematically it is represented as the following formula:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Where x_i and y_i are the individual sample points indexed with i , and $\bar{x}$ and $\bar{y}$ are the sample means. This coefficient results in a value between -1 and 1 inclusive, where: 1 indicates a perfect positive linear relationship, -1 indicates a perfect negative linear relationship, and 0 indicates no linear relationship.

The Correlation Matrix of survey responses gave insights into the respondents' experience with the AR-enhanced posters and their perceptions regarding the museum (Figure 34). **Dark Red** indicates strong positive correlations, suggesting that as one variable increases, the other variable tends to increase as well. **Light Colors** (light red and light blue) indicate weaker relationships. **Blue** would indicate negative correlations.

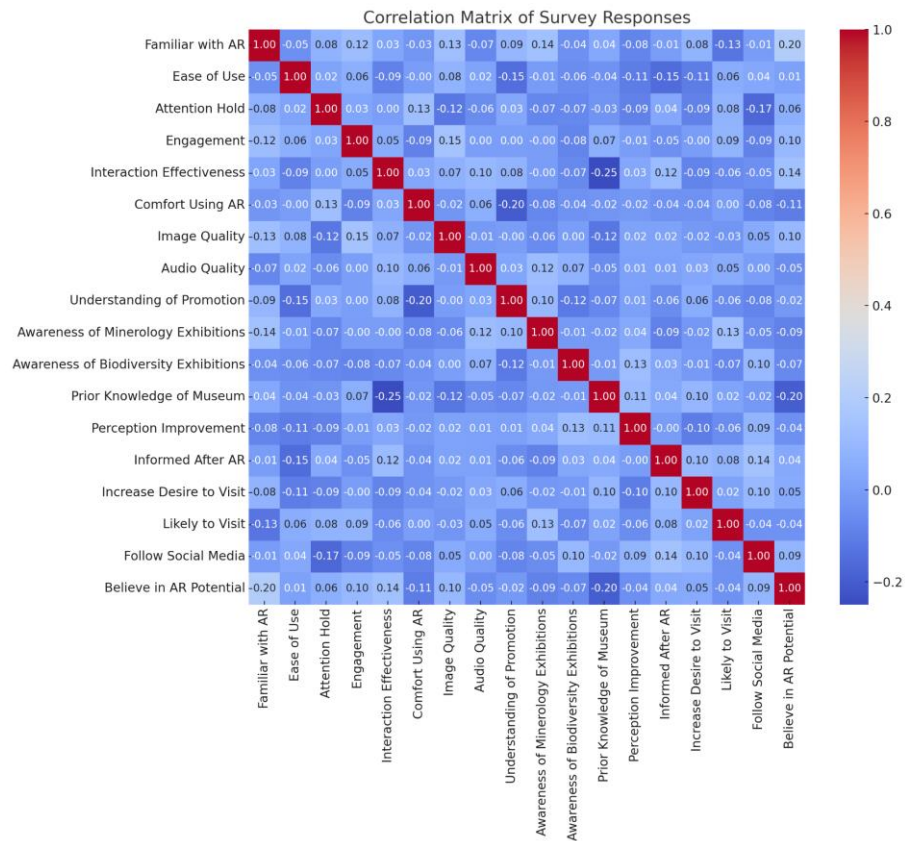


Figure 34. The Correlation Matrix of survey respondents.

Variables such as 'Ease of Use', 'Comfort Using AR', and 'Engagement' show moderate to strong positive correlations with each other, indicating that better usability of the AR features is closely

linked to higher engagement levels. 'Perception Improvement' and 'Believe in AR Potential' have positive correlations with engagement and usability metrics, suggesting that a positive interaction experience with the AR features contributes to improved brand perception and belief in AR's potential. 'Increase Desire to Visit' and 'Likely to Visit' are positively correlated with engagement and perception improvement, which aligns with the hypothesis that engaging and informative AR experiences can motivate actual museum visits.

Qualitative responses were analyzed using thematic analysis to identify common themes relating to user experience, suggestions for improvement and perceptions of AR as a marketing tool. Among the major themes were:

1. Technical challenges
2. Engagement and Interactivity
3. Educational value
4. Suggestions for improvement

A total of 42 out of 167 respondents (25%) reported encountering technical problems that prevented them from fully utilizing the capabilities of AR. Common problems included:

- Glitches and responsiveness: were a frequent comment echoed in various forms by respondents: *'Sometimes AR features would freeze or not load quickly, which was frustrating.'*, *'the app was slow'*, *'it was crushing'*.

- Usability issues: a significant amount of feedback from 30 respondents pointed to the clunky and unintuitive nature of the AR interface, summarizing a broader view that usability needs to be improved. For example: *'I found navigating the AR interface a bit clunky and not very intuitive.'*

Despite some technical setbacks, 112 out of 167 (67%) participants appreciated the AR posters for their engaging and interactive elements:

- Increased interest: *'posters made me more curious about visiting the exhibits in real life.'* - was an opinion shared by 69 respondents, which emphasizes the effectiveness of posters in arousing interest.

- Interactive experience: *'it was like being able to look inside the museum through a portal.'* - similar sentiments about the "look inside the museum" feeling was described by 43 respondents, illustrating the immersive quality of the AR experience.

Responses showed that the AR posters added educational value by making learning more dynamic and accessible:

- Informative content: *'it was interesting to read about crystals and look at them closely, as well as get a glimpse inside the botanical garden of the museum before even visiting it'* - echoed by 98 respondents, emphasized the informative aspect of the AR posters.

- Improved learning: *'I think using AR to present historical facts in an interactive way helps to remember the information better'* - was a viewpoint shared by 85 respondents, emphasizing that AR

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technology has potential in enhancing education and information remembering processes.

Feedback also included constructive suggestions aimed at enhancing the overall user experience by including more diverse information about lesser-known facts and improving the user interface for easier navigation and quicker access to information. Some participants realized that by drawing in younger people and offering interesting, instructive content in a fresh way, AR might completely change the way museums sell themselves.

Semi-structured interviews were conducted with four participants, three students from the Faculty of Engineering of the University of Porto (FEUP) and one from the Faculty of Fine Arts of the University of Porto (FBAUP). These interviews were designed to further explore personal experiences, perceptions and the potential of augmented reality (AR) technology in enhancing the museum experience. Each participant voluntarily agreed to participate after conducting the survey, signed an informed consent form, ensuring anonymity and adherence to research ethics. Interviews were conducted online in a semi-structured format, allowing for a deeper exploration of individual experiences while maintaining consistency across sessions. The data collected was thematically analyzed (Figure 35).

Key topic	Findings	Quotes
Initial Reaction	All participants were pleasantly surprised and intrigued by AR technology.	P1: "I was pleasantly surprised to see it in action..." P2: "The abstract designs really grabbed my attention..." P3: "It was very interesting! I wasn't 100% sure what to do with it first..." P4: "Firstly, I was attracted by the initial minimalist appealing design of the posters..."
Engagement & Expectations	The interactivity and immersiveness of AR exceeded the initial expectations of the participants.	P1: "I initially didn't have any expectations since I haven't interacted with AR posters before." P2: "It was so much cooler than I imagined." P3: "I didn't have any initial expectations, as I've never seen AR poster before." P4: "So, at first that interaction with these AR posters will provide me only with a 3D visual content. However, I was surprised to see additional information inside of the posters, which I could open up."

		..."
Educational Value	Participants appreciated the educational content of the AR posters, emphasizing the value of interactive learning.	P1: "I really liked the second poster, especially the animated animal models." P2: "I enjoyed reading about them. The whole experience felt more engaging." P3: "I reckon learning more about the rocks, because of the colours." P4: "Through this AR feature, I got some new information about minerals of Portugal..."
Influence on Museum Visits	AR posters effectively increase participants' interest in visiting the museum by showing them what to expect.	P1: "The 3D elements gave me a peek at what the exhibition is about." P2: "The AR posters showed me that the museum isn't stuck in the past..." P3: "It made me interested in the museum, but I think the name of the museum should be more prominent." P4: "Yes, definitely it made an influence to visit the museum."
Marketing Effectiveness	Participants viewed AR posters as a new and effective marketing tool that contrasts with traditional perceptions of museums.	P1: "I think they're pretty effective, since most people expect these types of museums to be more traditional..." P2: "I think AR posters are incredibly important and effective for museums." P3: "I'd say pretty effective, it's a very modern approach..." P4: "I think that AR posters can be really useful as a marketing tool..."
Unique Advantages of AR	AR was recognized for its unique ability to engage audiences through interactivity and immersion.	P1: "I think they provide an interesting approach to marketing..." P2: "AR brings a level of immersion that traditional marketing can't match." P3: "It gives a more interactive taste of what it can be like, and maybe sparks a desire to visit." P4: "From my point of view, museums such as Natural History Museums often lack interactivity..."

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Suggestions for Improvement	Participants suggested various enhancements to improve the AR experience, focusing on usability and depth of content.	P1: "I feel like it would be interesting to provide some bits of information about the exhibition in the AR poster..." P2: "One thing that could help is a zoom feature for the text—I found it a bit tricky to read." P3: "Yes, it was a bit shaky, you couldn't always read it very well..." P4: "Stability of the AR experience..."
Future Innovations	Participants presented innovative options for using AR in the future, offering a more dynamic and personalized experience.	P1: "I think it would be interesting to provide the audience with a snippet of information or a question of some sort on a poster..." P2: "Maybe AR could create a more convincing storytelling narrative during the promotion making the marketing seem more like a treasure hunt, where you are trying to open all the qr codes and experience something different every time....It could also be cool to send out AR invitations to special events or exhibition openings" P3: "Maybe you can have different motion on the posters..." P4: "In my opinion, museums could innovate further with AR by integrating some sort of AI solutions, which could enable dynamic storytelling, where AR adapts and evolves based on visitor interactions, deepening engagement. ..."

Figure 35. Thematic analysis table for AR-Enhanced Posters interviews.

The thematic analysis of the interview responses reveals several key insights into the effectiveness of AR-enhanced posters as tools for engaging visitors and promoting museums. When participants interacted with AR posters, they consistently reported feeling surprised and intrigued. Such reactions highlight the novelty and attractiveness of incorporating AR into a typical museum setting, which is frequently viewed as static and less engaging. For example, one participant reported that the imaginative inclusion of interactive features to a static show considerably boosted engagement (P1). This

implies that augmented reality might effectively attract visitors' attention, producing a strong initial impression and providing a foundation for further investigation of museum offerings.

Participants with no prior expectations or limited exposure to AR technology were notably delighted with the depth and quality of engagement (P2, P4). This demonstrates AR's ability to shift perceptions of museum exhibits from passive to active learning environments, attracting a generation that values digital involvement.

An important outcome of the interviews was the impact of AR posters on participants' interest in visiting the museum. The 3D elements and interactive features provided a “sneak peek” of what visitors could expect, making the museum exhibits more attractive and accessible before the actual visit (P1, P2, P3, P4). And also one interviewee expressed that such a promotional campaign made them think that “the museum isn't stuck in the past” (P2). These aspects of AR can play a crucial role in converting the interest generated by marketing into actual visitor numbers, addressing the challenge museums face in attracting a young, tech-savvy audience.

Participants mentioned the educational value of AR, praising how the technology allowed them to learn about exhibitions in an engaging way. Minerals and biodiversity were presented in detail through interactive AR posters, which helped participants better grasp these topics and may have increased retention and pleasure (P3, P4). This higher level of information is consistent with museums' mission to educate the public, implying that augmented reality can be an effective tool for enriching the visitor experience.

The effectiveness of AR as a marketing tool was confirmed by its ability to modernize the museum's image and distinguish it from other cultural institutions. AR was seen as a key element in making museums appear more modern and in line with current technological trends (P1, P2, P3, P4). Moreover, the unique advantage of AR in creating immersive experiences was thought to increase the memorability of the marketing message and promote deeper engagement with museum content.

Despite the positive feedback, there were several suggestions for improving the AR experience. Participants noted the need to improve the stability, usability, and information content of the AR interface (P2, P4). Looking to the future, participants noted that AR could incorporate artificial intelligence for personalized experiences and dynamic storytelling (P4), suggested making such immersive campaigns more epic that would attract the crowd (P3) or more playful like a treasure hunt (P1, P2), and suggested that museums could further leverage the power of AR to create engaging and educational narratives beyond traditional methods (P4).

Thematic analysis of the interviews indicates that AR-enhanced posters have considerable potential as a tool for boosting visitor engagement, educational outreach, and museum marketing success. By incorporating the technological and content changes recommended by participants, museums can better use AR's potential to meet evolving audience expectations, enhancing the visiting experience and

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broadening their educational impact.

3.3.3 Results

This chapter summarizes the results of the preceding data analysis and directly addresses the research questions posed at the beginning of this study. The emphasis is on analyzing how the findings connect to the larger implications of using immersive technologies into museum branding, particularly among young adult audiences. The debate is structured around each study matter, allowing for a thorough evaluation of the findings' consequences.

Research Question 1: How does immersive technology interest young adults to visit the museum?

The participants' reactions to AR-enhanced posters were largely favorable, most reporting greater curiosity and a desire to see the exhibitions in person. This interest was sparked primarily by the technology's interactive and immersive nature, which offers a fresh way of experiencing classic museum content. Thus, AR serves not only as an attraction tool, but also as a link between potential visitors and museum exhibits, increasing the possibility of a visit.

Research Question 2: What is the influence of immersive technologies on museums in terms of brand awareness and brand engagement?

AR applications in museum contexts improve the museum's image as a forward-thinking organization. This study discovered that AR not only raised awareness of the museum's offerings, but also enhanced participation by creating interactive experiences that were both informative and enjoyable. As a result, museums that adopt these technologies are likely to experience greater brand affiliation and loyalty, particularly among tech-savvy young adults.

Research Question 3: Do out-of-the-walls immersive, technology-based promotional campaigns for museums increase visitations?

Our findings suggest that AR experiences in publicly accessible areas act as an effective promotional tool, extending the museum's outreach and engaging broader audiences. Participants responded positively to the AR-enhanced posters, indicating increased curiosity and a greater desire to visit the museum, showcasing the potential of AR technologies in museum promotions. While this method appears to enhance the museum's visibility and attract potential visitors, our study could not empirically test whether these interactions directly resulted in actual visits due to time constraints. Therefore, while responses suggest a hypothetical increase in visitation intent, future research should aim to track these interactions to concrete visitation metrics to validate the effectiveness of such campaigns fully.

Research Question 4: What are the perceptions of young adults on the potential of immersive technologies as a marketing tool for museums?

Young adults see immersive technologies as important and highly successful marketing tools for museums. They enjoy how these technologies enhance the museum experience and bring it in line with current digital experiences. AR's ability to alter museum marketing is viewed as critical to reaching younger audiences that want engaging, dynamic, and interactive material. Furthermore, participants stated that ongoing AR innovation may constantly renew and improve the museum's appeal, keeping it relevant in a quickly changing digital context.

This analysis sets the stage for a discussion of how AR technologies can be optimized for museum promotion and provides empirical evidence of their effectiveness as a marketing tool. It also lays the groundwork for potential strategic recommendations for museum marketers to increase visitor engagement through AR technologies.

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The development and evaluation of AR-enhanced posters for the University of Porto's Natural History and Science Museum revealed important insights into augmented reality technologies' potential to improve museum branding and engage a younger audience. The poll of university students provided useful data that highlighted both the strengths and places for improvement in the usage of AR in museum settings.

A key limitation of this study was the inability to physically place AR posters at the university due to unforeseen circumstances, resulting in the survey being distributed exclusively online. This shift likely influenced the nature of participants' interaction with AR, potentially limiting the depth of engagement compared to face-to-face interaction. Conducting the survey online may also have affected the familiarity and comfort level with technology among respondents, as those less inclined to engage digitally may not have been as engaged. The study's limitations extend beyond the survey's online launch. The sample was limited to university students; therefore, it may not accurately reflect the demographics of museum visitors. Furthermore, the dependence on self-reported data introduces a level of subjective bias that may influence the results. In addition, the study could have benefited from measuring the number of experiential participants who actually visited the museum afterwards.

Despite these challenges, the study showed that AR technologies have significant potential to increase visitor engagement and brand awareness in museums. However, technical challenges such as glitches and user interface issues have been highlighted as significant barriers to optimal user experience. These technical challenges, along with usability feedback from respondents, point to critical areas for improvement.

The study aimed to answer several research questions about the impact of AR technology on museum visitor engagement and brand perception. The results suggest that AR technology can significantly increase the engagement of university students, as evidenced by high engagement rates. Students commented that the interactive features of AR were particularly engaging. Those who interacted with AR posters had a markedly improved perception of the museum's brand. This suggests that AR can

be an effective tool not only to engage visitors, but also to improve their perception of the museum as innovative and educational. The technical challenges encountered emphasize the need for careful technical development and testing before implementing such technologies on a large scale.

Future research should focus on the implementation of AR technologies in a controlled physical environment to better assess face-to-face interaction and its impact on engagement and learning. Further research could also focus on a broader demographic to understand how different age groups and populations interact with and benefit from AR technologies in a cultural setting. It would be useful to develop more robust and user-friendly AR applications, taking into account the improvements suggested by participants. Longitudinal studies can also be valuable for assessing how perceptions and engagement change over time with repeated use of AR. The transition from planned physical deployment to an 'online-only' format has highlighted the need for flexibility and robust planning in research methodology. Future initiatives should include contingency plans that allow for a smooth transition from one mode of deployment to another.

This study provides a solid framework for evaluating the impact of augmented reality on museum experiences. The findings highlight the great promise of these technologies in cultural settings, while also emphasizing the significance of fixing technical challenges in order to fully harness AR's capabilities. As we move forward, these insights will influence the improvement of AR applications, ensuring that they are more in line with user wants and expectations, increasing the museum promotional experience for all potential visitors.

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Appendix A: Interview Transcripts and Questionnaire

This appendix contains the transcripts of semi-structured interviews conducted with participants from the Faculty of Engineering of the University of Porto (FEUP) and the Faculty of Fine Arts of the University of Porto (FBAUP). The interviews aimed to assess the impact of augmented reality (AR) technologies on museum visitor engagement. All interviews were conducted under confidentiality conditions, with informed consent from each participant, ensuring their anonymity.

Interview Questions and Responses:

Question 1: Can you describe your initial reaction when you first interacted with the AR posters?

- **Participant 1 (P1, Female, 25, FEUP):** "Since I haven't used AR a lot before, I was pleasantly surprised to see it in action. I thought they were creative and add a certain interaction element to an otherwise static poster."
- **Participant 2 (P2, Female, 26, FEUP):** "When I first saw the AR posters, I felt pretty curious. The abstract designs really grabbed my attention, especially the crystal-like shapes—I had no idea what they were supposed to be, and that just made me even more excited to scan the code and see what would pop up. The mystery pulled me in."
- **Participant 3 (P3, Female, 23, FBAUP):** "It was very interesting! I wasn't 100% sure what to do with it first. But looked very attractive!"
- **Participant 4 (P4, Male, 27, FEUP):** "Firstly, I was attracted by the initial minimalist appealing design of the posters. They have a clean and modern look that invites further exploration. Their simplicity drew my attention and made me curious to explore more and interact with the AR feature."

Question 2: How did your interaction with the AR poster differ from your expectations?

- **P1:** "I initially didn't have any expectations since I haven't interacted with AR posters before."
- **P2:** "When I first scanned the leaf poster, I expected to just see a tree or something nature related. But when animals showed up, and everything was animated, I was totally surprised—it was so much cooler than I imagined. Same with the crystals—I didn't know what to expect at all, but the animations and how interactive and pretty everything was really made me interested."
- **P3:** "I didn't have any initial expectations, as I've never seen AR poster before."
- **P4:** "So, at first that interaction with these AR posters will provide me only with a 3D visual content. However, I was surprised to see additional information inside of the posters, which I could open up. In one of the posters, I also liked a small sound design feature. In addition,

both of the Posters provide quick links to the museum website and social media, which I consider as a big positive plus."

Question 3: Did the AR posters influence your interest in visiting the museum? Can you elaborate on how?

- **P1:** "I think the posters peaked my interest and would make me want to visit the museum. The 3D elements gave me a peek at what the exhibition is about."
- **P2:** "Definitely! The AR posters showed me that the museum isn't stuck in the past—they're using cool tech, which always catches my interest. I'm really curious about how they blend technology with their exhibits. Plus, the exhibitions themselves looked pretty and had a soft, appealing vibe, which is totally my style."
- **P3:** "It made me interested in the museum, but I think the name of the museum should be more prominent. I feel when your eyes are caught by the AR experience, you don't see the name of the museum very much, so this is why you don't really understand what is being promoted."
- **P4:** "Yes, definitely it made an influence to visit the museum. As a good example, through this AR feature, I got some new information about minerals of Portugal, which I didn't know previously. In the regular static poster, I would never receive the same amount of information such easily. Also, the interactive AR experience got me interested to know if the whole museum is able to provide me some of these features during the visit."

Question 4: What aspects of the museum or its exhibitions did the AR posters make you more curious about?

- **P1:** "I really liked the second poster, the breath of earth, especially the animated animal models. I think the flashy animations peaked my interest because I expected the AR elements to be more minimalistic."
- **P2:** "The crystal poster grabbed my attention the most. I think it was because it was more interactive—I could click on different objects and even place the crystals in my own space, which was nice. Plus, I enjoyed reading about them. The whole experience felt more engaging than the leaf one."
- **P3:** "I reckon learning more about the rocks, because of the colours. I didn't know that Portugal has such diverse and vibrant rock formations."
- **P4:** "My attention was caught by the AR posters about biodiversity and Portugal's minerals because they both presented fresh data in an interesting and interactive manner. Specifically, due to the 3D visuals that are included in the poster about biodiversity, made me really curious about this topic. The poster with minerals also was quite interesting one. I liked the feature that allowed not only to see the short information about the mineral itself, but also see how it looks like and rotate it."

Question 5: In your opinion, how effective are AR posters as a marketing tool for museums

like the Natural History and Science Museum?

- **P1:** "I think they're pretty effective, since most people expect these types of museums to be more traditional and old-fashioned, so bringing in modern elements makes the museum seem more contemporary."
- **P2:** "I think AR posters are incredibly important and effective for museums. With so many choices, people naturally gravitate toward places that feel modern and forward-thinking, especially for topics like history and science. Museums need to break away from the stereotype that everything will be dull or just about staring at exhibits and reading text. AR posters signal innovation, ignite curiosity, and help certain museums stand out from the crowd."
- **P3:** "I'd say pretty effective, it's a very modern approach that gives a museum a pretty modern feel, which should be good for promotion of something old."
- **P4:** "I think that AR posters can be really useful as a marketing tool for museums, especially if they are properly designed. Such posters can increase the engagement and highlight the interactivity, as well as create a unique experience for the people who are seeing such posters for the first time."

Question 6: What unique advantages do you think AR brings to museum marketing?

- **P1:** "I think they provide an interesting approach to marketing, since it brings a sense of interaction to the advertisement, which makes the audience feel like they're participating even before they visit the museum."
- **P2:** "I think I kind of answered this question in the previous answer but maybe something else I can say is that AR brings a level of immersion that traditional marketing can't match. It lets people interact with exhibits in a fun, hands-on way before they even step foot in the museum, creating a more memorable experience."
- **P3:** "It gives a more interactive taste of what it can be like, and maybe sparks a desire to visit."
- **P4:** "From my point of view, museums such as Natural History Museums often lack interactivity and immersion, which can make them feel less engaging for modern audiences. For me, the generic graphic posters that are often used for museums are static and not very attractive to those people seeking dynamic experience. If something is mentioned in the poster about interactivity, I am always going to try it out."

Question 7: Were there any elements of the AR experience that you felt could be improved?

- **P1:** "I feel like it would be interesting to provide some bits of information about the exhibition in the AR poster, maybe add some fun facts about the contents of the exhibit to make peak the audiences' interest and make them want to learn more and visit the museum."
- **P2:** "There's always room for improvement, but considering it was a prototype, it was really impressive. One thing that could help is a zoom feature for the text—I found it a bit tricky

to read. Also, while I get that it's for marketing, the social media icons felt a bit too in-your-face and took away from the overall design of the posters."

- **P3:** "Yes, it was a bit shaky, you couldn't always read it very well, maybe it would benefit from having less written information and more pictures to play with."
- **P4:** "Stability of the AR experience. Sometimes the posters worked perfectly, but sometimes it took time to calibrate them or even reload again."

Question 8: Do you have any suggestions for how AR could be better utilized by museums in the future?

- **P1:** "I think it would be interesting to provide the audience with a snippet of information or a question of some sort on a poster or a sign, and by scanning the QR code they could see the answer on the poster with AR elements, making them interested and forcing them to interact with the poster."
- **P2:** "Maybe AR could create a more convincing storytelling narrative during the promotion, making the marketing seem more like a treasure hunt, where you are trying to open all the QR codes and experience something different every time. The AR filters on social media might also work in the promotion, like a beautiful nature filter or even makeup for the natural exhibition making a person using the filter 'blend right in' to the environment."
- **P3:** "Maybe you can have different motion on the posters, like historic events and battles, something epic that would attract the crowd."
- **P4:** "In my opinion, museums could innovate further with AR by integrating some sort of AI solutions, which could enable dynamic storytelling, where AR adapts and evolves based on visitor interactions, deepening engagement. In addition, AR can be used not only for marketing but also inside of museums. For example, with AR, it is possible to make tours more entertaining or attract young generations."

Appendix B: Survey Questionnaire

This appendix contains a survey administered to students at the University of Porto as part of the project 'Enhancing museum brand awareness with immersive technologies: a case study'. The poll sought information on participants' perceptions on the use of AR-technology posters and their influence on museum brand awareness and attendance. The survey data is significant for the analyses offered in the thesis's key chapters.

Survey Questions:

Section 1: Demographics

1. Your age:

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

2. Your gender:

- Male
- Female
- Other
- Prefer not to say

3. Your country:

(Open-ended response)

4. Your university:

- University of Porto (FEUP)
- University of Porto (Other faculties)
- Other

5. Your field of study/occupation:

- Science
- Engineering
- Humanities
- Business
- Arts

Section 2: Prior Experience with AR Technologies

6. I am familiar with augmented reality (AR) technologies:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

7. I have used AR applications before:

- Yes
- No

8. If yes, what type of AR applications have you used? (Select all that apply)

- Gaming
- Education
- Marketing/Advertising
- Social Media
- Other

Section 3: User Interaction with the AR Posters

9. It was easy to use the AR features on the posters:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

10. The AR posters held my attention longer than traditional posters:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

11. I found the AR features engaging:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

12. I was able to interact with various multimedia elements (e.g., 3D models, icons, animations) effectively on the AR posters:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

13. The quality of images and videos in the AR posters was high:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

14. The audio used in the AR posters was clear and enhanced the experience:

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

6. Awareness and Perception of the Museum

15. I understood that the posters were promoting the Natural History and Science Museum of the University of Porto (MHNC-UP).

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

16. I understood that the Natural History and Science Museum of the University of Porto has exhibitions about mineralogy and geology.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

17. I understood that the Natural History and Science Museum of the University of Porto has exhibitions about biodiversity.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

18. I had heard about the MHNC-UP Museum before seeing the posters.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

19. My perception of the MHNC-UP Museum has improved after interacting with the AR posters.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

20. I feel more informed about the museum's exhibits after using the AR posters.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

7. Intention to Visit the Museum

21. The AR posters increased my desire to visit the MHNC-UP Museum.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

22. I am likely to visit the MHNC-UP Museum within the next 6 months.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

23. I will follow the museum's social media channels for updates.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

8. Overall Feedback on the AR Experience

24. What did you like the most about the AR posters?

25. What did you like the least about the AR posters?

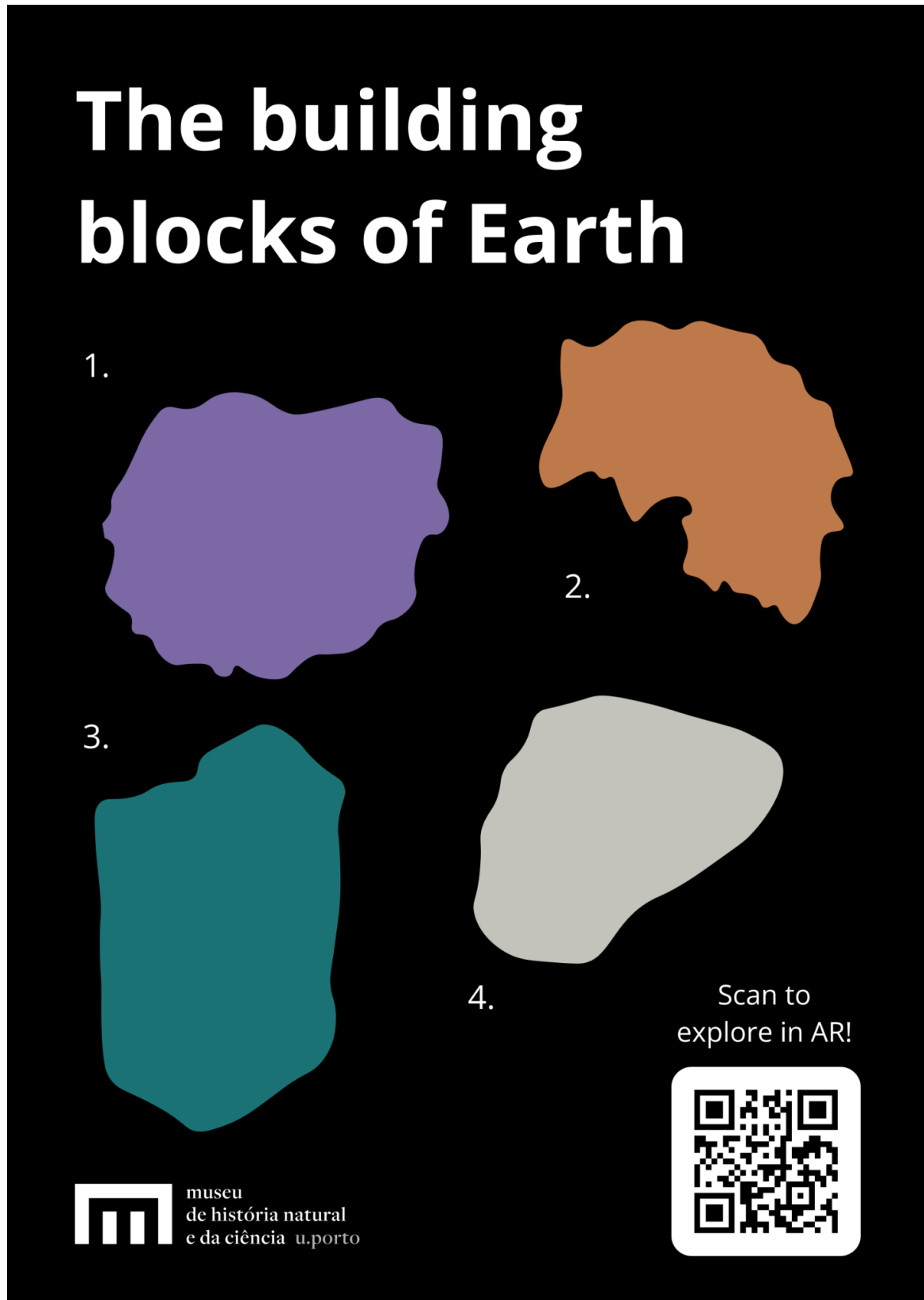
26. Do you have any suggestions for improving the AR experience on the posters?

27. I believe AR has potential as a marketing tool for museums.

- 1 - Strongly disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly agree

Appendix C: Posters Prototype

Poster 1



The breath of Earth



Scan to
explore in AR!



museu
de história natural
e da ciência u.porto