

Past Meets Pixel: Enhancing Cultural Heritage Engagement with XR

George Efthimiou¹, Michail Potsikas², Konstantina Prouska³, Katerina Plakitsi⁴

Abstract: This research delves into the burgeoning domain of integrating Virtual Reality (VR) and Augmented Reality (AR) technologies in the field of cultural heritage. Extended Reality (XR) refers to all combined real and virtual environments. Drawing upon activity theory as a theoretical foundation, the study examined the efficacy of AR in facilitating a deeper understanding and engagement with cultural heritage sites. Master's students of the Interdepartmental master's program "Environmental Sciences and Education for Sustainability" was introduced to a unique experience: an educational activity with embedded AR markers at various historical sites between Ioannina and Arta on the road alongside the river Louros as part of an action titled "Marble Sustainability Matters II". The subsequent questionnaire captured participants' perspectives across various dimensions, such as perceived usefulness, user experience, information quality, social interaction, and more. Results indicated a predominant positive inclination towards the use of AR in cultural heritage contexts, with particularly high scores in perceived usefulness and educational value. This research points to a significant potential for cultural institutions, policymakers, and VR/AR developers to further harness these technologies for educational and engagement purposes

Keywords: Virtual Reality, Augmented Reality, Cultural Heritage, Activity Theory

Το παρελθόν συναντά τα pixel: Ενισχύοντας την Πολιτισμική Κληρονομιά με Εκτεταμένη Πραγματικότητα

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Περίληψη: Το άρθρο αυτό ερευνά τον αναπτυσσόμενο τομέα της ενσωμάτωσης των τεχνολογιών Εικονικής Πραγματικότητας (VR) και Επαυξημένης Πραγματικότητας (AR) στον τομέα της πολιτισμικής κληρονομιάς. Η εκτεταμένη πραγματικότητα (XR – extended reality) είναι ένας όρος που αναφέρεται στην αλληλεπίδραση του ανθρώπου είτε με AR είτε με VR. Με βάση την θεωρία της δραστηριότητας, το άρθρο εξέτασε την αποτελεσματικότητα της AR στη διευκόλυνση μιας βαθύτερης κατανόησης και αλληλεπίδρασης με τους πολιτισμικούς χώρους. Οι μεταπτυχιακοί φοιτητές του διατμηματικού μεταπτυχιακού προγράμματος «Επιστήμες του Περιβάλλοντος και Εκπαίδευση για την Αειφορία» εισήχθησαν σε μια μοναδική εμπειρία: μια δραστηριότητα με ενσωματωμένους δείκτες AR σε διάφορα σημεία πολιτισμικής κληρονομιάς μεταξύ Ιωαννίνων και Άρτας κατά μήκος του ποταμού Λούρου. Η δραστηριότητα ονομάστηκε "Marble Sustainability Matters II". Το ερωτηματολόγιο που

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ακολούθησε αποτύπωσε τις απόψεις των συμμετεχόντων σε διάφορες διαστάσεις, όπως η αντιληπτή χρησιμότητα, η εμπειρία χρήση, η ποιότητα των πληροφοριών, η κοινωνική αλληλεπίδραση και περισσότερο. Τα αποτελέσματα έδειξαν μια κυρίαρχα θετική τάση προς τη χρήση της AR σε πλαίσιο πολιτιστικής κληρονομιάς, με ιδιαίτερο ενδιαφέρον στην αντιληπτή χρησιμότητα και εκπαιδευτική αξία. Η έρευνα δείχνει σημαντικό δυναμικό για πολιτιστικούς οργανισμούς, νομοθέτες και προγραμματιστές VR/AR να αξιοποιήσουν περαιτέρω αυτές τις τεχνολογίες για εκπαιδευτικούς και διαδραστικούς σκοπούς.

Λέξεις κλειδιά: Εικονική Πραγματικότητα, Επαυξημένη Πραγματικότητα, Πολιτιστική Κληρονομιά, Θεωρία Δραστηριότητας

Introduction

Background

Introduction to Virtual and Augmented Reality.

Virtual Reality (VR) and Augmented Reality (AR) are emerging as game-changers, reshaping numerous sectors from leisure to learning. VR places individuals in a digitally-created representation of a setting, typically facilitated by visual and sound equipment, letting them engage with this virtual environment in a three-dimensional manner (Sherman & Craig, 2018). This deep immersion imparts a feeling of "being there", making participants sense they are truly within this digital universe, actively engaging with its components.

Contrastingly, Augmented Reality doesn't supplant our reality but superimposes digital elements onto it. AR fuses electronic data with an individual's real-time surroundings, enhancing their real-world view (Azuma, 1997). With AR, individuals can engage with both their actual surroundings and the digitally-added components. Often used through tools such as mobiles or AR spectacles, its utility spans from recreational activities like the renowned Pokémon Go to intricate medical tasks, providing on-the-spot data enhancements.



Image 1: From left to right: Oculus rift, htc vive, microsoft hololens

The promise of VR and AR has piqued immense interest, particularly with the emergence of more cost-effective and intuitive gadgets. For example, Oculus Rift, HTC Vive, and HoloLens by Microsoft (Image 1) are now widely recognized, setting new standards for digital immersion and enriched interactions (Mazuryk & Gervautz, 1996). The surge in processing capabilities and strides in visual displays have heightened the authenticity and agility of these digital realms, amplifying their suitability for diverse uses.

Beyond just leisure and play, VR and AR hold great promise for pedagogy, skill-building, and cultural outreach. These tools introduce innovative methods to represent intricate ideas, imitate real-world situations, and provide immersive learning experiences (Billinghurst & Duenser, 2012). Notably, in preserving cultural heritage, such tools can transcend temporal and spatial barriers, letting individuals digitally traverse olden cultures or observe age-old relics in enriched setups.

As the maturation of VR and AR technologies progresses, they usher in a new era in our engagement with the digital and tangible realms. They redefine classical concepts of interactivity, immersion, and user experience, prompting scholars and creators to probe into their expansive and yet uncharted possibilities.

The significance of cultural heritage preservation and engagement.

Cultural legacies, seen in landmarks, relics, customs, and values passed down, are instrumental in shaping societal identity and ensuring its continuity (Smith, 2006). They act as historical snapshots, highlighting the progression and milestones of civilizations while shedding light on their dreams, challenges, and triumphs. Safeguarding this legacy isn't just about cherishing the bygone times; it's a dedication to upcoming generations, offering them a bridge to their ancestry and a backdrop to their current realities (De La Torre, 2005).

Interacting with this rich heritage, via avenues like academics, travel, and broadcasting, nurtures a communal bond and shared chronicle. When people explore historical places or engage in age-old customs, they're not mere spectators; they're contributors to the societal tapestry, linking eras and fostering dialogues across generations (Lowenthal, 2015).

In today's swiftly globalizing era, where distinct cultural markers face potential overshadowing, safeguarding heritage stands resilient, applauding regional diversity and stories (Kirshenblatt-Gimblett, 1998). This dedication has tangible financial benefits too. Heritage-driven tourism, anchored by well-maintained landmarks and compelling narratives, can elevate regional economies by attracting global curiosity and resources.

But the value of cultural legacies isn't restricted to identity or economic facets. It's pivotal for sustainable growth. UNESCO's inclusion of cultural facets in its Sustainable Development Aims highlights the significance of heritage in enhancing adaptability, championing harmony, and steering urban sustainability (UNESCO, 2013). Historically preserved sites can often provide lessons on enduring and sustainable techniques.

A noteworthy dimension of cultural legacies lies in its potential for healing. Recent studies suggest that immersing oneself in cultural activities and landmarks can bolster mental health, trigger positive feelings, and even assist in overcoming traumas (Thomson & Chatterjee, 2016).

In conclusion, maintaining cultural heritage is also intertwined with environmental stewardship. Ancient locations and nature-rich heritage zones frequently support biodiversity conservation. Age-old wisdom embedded in certain societies can give cues for eco-friendly farming, woodland governance, and preservation strategies (Berkes, 2018).

Cultural heritage preservation and engagement.

Greece, boasting a vast historical canvas that stretches over centuries, embodies the essence of cultural legacies. Recognized as the birthplace of Western thought, its gifts to global society include profound developments in thinking, artistic expression, structural design, and governance systems (Hall, 2010). Landmarks like the Athenian edifices, the enigmas of Delphi, and the splendor of Olympia (Image 2) don't merely echo the spirit of ancient Greece but have also molded universal cultural tales.

The financial benefits of Greek heritage are palpable. Tourism, centered majorly on its age-old landmarks and cultural events, is a vital economic pillar. Attractions such as the Acropolis, the allure of Santorini evenings, and the Minoan remnants in Crete, magnetize countless visitors every year, underscoring the fiscal advantages of conserving heritage (Gaitanakis et al, 2015).

But Greece's interaction with its historical inheritance transcends international influence or monetary gains. For its inhabitants, this heritage serves as a vibrant link to their storied

forebears, a symbol of tenacity in tumultuous eras, and a guiding light for subsequent epochs. The passion with which Greece advocates for the repatriation of the Parthenon Marbles speaks volumes about the intrinsic and national worth ascribed to their legacy (Hamilakis, 2007).



Image 2: *School students use a mobile app at the ancient site of Olympia, southwestern Greece, Wednesday, Nov. 10, 2021.*

Epirus, nestled in Greece's northwest, is a realm drenched in tales and natural allure, with the Louros river weaving a vital thread in its cultural and environmental mosaic. This waterway has been pivotal for several communities, molding their societal activities, habitation choices, and commerce pathways (Papayiannis, 2008). Its environs have borne witness to myriad events, from age-old ceremonies to crucial historical junctures, capturing stories of tenacity, strife, and unity.

The commitment to safeguarding and celebrating the historical essence of the Louros river goes beyond mere homage to bygone times; it signals a vision for the region's future. Like various Greek rivers, it is a repository of legends, oral accounts, and traditions that offer insights into the metamorphosis of local ethos, principles, and convictions. The melodies, choreography, and folklore shaped by the river's dynamics have been instrumental in crafting Epirus's cultural identity.

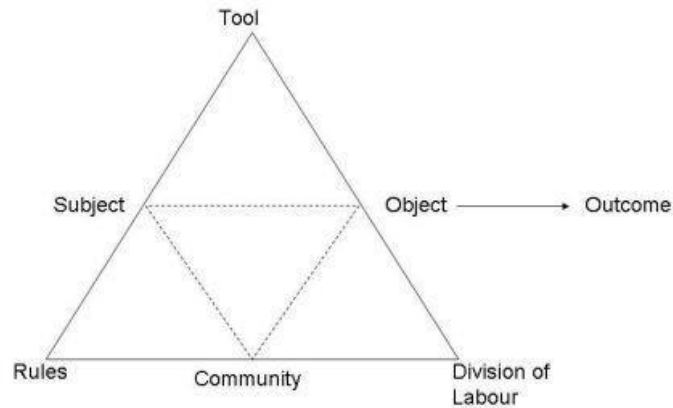
Furthermore, the Louros river, with its scenic grandeur and historical gravitas, emerges as a cornerstone for ecologically sound cultural tourism in Epirus. By safeguarding and showcasing its heritage spots, customs, and tales, Epirus could captivate a global cohort eager to immerse in genuine Greek traditions set against awe-inspiring terrains. Such ventures could yield fiscal rewards for the region while championing the reverence and safeguarding of its rich inheritance (Gaitanakis et al, 2015).

Zooming out to Greece's overarching dedication to nurturing its cultural and natural legacies, the Louros river epitomizes both timelessness and evolution. It echoes the intricate dance between human aspirations and the natural world, emphasizing the imperative to celebrate and safeguard the interconnected narratives of humanity, legend, and waterways.

1.4. Activity Theory as a Framework for Analyzing Human Interactions with Tools

Activity Theory (AT), provides a holistic framework to understand human actions in the context of their socio-cultural environment (Leontiev, 1978). Central to AT is the idea that human

activity is always mediated by tools or instruments, which can be both tangible (like a hammer) or intangible (like language). These tools are not just neutral intermediaries; they carry historical and cultural significances and actively shape the nature of the activity (Engeström, 1987)



The structure of human activity (p. 78, Engeström, Y. (1987): Learning by Expanding: An activity-theoretical approach to developmental re-search, Helsinki: Orienta-Konsultit Oy).

Within the scope of contemporary tech innovations, VR (Virtual Reality) and AR (Augmented Reality) can be assessed using the AT perspective as mechanisms that shape human encounters and redefine modes of engagement. These immersive platforms, by introducing or mimicking digital elements, present enhanced or alternative perceptions of reality. Yet, the interaction isn't solely a direct link between the individual and the tech; it's a threefold dynamic that includes the user, the tech (VR/AR), and the underlying purpose of the engagement (Kaptelinin & Nardi, 2006).

Evaluating VR/AR engagements through AT can reveal the broader societal and cultural ramifications of these tools. For example, a VR-guided journey of a historical site transcends merely being a tech-driven experience; it becomes a culturally influenced endeavor where VR serves as a connector between contemporary viewers and age-old stories, potentially modifying their viewpoints and comprehension (Rogers, 2009).

Moreover, AT's focus on the role of communal norms and regulations in determining activities offers clarity on the societal framing and regulation of VR/AR. As these innovations become more entrenched in routine experiences, the societal guidelines, standards, and customs tied to their application will play a pivotal role in determining their efficacy and the depth of human connections with them (Daniels et al., 2007).

Objective

Potential Synergy between VR/AR and Cultural Heritage Engagement

Virtual Reality (VR) and Augmented Reality (AR) tools are leading the transformation in various spheres of human interaction, especially in the context of cultural heritage. By creating immersive and dynamic settings, VR/AR presents an unparalleled platform for intensifying the recognition, comprehension, and conservation of cultural treasures (Forte, 2016).

One of the clear intersections of these technologies is their ability to bring remote or otherwise inaccessible heritage sites closer to a worldwide audience. There are numerous iconic sites that, due to geographic constraints, political tensions, or preservation-based restrictions, are off-limits to many. VR offers a portal to these spots, delivering in-depth

explorations that not only replicate but occasionally surpass real-life visits, broadening the accessibility of global cultural assets (Pietroni et al, 2012).

Furthermore, AR has the potential to layer contextual details, stories, and visual reconstructions on top of real-world heritage landmarks. Envision walking through the remnants of a historic amphitheater and, with the aid of AR eyewear, witnessing its majestic past — perhaps even actors enacting a scene. These enhancements breathe life into history, amplifying the visitor's comprehension and emotional ties to the location (Ch'ng et al., 2013).

Cultural relics also benefit from an enriched level of engagement via VR/AR. While tangible items might be secured behind glass in museums, their digital avatars within VR allow for more interactive exploration, permitting users to scrutinize them thoroughly, and even envision them in their pristine state. Such dynamic interactions offer a tactile learning journey, notably advantageous for educational endeavors (Sylaiou et al., 2010).

Beyond solitary experiences, VR/AR serves as a communal hub where participants from various geographies can simultaneously explore and converse about cultural heritage in a mutual virtual environment. These collective experiences encourage global cultural dialogues, support common principles, and can play a crucial role in fostering intercultural empathy and peace-building efforts (Roussou & Drettakis, 2003).

In conclusion, from a conservation standpoint, VR/AR carries significant weight. Digitally crafted representations of locations and objects ensure that even if their tangible counterparts succumb to disasters, disputes, or simply time, their digital doppelgangers endure, safeguarding the collective digital legacy of mankind (Huggett, 2017)..

2.2. Research questions

The rapid emergence and incorporation of Virtual Reality (VR) and Augmented Reality (AR) technologies into various sectors present intriguing implications for the realm of cultural heritage. These digital tools can drastically reshape our engagement with cultural assets. Simultaneously, theoretical frameworks, such as activity theory, offer potential insights into understanding the nuanced interplay between these advanced tools, their users, and the rich cultural content they aim to mediate (Kaptelinin & Nardi, 2017). Moreover, practical insights from primary research tools, like questionnaires, remain paramount in guiding the pragmatic aspects of VR/AR tool design within the cultural sector (Ch'ng, Gaffney, & Chapman, 2013).

Given this context, our study aims to address the following research questions:

1. **How does the integration of VR and AR technologies impact engagement with cultural heritage?** This question seeks to uncover the potential enhancements or challenges posed by VR/AR in terms of accessibility, immersion, and interactive capacities in engaging with cultural landmarks and artifacts.
2. **How does activity theory help explain the dynamics between VR/AR tools, users, and cultural content?** With the backdrop of activity theory, we aim to analyze the multi-faceted interactions occurring between the technological mediums (VR/AR), the users that employ them, and the cultural narratives and sites they engage with.
3. **What insights from the questionnaire can guide future design and implementation of VR/AR tools in the cultural heritage sector?** Harnessing primary data from a curated questionnaire, we aspire to derive actionable insights that can inform the future trajectory of VR/AR tool development, ensuring they are in resonance with the needs and preferences of end-users within the cultural domain.

Literature Review

VR and AR in Cultural Heritage: An Examination of Recent Endeavors

During the last ten years, Virtual Reality (VR) and Augmented Reality (AR) have deeply impacted the realm of cultural heritage. This part illuminates prominent initiatives and research that have adeptly merged VR/AR into the preservation of cultural legacy.

Digital Reconstructions with VR

Historical sites have been given new life through VR. A quintessential example is the "Virtual Rome" project, where users can immerse themselves in iconic landmarks such as the Roman Forum as it once was (Pietroni et al, 2012).

AR-enhanced Tours

In addition to VR, AR has made its mark by enriching on-site visitor experiences. Notably, an initiative at Pompeii uses AR to overlay digital reconstructions on the present-day ruins (Image 3), breathing life into the ancient city (Papagiannakis et al., 2005).

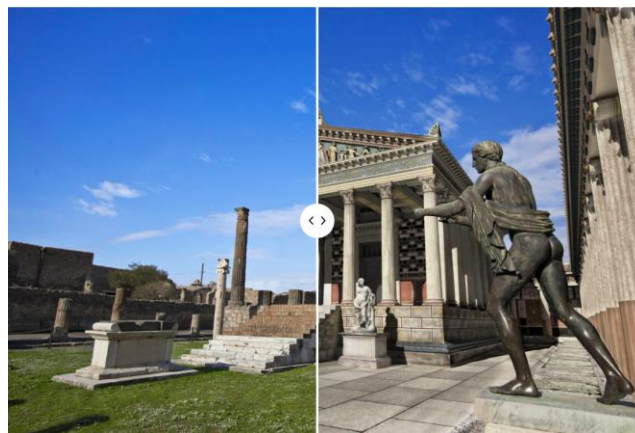


Image 3: AR Tour, digital reconstruction on present-day ruins

Interactivity with Cultural Artifacts

Prominent museums, including the British Museum, have employed VR to enable visitors to engage with digital replicas of precious artifacts, bypassing physical limitations and potential damage risks (Vosinakis et al., 2018).

Narratives and Storytelling

Cultural heritage extends beyond artifacts and sites, delving into the realm of stories. VR has been instrumental in projects like melding rich narratives with immersive environments.

Collaborative Experiences

Shared VR platforms, like the "Virtual Museum Transnational Network," have emphasized community engagement, creating collaborative spaces for international users to jointly explore and discuss art (Kenderdine, 2017).

Preservation Initiatives

AR/VR has a pivotal role in documenting at-risk heritage sites. A salient example is the "Preserving Syria's Heritage" project, which harnesses VR for digitally safeguarding heritage sites imperiled by political unrest (Barsanti et al., 2012).

VR/AR in Education

The educational sector has also adopted VR/AR, with endeavors presenting historical events, such as the French Revolution, in VR for a comprehensive student experience

Cultural Heritage Gaming

Bridging entertainment and education, games like "Time Machine VR" allow players to delve into historical periods, making learning an exhilarating experience.

Theoretical Framework: Activity Theory

When analyzing the engagements of our participants throughout the MSM II activity from Ioannina to Arta described below, it's essential to utilize a conceptual framework that delves into human actions within socio-cultural backdrops. Activity Theory (AT) serves this role aptly, emphasizing the interplay of individuals and their environment (Nardi, 2018).

Activity Theory posits that human activities are not isolated actions but are deeply embedded within a cultural and social matrix. Central to this theory is the concept of an "activity system." This system comprises several interrelated components:

Subject: Refers to the individual or group engaged in the activity. In our study's context, this would be the master's students participating in the treasure hunt.

Tools: Mediators that assist the subject in the activity. In our scenario, the smartphones and augmented reality application function as tools.

Object: The aim or motive of the activity. Here, the object would be the markers and artifacts that are found to continue the activity.

Rules: Regulate actions and interactions within the activity system. These could be the guidelines provided to the students before starting the treasure hunt.

Community: The larger group or context in which the subject operates. In this study, the broader cohort of master's students and perhaps the academic institution itself can be seen as the community.

Division of Labor: Refers to the distribution of tasks and roles. While this is more applicable to collaborative activities, for our treasure hunt, it might pertain to any roles the students organically assumed, such as leader, navigator, or researcher.

Using Activity Theory, we can decipher the intricate dynamics of our participants' engagements during the treasure hunt, understanding not just the actions, but the cultural and social implications interwoven with those actions. Such an approach not only enriches our data interpretation but also aligns with contemporary research methodologies that advocate for holistic, contextually grounded research paradigms (Bedny & Harris, 2005; Crichton & Kinash, 2003).

Methodology

Description

On Saturday, June 10, 2023, the Early Childhood Education Department in collaboration with the Ephorate of Antiquities of Ioannina, within the framework of the project "Center for Research, Qualitative Analysis of Cultural Heritage Materials and Science Communication (KE-ΥΠΚ)", presented with particular success to the students of the Interdepartmental Master's program "Environmental Sciences and Education for Sustainability", the action of highlighting the colorful marble floor and the 13th-century marble cuirass with a gryphon representation that are exhibited in the Gliptothiki Parigoritissas in Arta (Image 4), titled "Marble Sustainability Matters II".



Image 4: Colorful marble floor

The activity started at Ioannina and ended in Arta.

The in-between stops were:

- Lake Virou
- Asprochaliko Cave
- Roman Aqueduct of Ancient Nikopolis
- St. George's Hole
- Louros river hydroelectric power station
- Kokkinopilos
- Pantanassa Holy Convent

Along the path different markers were placed and with the help of an app, digital models would appear. Putting all the pieces together would allow you to solve the puzzle. All models combined would make the mythical creature appear (Image 5).



Image 5: The combination of all digital models make the mythical creature

The activity provided markers that each one will appear to the user one of the five biochemical cycles. The nitrogen cycle, the sulfur cycle, the carbon cycle, the water cycle and the phosphorous cycle. The combination of the five cycles will appear as the five circles on the colorful marble slate (Image 6).

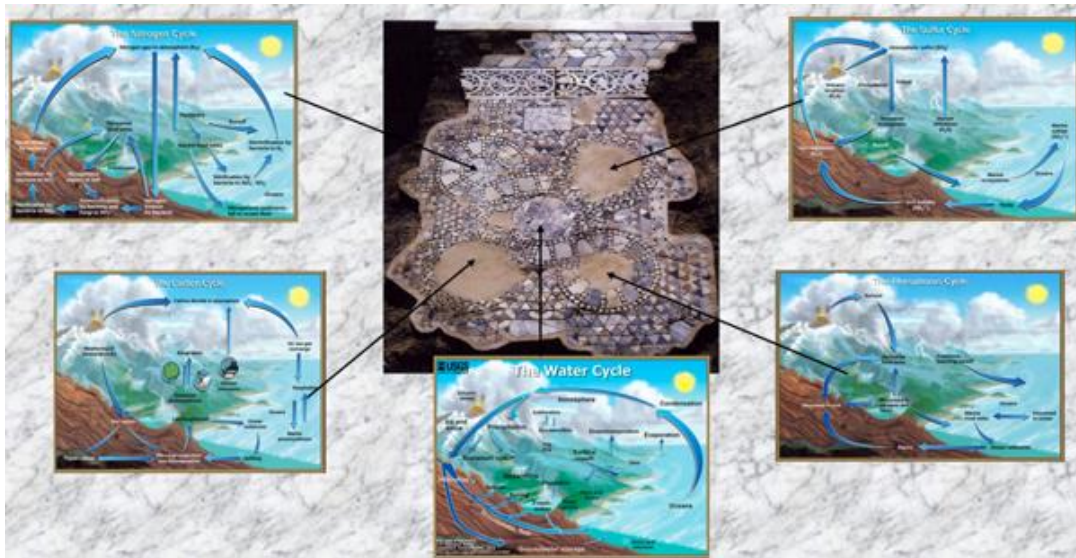


Image 6: The five biochemical cycles & the marble slate

Questionnaire Design

To understand the participants' perceptions and experiences with augmented reality after the activity, a questionnaire was administered. The questionnaire was divided into eight distinct categories, addressing various dimensions of augmented reality's impact on cultural heritage engagement:

Perceived Usefulness: Focused on the participants' perception of the utility of augmented reality in enhancing their understanding and engagement with cultural heritage.

User Experience: Addressed the enjoyment and ease of use of augmented reality during the activity.

Information Quality: Assessed the accuracy, enhancement of knowledge, and comprehensiveness of information provided by the augmented reality.

Social Interaction: Explored how augmented reality influenced interactions among participants and the sharing of experiences.

Preservation and Conservation: Evaluated participants' perceptions of the role of augmented reality in conserving and preserving cultural heritage sites.

Educational Value: Addressed the educational impact of the augmented reality experience.

Personal Satisfaction: Determined the overall satisfaction and enhanced enjoyment derived from the augmented reality.

Future Adoption: Assessed the participants' willingness to adopt augmented reality in future cultural heritage site visits and their propensity to recommend it to others.

Each category consisted of three statements, and participants were asked to indicate their level of agreement with each statement on a Likert scale (e.g., 1 = Strongly Disagree to 5 = Strongly Agree).

Participants

The questionnaire was administered to the students of the Interdepartmental Master's program "Environmental Sciences and Education for Sustainability" (Image 7) as part of the action "Marble Sustainability Matters II". The participants for this study consisted of 23

master's students, with ages ranging from 22 to 47 years. The cohort displayed a gender distribution of 17 men and 6 women. These students, hailing from diverse age brackets, provided a range of perspectives which enriched the depth of data gathered. Given their academic standing, it was anticipated that their responses would offer informed and critical feedback on the augmented reality experiences within the cultural heritage context.



Image 7: Masters students at the roman Roman Aqueduct of Ancient Nikopolis

Given their academic standing, it was anticipated that their responses would offer informed and critical feedback on the augmented reality experiences within the cultural heritage context (Image 8).



Image 8: Participants engaging in the activity at kokkinopilos

5. Data Analysis

To elucidate the sentiments and tendencies of our participants, a comprehensive statistical approach was employed. First and foremost, the mean scores of the responses for each question were computed. This provided an overarching view of the general inclination of the participants towards each statement. Such a computation serves as an initial measure of central tendency, illuminating the collective consciousness of the sample.

A frequency analysis was then conducted, which allowed us to enumerate how many participants selected each specific option on our Likert scale. This frequency distribution shed light on the range and concentration of opinions, offering a more granulated perspective of participants' views.

Subsequent to these initial analyses, we turned to other descriptive statistical tools. Specifically, for each question, both the median and mode were computed. The median offered insight into the central position of our data, revealing the middle-ground response, while the mode pinpointed the most frequently occurring sentiment among our participants.

Diversity of opinion and the consistency of responses were gauged through the calculation of the standard deviation for each question. A pivotal measure, the standard deviation indicated the extent to which our participants' responses deviated from the mean, thus offering a window into the variability or consistency of opinions.

In sum, our multifaceted statistical strategy was meticulously designed to weave both a macro and micro narrative of our participant's views, ensuring a robust and comprehensive exploration of the data.

Results

Group 1: Perceived Usefulness

Analysis:

All participants either agreed or strongly agreed with the perceived usefulness of augmented reality (AR) in enhancing understanding, engagement, and appreciation of cultural heritage. This shows a high level of recognition regarding the benefits AR can offer in this context (Image 9).

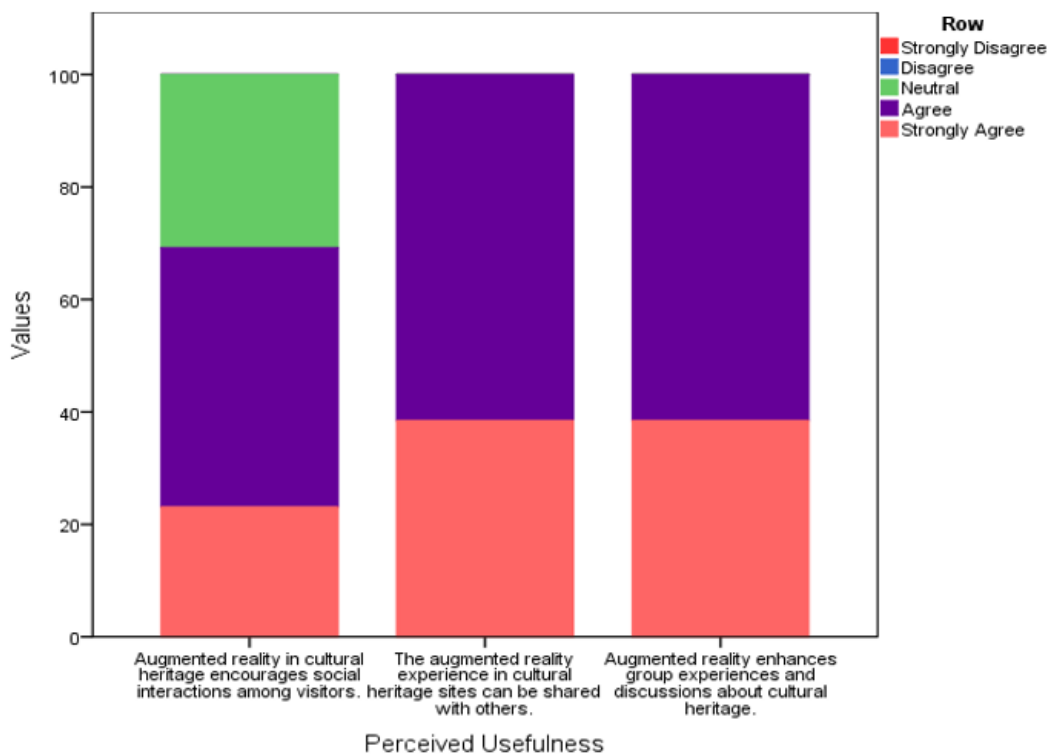


Image 9: Analysis of Group 1: Perceived Usefulness

Group 2: User Experience

Analysis:

There's a clear indication that most participants found the AR experience enjoyable, with seamless integration into the cultural heritage sites, and easy to use. Very few participants remained neutral about the AR experience, while none disagreed or strongly disagreed, suggesting an overall positive reception (Image 10).

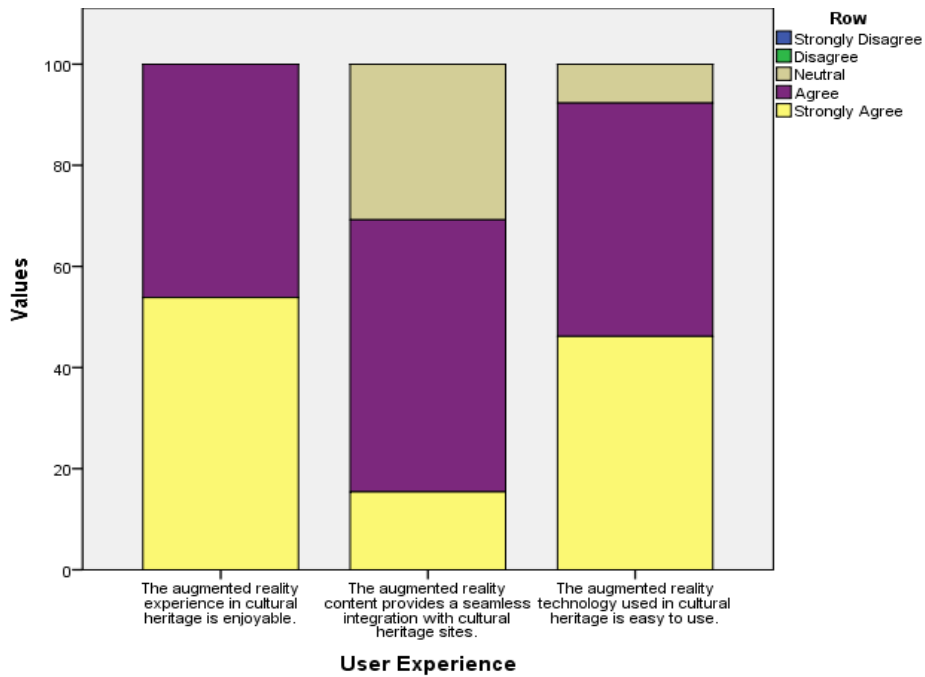


Image 10: Analysis of Group 2: User Experience

Group 3: Information Quality

Analysis:

Every participant either agreed or strongly agreed that AR provides accurate, enhancing, and comprehensive information about cultural heritage. This unanimous recognition of the value of AR information quality in cultural heritage contexts is significant.

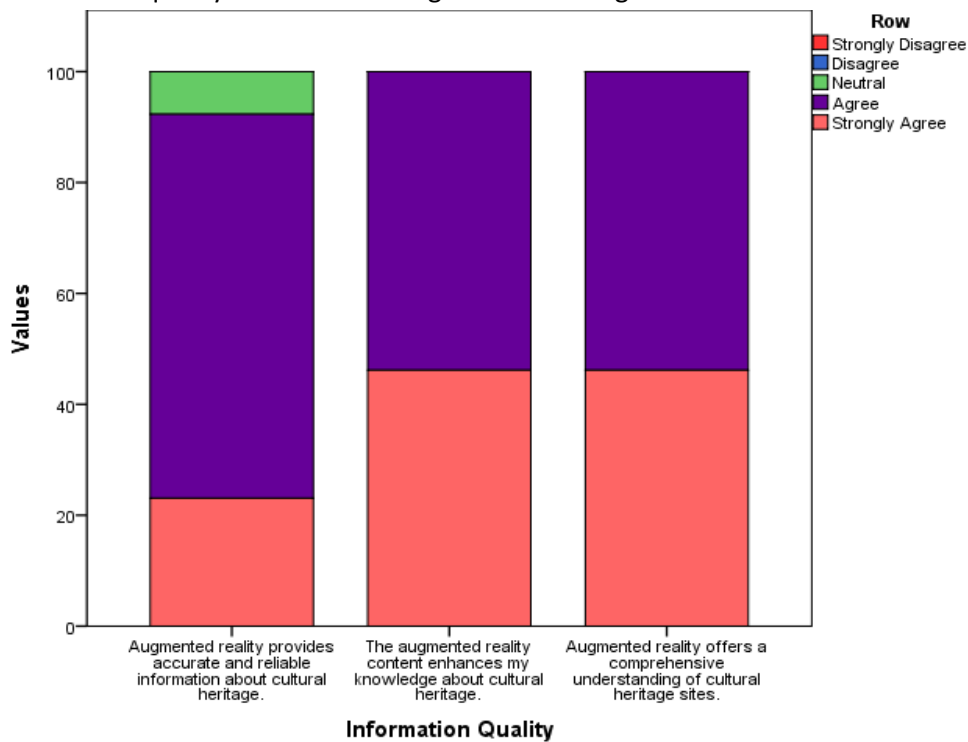


Image 11: Analysis Group 3: Information Quality

Group 4: Social Interaction

Analysis:

A majority of the participants felt that AR promotes social interactions among visitors. However, a noticeable portion was neutral regarding AR's capacity to encourage such interactions. Nevertheless, there's overwhelming agreement on AR's role in enhancing group experiences and discussions about cultural heritage.

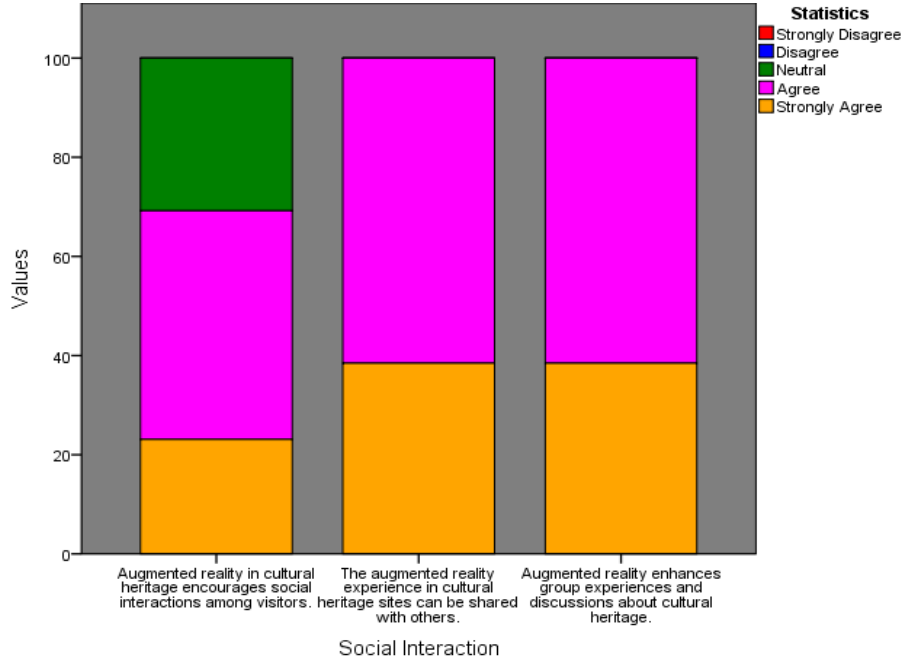


Image 12: analysis of Group 4: Social Interaction

Group 5: Preservation and Conservation

Analysis:

While the majority agreed or strongly agreed that AR contributes to preservation and conservation, there is a slightly higher neutral response rate in this category. This might suggest some participants are unsure or unaware of AR's role in preserving cultural heritage.

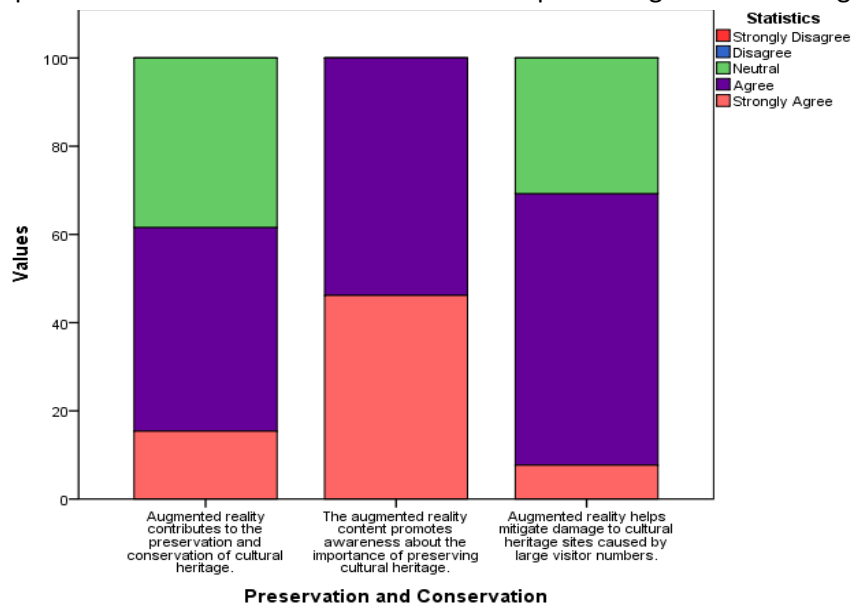


Image 13: Analysis Group 5: Preservation and Conservation

Group 6: Educational Value

Analysis:

The data reveals a unanimous agreement among participants regarding the educational value of AR in relation to cultural heritage. All participants recognized the ability of AR to enhance educational experiences, provide valuable insights, and make learning more engaging.

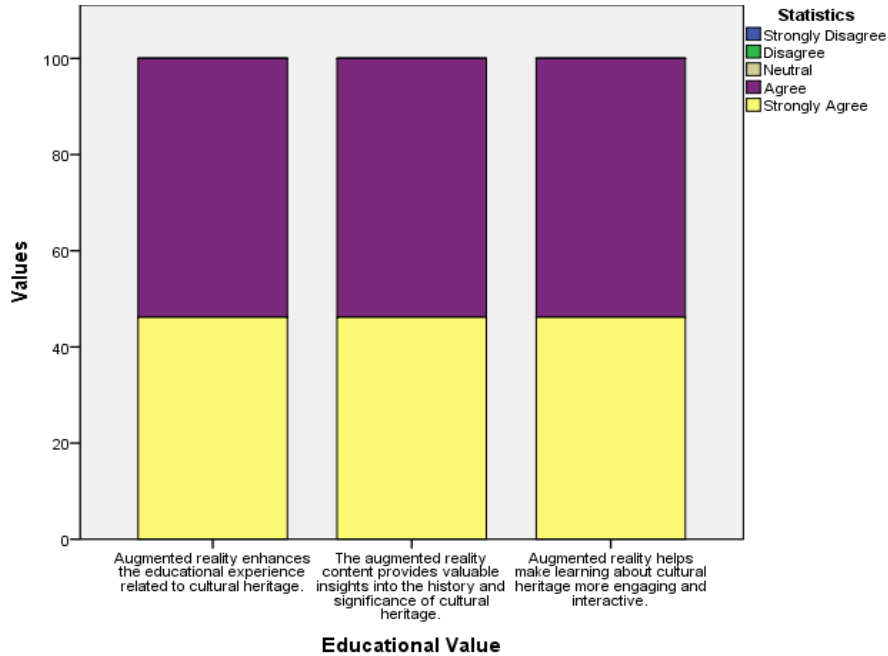


Image 14: Analysis Group 6: Educational Value

Group 7: Personal Satisfaction

Analysis:

A vast majority of participants felt more satisfied with their visits when AR was involved. A small number remained neutral about their overall experience, but none expressed dissatisfaction.

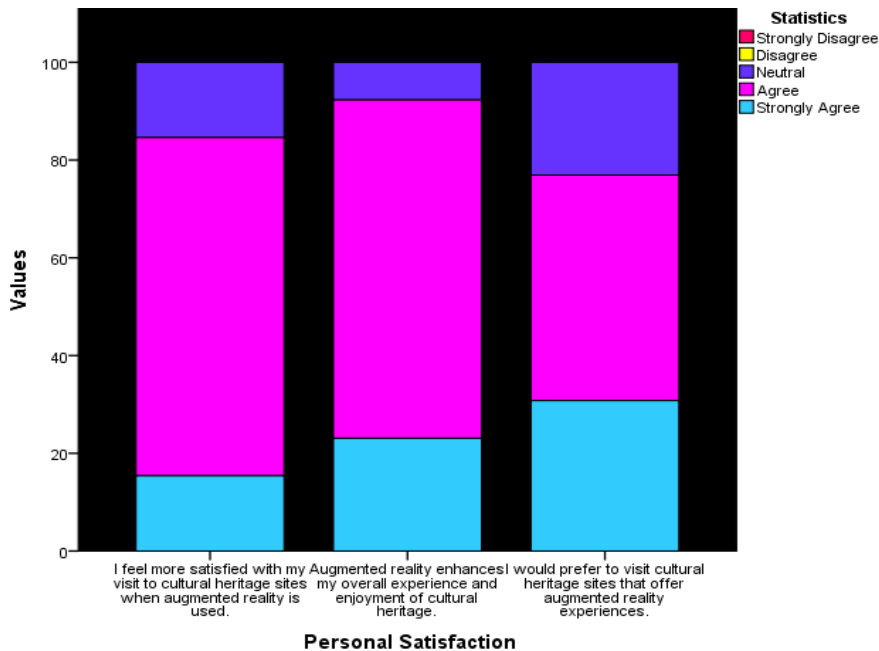


Image 15: Analysis Group 7: Personal Satisfaction

Group 8: Future Adoption

Analysis:

Although most participants agree or strongly agree that they would be more likely to visit cultural heritage sites if AR is available, a few remained neutral on this matter. However, there's a clear inclination towards recommending AR in cultural heritage to others.

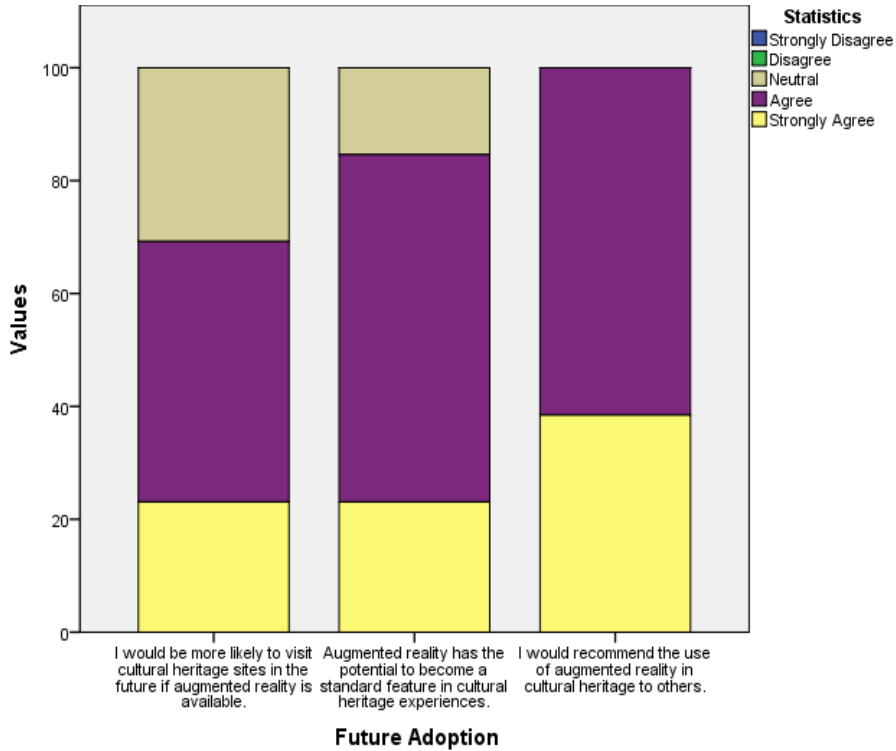


Image 16: Analysis Group 8: Future Adoption

General Insight:

From the data, it's evident that AR's integration into cultural heritage is largely viewed positively, with its perceived usefulness, educational value, and potential for future adoption standing out. While most participants see the value of AR in cultural heritage, there are areas (such as social interaction and preservation) where some participants remain uncertain or neutral.

Below is the table of the mean scores per group.

Group Name	Mean Score
Perceived Usefulness	4.21
User Experience	4.26
Information Quality	4.36
Social Interaction	4.23
Preservation and Conservation	4.13
Educational Value	4.46
Personal Satisfaction	4.08
Future Adoption	4.13

From the analysis of the questionnaire responses and the mean scores, several findings emerge.

- **High Overall Satisfaction with AR in Cultural Heritage:** There isn't any question or category where the mean falls below 4. This indicates that, in general, the participants had a positive experience using augmented reality in the context of cultural heritage.
- **Educational Value Stands Out:** The category with the highest mean score is the 'Educational Value' (4.46). Participants strongly felt that augmented reality enhances the educational experience related to cultural heritage, providing valuable insights into history and making the learning process more engaging and interactive.
- **Information Quality is Key:** The 'Information Quality' category has a mean score of 4.36, showing that participants find AR provides accurate, reliable, and comprehensive information about cultural heritage.
- **User Experience and Social Interaction are Positive:** The scores in these categories are 4.26 and 4.23, respectively. It suggests that participants found the AR technology enjoyable, easy to use, and felt that it encourages social interactions.
- **Room for Improvement in Preservation Awareness:** While the 'Preservation and Conservation' category had a positive score (4.13), it was comparatively lower than some other categories. This may suggest that while AR contributes to the conservation of cultural heritage, its role in promoting awareness about preservation could be further emphasized or improved.
- **Perceived Usefulness and Future Adoption:** The positive scores in these categories (4.21 and 4.13 respectively) show that participants find AR useful in understanding and engaging with cultural heritage and would likely advocate for its adoption in future cultural heritage experiences.
- **Personal Satisfaction and Adoption:** Participants felt more satisfied with their visits when AR was involved, and they are likely to prefer and recommend AR experiences in the future. However, this category, along with 'Future Adoption' and 'Preservation and Conservation', had slightly lower scores compared to others, indicating potential areas to refine..

In summary, the integration of AR in cultural heritage contexts was viewed positively by the majority of participants, especially regarding its educational value and information quality. Some areas, although still receiving positive feedback, might benefit from further refinement to enhance the overall AR experience in cultural heritage settings.

Furthermore, the standard deviation was calculated for each question. A high standard deviation suggests that participants had varied responses, whereas a low one indicates that most participants responded similarly.

The table below demonstrates the variability of responses around the mean for each question. A lower standard deviation suggests that answers were more consistent among students, while a higher one indicates more variability.

Group	Question	Standard Deviation	Group	Question	Standard Deviation
1	1.1	0.466	5	5.13	0.640
	1.2	0.480		5.14	0.442
	1.3	0.452		5.15	0.651
2	2.4	0.442	6	6.16	0.442
	2.5	0.640		6.17	0.442
	2.6	0.480		6.18	0.442
3	3.7	0.466	7	7.19	0.640
	3.8	0.442		7.20	0.466
	3.9	0.442		7.21	0.640
4	4.10	0.640	8	8.22	0.640
	4.11	0.442		8.23	0.480
	4.12	0.442		8.24	0.442

Let's interpret the standard deviations based on the data provided:

Considering the Likert scale ranges from 1 to 5, any standard deviation closer to 0 suggests consistent answers, while values closer to 2 (or the range's midpoint) indicate higher variability.

From the provided standard deviations:

- The highest standard deviation we have is ≈ 0.651 for Question 5.15.
- The lowest standard deviation we have is ≈ 0.442 for multiple questions like 2.4, 3.8, 3.9, etc.

Given that all standard deviations are relatively low (all well below 2 and even below 1, the scale's midpoint), it suggests that the responses across all questions were generally consistent among students. There's some variability, but it's quite minor given the nature of the Likert scale.

In summary, participants' responses across all questions were largely consistent, with only slight variability in their opinions or perceptions about the statements in the questionnaire.

Discussion

Research Questions

Impact of VR and AR on Engagement with Cultural Heritage.

The data suggests a generally positive reception to the integration of VR and AR technologies with cultural heritage engagement. The mean scores, especially within the "Perceived Usefulness" and "User Experience" categories, show that a significant majority of participants felt that these technologies enhanced their understanding, engagement, and appreciation of cultural heritage sites (Bower et al., 2014). This is consistent with recent research suggesting that AR and VR offer immersive experiences that can deepen users' engagement with historical content (Billinghurst & Duenser, 2012).

Activity Theory and VR/AR Dynamics.

Activity theory, which examines the relationship between tools, users, and tasks, can provide insights into how AR and VR tools impact cultural heritage engagement. The high mean scores in the "User Experience" category suggest that these tools are being received as beneficial

mediators that enhance the interaction between users and the cultural content. This is in line with activity theory's assertion that tools can mediate and enhance the relationship between the subject (users) and the object (cultural heritage content) (Engeström, Y. (2015). However, for a comprehensive understanding, further studies may need to examine the rules, community, and division of labor in this context.

Insights for Future VR/AR Design in Cultural Heritage

The questionnaire results provide valuable insights for the design and implementation of VR/AR tools in the cultural heritage sector. Areas such as "Information Quality" and "Educational Value" received notably high scores, indicating that participants found the AR content to be both informative and educationally enriching (Dünser et al., 2012). On the other hand, areas like "Preservation and Conservation" had slightly lower mean scores, suggesting potential room for improvement. The feedback from "Future Adoption" can guide stakeholders in understanding that a majority of participants see potential in the broader adoption of such technologies in cultural heritage experiences (Wu et al., 2013).

Relating to the existing literature.

The positive reception of AR's ability to enhance understanding, engagement, and appreciation of cultural heritage in our survey is congruent the transformative potential of AR in offering immersive historical and cultural experiences. Our respondents' belief that AR offers an enjoyable experience aligns with the findings of Han et al. (2019), who showed that AR contributes to a richer user experience in cultural sites.

The high scores on information quality, with respondents believing AR provides accurate and reliable information, echo the sentiments of Tom Dieck and Jung (2017), who found that visitors trust AR's informational content, especially when contextualized adequately within the cultural or historical site.

Furthermore, the perceived potential for AR to foster social interactions among visitors is an interesting confirmation of the work by Bonacini (2017), who found that such technologies could indeed provide shared experiences, facilitating group discussions and interactions at heritage sites.

Surprises or confirmations

The affirmation of AR's educational value is not surprising. However, the magnitude of agreement is noteworthy and reiterates the perspective of Perry (2019) who opined that AR can revolutionize educational experiences, making them more engaging and interactive, especially in cultural contexts.

A somewhat unexpected insight from our survey pertains to the mixed reception regarding AR's contribution to cultural heritage preservation and conservation. While many scholars, including Moro et al. (2020), have championed the benefits of AR in potentially minimizing physical footprints at heritage sites, some of our participants seemed ambivalent. This suggests a need for clearer communication about the conservation benefits of AR to visitors.

Activity Theory Analysis

In the analysis of the augmented reality (AR) experience in cultural heritage settings, Activity Theory provides a useful framework to explain the interplay between users, technology, and the cultural environment.

- **Subjects, Tools, and Objects:** Our primary subjects – visitors of cultural heritage sites using AR – interact with the AR tool to achieve their objectives, whether that's gaining

knowledge, experiencing immersion, or socially interacting. The overwhelmingly positive responses towards the perceived usefulness of AR indicate that the tool effectively bridges the gap between the subject and the object of activity (learning and experiencing cultural heritage). Digital tools, like AR, enhance user engagement and understanding when interfaced with cultural artifacts.

- **Community, Rules, and Division of Labor:** The survey's mixed responses concerning AR's contribution to preservation might be illuminated when considering the broader community (including conservators, educators, general public), rules (conservation guidelines, visitor etiquettes), and the division of labor (roles of guides, educators, conservators).
- **Contradictions:** Engeström (2001) posits that contradictions, or conflicts within and between activity systems, can spur transformation and innovation. Furthermore, tensions might arise from differing expectations and values within this Activity System. For instance, while conservators might value AR for minimizing physical interaction with artifacts, visitors might feel it dilutes the authenticity of their experience.

The neutrality observed in some groups regarding AR's educational value might signal underlying contradictions. This could be between users' traditional expectations of learning in museums (e.g., guided tours, placards) and the newer, technology-augmented methods. Recognizing these contradictions could lead to more effective AR implementations that balance traditional and technological educational approaches

In conclusion, the application of Activity Theory to our dataset elucidates the intricate dynamics shaping user experiences with AR in cultural heritage settings. The theory emphasizes that to fully understand and enhance this experience, one must consider the broader ecosystem, comprising tools, individuals, communities, and their interrelations.

Implications

The findings of our research provide a trove of insights with multifaceted implications for a spectrum of stakeholders involved in the realm of cultural heritage, augmented reality (AR), and virtual reality (VR).

For Cultural Institutions:

The overwhelmingly positive perception of AR's usefulness and user experience highlights the potential of AR as a robust tool for cultural transmission. It suggests that integrating AR can enhance visitor engagement, making heritage sites more appealing, especially to the tech-savvy younger generations (Pujol et al., 2012). However, neutrality towards certain aspects like preservation indicates the need for a balanced approach. While AR can minimize physical interactions with delicate artifacts, care should be taken to ensure that the authenticity and essence of the experience aren't diluted. Museums and heritage sites might need to combine traditional methods with AR to cater to diverse visitor expectations.

For VR/AR Developers:

The data underscores the importance of tailoring AR applications to fit the cultural heritage context. It's not just about superimposing information but creating a seamless blend of the real and the virtual. Developers should work closely with historians, archaeologists, and conservators to ensure the accuracy and relevance of the content (Han et al., 2014). The emphasis on social interaction suggests that there's potential for collaborative AR experiences, where users can share and discuss their findings in real-time.

For Policymakers:

The evident appreciation of AR in cultural settings can guide policy decisions related to funding and tech integration in heritage sites. Policymakers should consider facilitating collaborations

between technologists, cultural experts, and educators to devise comprehensive AR solutions. Moreover, with the rise of AR, there may be a need to establish guidelines ensuring that the implementation of such technology respects the sanctity and conservation needs of heritage sites (Damala et al., 2014).

In summary, the integration of AR and VR in cultural heritage sites is not just a trend but a transformative step towards reshaping how we perceive and interact with history. By understanding its implications, stakeholders can pave the way for a harmonious fusion of the past with the future.

Conclusion

One of the limitations of the research is that it involved a small group of participants. While the findings offer insights into how people perceive and experience augmented reality in cultural heritage contexts, we can't fully apply these conclusions to populations. When sample sizes are small there's a chance of sampling error meaning that the sample may not accurately represent the population, it was drawn from (Sedgwick, 2014).

Moreover, while smaller groups allow for analysis and can provide rich qualitative data it may compromise the statistical power for quantitative analysis. This limitation could make it harder to detect effects or subtle differences among subgroups within the sample. Additionally external validity – which measures how well these results can be generalized to settings, people, times and measures – might be somewhat limited due to the sample size (Calder, Phillips & Tybout 1981).

For research on this topic to be more valuable it would be beneficial to recruit a more diverse sample from various demographic and geographic backgrounds. This would help enhance the generalizability of the findings and provide an understanding of both the benefits and challenges associated with augmented reality, in cultural heritage.

The integration of AR and VR technologies in the cultural and heritage sector has unveiled a new era of immersive and enriching experiences for visitors. This study's significance lies in its systematic exploration of user perceptions towards this integration, offering valuable insights for multiple stakeholders. Our findings emphasize the potential of AR in enhancing visitor engagement, underscoring its importance for cultural institutions that seek to remain relevant in an increasingly digital age. This is consistent with previous findings that highlight the increasing importance of digital tools in cultural and museum settings (Pujol et al., 2012; Han et al., 2019).

However, while the potential is vast, our study also hints at areas of caution. The nuanced responses on preservation and conservation suggest that while technology can be an enabler, it shouldn't overshadow the core values and essence of cultural institutions. It's a delicate balance that needs to be achieved.

Future research could delve deeper into understanding the specifics of AR implementation. Are there certain types of AR experiences that are more effective than others? How can AR be tailored to cater to different demographic segments? Further, exploring the educators' and curators' perspectives on this integration can provide a more holistic view of the AR's role in cultural heritage. Additionally, as the field of AR technology continues to evolve rapidly, staying updated on its latest advancements and their implications for cultural settings will be of paramount importance (Damala et al., 2014).

In closing, the intersection of technology and cultural heritage is both exciting and challenging. With careful planning, collaboration, and continuous research, the future promises richer, more interactive, and more enlightening cultural experiences.

Acknowledgments

The study was supported by the Centre for Research, Qualitative Analysis of Materials, Cultural Heritage, and Communication of Science, which is financially supported by the Operational Program “Competitiveness Entrepreneurship & Innovation” (EPAnEK) of the National Strategic Reference Framework (NSRF) 2014-2020, Invitation:111. Supporting Regional Excellence.

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Βιβλιογραφική αναφορά

Efthimiou, G., Potsikas, M., Prouska, K., Plakitsi, K. (2023). Past Meets Pixel: Enhancing Cultural Heritage Engagement with XR, *Science Education Research and Praxis*, (87-88): 8-32. ISSN 1792-3166, Retrieved from <https://serp.ecedu.uoi.gr/>