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The Impact of Immersive Virtual Reality on Knowledge Acquisition and Adolescent Perceptions in Cultural Education

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Abstract: Understanding local history is fundamental to fostering a comprehensive global viewpoint. As technological advances shape our pedagogical tools, Virtual Reality (VR) stands out for its potential educational impact. Though its promise in educational settings is widely acknowledged, especially in science, technology, engineering and mathematics (STEM) fields, there is a noticeable decrease in research exploring VR's efficacy in arts. The present study examines the effects of VR-mediated interventions on cultural education. In greater detail, secondary school adolescents ($N = 52$) embarked on a journey into local history through an immersive 360° VR experience. As part of our research approach, we conducted pre- and post-intervention assessments to gauge participants' grasp of the content and further distributed psychometric instruments to evaluate their reception of VR as an instructional approach. The analysis indicates that VR's immersive elements enhance knowledge acquisition but the impact is modulated by the complexity of the subject matter. Additionally, the study reveals that a tailored, context-sensitive, instructional design is paramount for optimising learning outcomes and mitigating educational inequities. This work challenges the "one-size-fits-all" approach to educational VR, advocating for a more targeted instructional approach. Consequently, it emphasises the need for educators and VR developers to collaboratively tailor interventions that are both culturally and contextually relevant.

Keywords: virtual reality; history education; cultural education; immersive technologies; 360° experience

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1. Introduction

In the context of contemporary globalisation, understanding the multifaceted nature of diverse cultures has become essential [1]. Cultural education, defined as the structured study and interpretation of cultural practices, beliefs, arts, and histories, is pivotal for broadening academic learning and fostering informed global citizenry [2]. Providing youths with opportunities to develop an understanding of socio-cultural norms and practices enables them to gain a deeper comprehension of the complexities that differentiate and unify human societies [3]. Such an understanding goes beyond mere superficial knowledge as it also equips them with critical thinking skills which are required for a better interpretation of the global socio-cultural landscape [4]. This perspective is especially crucial in an era where simplistic stereotypes and misconceptions can perpetuate biases and misunderstandings [1]. At the same time, the interconnected nature of the world renders intercultural competency indispensable [5]. Cultural education serves as a preparatory ground for equipping individuals with the knowledge and skills required to effectively engage in multicultural environments whether they be academic, professional, or social [6]. Beyond this, the emphasis on cultural education has broader societal implications. It acts as a 'safeguard' against divisive and exclusionary narratives by promoting social cohesion and understanding in diverse societies. In view of the above, it can be argued that cultural education is not merely an academic exercise but an essential tool for nurturing informed, adaptable, and inclusive individuals.

1.1. Motivation of the Study

In the evolving landscape of technological innovation, Virtual Reality (VR) emerges as a significant advancement with the potential to reshape educational methodologies. Characterised by its capacity to create immersive digital environments, VR is increasingly being adopted in educational settings transforming both the delivery and the assimilation of knowledge [7–9].

Central to VR's appeal is its capability to simulate real-world experiences or create entirely new ones [10,11]. Unlike traditional teaching mediums, which often employ abstract representation, VR allows learners to interact directly with the subject matter. This 'hands-on' approach not only makes the learning process more engaging but also enhances memory retention [12–14]. To date, a large body of the literature on VR in education highlights its transformative potential across various disciplines, including science, technology, engineering, and mathematics (STEM) [15–18].

Cultural education, with its focus on understanding diverse worldviews and traditions, offers a compelling landscape for VR applications. Indeed, one specific application of VR in cultural education is the use of 'virtual field trips' which liberate students from geographical and financial constraints and allow them to explore different destinations without leaving the brick-and-mortar classroom [13]. This active exploration replaces passive learning by stimulating curiosity and wonder [14]. Additionally, historical recreations in VR provide students with the opportunity to witness significant events or explore ancient civilisations that would otherwise be impossible to explore. Naturally, this enriched experience offers a richer contextual understanding than traditional resources (e.g., books, videos) might deliver [8,15].

Despite the intuitive immersive capabilities of VR, empirical studies exploring the cultural intersection are scarce [19–21]. Existing research primarily addresses VR's role in recreating historical sites, events, or artifacts [22–24] but neglects the broader spectrum of cultural education which includes contemporary practices, beliefs, and interrelations. While such endeavors hold merit, this gap in empirical studies underscores the need for investigations that can articulate the full range of VR's capabilities in fostering a more complete and culturally inclusive educational experience.

1.2. Virtual Reality in Cultural Education

The transformative capacity of VR in STEM education has been acknowledged by scholars, technologists, and educators across various disciplines [10,16]. The findings from recent reviews [21] and metanalyses [25,26] affirm that VR-based educational methodologies consistently outperform conventional instructional techniques in multiple aspects including knowledge acquisition, skill development, and motivational levels. These advantages are primarily attributed to the high levels of interactivity and the degree of immersion that VR platforms afford [27].

When it comes to cultural education, VR presents a promising avenue. The authors in [28] Marto catalogued a range of applications from virtual tours to educational games, underlining the multifaceted advantages of Virtual/Augmented Reality in the cultural heritage sector. Other researchers [19,29] have leveraged VR to animate historical settings as a means of providing a firsthand understanding of diverse cultures. Moving beyond historical perspectives, recent works [30–32] have demonstrated that VR's applicability is broad—extending to contemporary cultural contexts—including interactive museum exhibitions and storytelling about indigenous cultures as well as the illumination of specific cultural practices. These applications have consistently shown not only a higher retention of details but also an increased motivational drive among students to explore cultural practices more deeply. Additionally, as the Extended Reality (XR) spectrum evolves, researchers are integrating additional elements to create hybrid educational environments. For instance, the authors in [33] developed a Virtual/Augmented Reality platform which aimed at enhancing cultural literacy through situational learning. This integration blurs the boundaries between virtual and physical learning experiences as it augments both the level of interactivity and the depth of engagement with the cultural elements.

Moreover, advancements in data analytics have brought the potential of enhancing the personalisation of learning experiences [34]. An indicative example is the work of [35], who designed a platform that leverages Learning Analytics (LA) and adaptive algorithms to customise learning experiences according to individual cognitive profiles. In the realm of cultural education, the study by [36] serves as a notable example of the transformative potential of integrating LA with immersive technologies. By enabling learners to actively seek and discover local cultural knowledge through gamified field exploration, it enhanced learners' cultural competence and facilitated knowledge retention.

The abovementioned studies highlight the effectiveness of immersive technologies in enriching cultural education. The adoption of these alternative educational methods shifts the instructional approach from being teacher-centred to being learner-centric; a model which has been proven to be more efficient and effective [37]. However, the current research often focuses too narrowly on specific applications and neglects broader educational use-cases. This limitation creates both a knowledge gap and a research bias that hampers the development of a comprehensive understanding over the pedagogical potential of these technologies in fields like that of cultural education. Consequently, this creates the need for the conduct of empirical studies to fill these gaps and inform the development of optimised immersive educational platforms. Such research could reveal the potential of these technologies not only in knowledge acquisition and retention but also in fostering empathy and global awareness.

The present study endeavours to explore the potential of VR in augmenting cultural education by discerning the distinct advantages and drawbacks of employing such a tool as the main instructional method. To facilitate this objective, the research design involved both the examination of knowledge acquisition and an investigation over learners' perceptions. This enabled us to determine whether VR merely complements teaching modalities or if it signifies a paradigmatic shift in the delivery of cultural-related knowledge. To contextualise our inquiry, the study is anchored by the following Research Questions (RQs):

RQ1: *How does participation in a VR-based cultural education program impact students' academic performance*?

RQ2: *How do students' perceptions and attitudes towards educational VR evolve after engaging with a VR-based cultural education program?*

2. Methods

2.1. Theoretical Frameworks

2.1.1. Cognitive Load Theory

The Cognitive Load Theory (CLT) has emerged as a framework for educators and researchers aiming to understand the interplay between instructional design and cognitive capabilities. According to [38], the human cognitive system has a finite working memory, which is particularly sensitive to overload. The theory categorises cognitive load into three distinct types: (1) intrinsic, (2) extraneous, and (3) germane. Intrinsic load refers to the inherent complexity of the material being learned. Extraneous load involves the mental effort expended on tasks or information not directly relevant to achieving the learning objectives. Germane load refers to the cognitive activity that contributes to learning such as the assimilation of new information into long-term memory. Optimising these types of loads is crucial for educational efficacy, as it ensures that learners can fully engage with and absorb the material without being overwhelmed. In the context of VR, CLT gains significant relevance as immersive environments can offer more direct, experiential, learning scenarios that minimise the extraneous cognitive load. For instance, learners can focus on the essential information at hand without the distraction of unrelated elements often found in traditional educational settings [36]. Nonetheless, the potential for immersion inherent in this technology presents both advantages and drawbacks. On the one hand, the richness of VR experiences can foster deeper engagement and a more profound understanding of complex subjects by elevating the germane load. On the other, the multitude of sensory stimuli can also risk inducing cognitive overload, particularly in intricate or fast-paced scenarios. Therefore, a clear understanding of CLT in the design of VR experiences is essential both for maximising its educational potential and for minimising cognitive pitfalls.

The applicability of CLT is not monolithic across all academic disciplines; instead, researchers have concluded that it is rather context-sensitive [39]. Different fields of study carry inherent complexities that either accentuate or alleviate cognitive loads. For instance, in historical or sociopolitical disciplines, the multifaceted interactions of events, ideologies, and agents can significantly heighten the intrinsic cognitive load. This contrasts with, perhaps, more procedural or formulaic disciplines like mathematics, where the cognitive load is often predictable and can be more straightforwardly managed. Therefore, when considering the integration of VR into educational settings, it becomes imperative to tailor the design and pedagogical approaches to the specific demands and intricacies of the subject at hand [40]. This entails not merely 'transferring' existing educational content into a virtual format but, instead, involves a conscientious redesign that factors in subject-specific variabilities. For example, in the cultural education context, VR designs might need to account for complex narratives, historical backdrops, and diverse societal norms, all of which contribute to the overall cognitive load. In science education, the focus might instead be on visualising complex systems or phenomena, thus requiring VR to simplify and elucidate rather than add layers of complexity [41].

2.1.2. Technology Acceptance Model

The Extended Technology Acceptance Model goes beyond the scope of cognitive factors to incorporate behavioural aspects that are instrumental in the successful adoption and integration of technologies. The framework's value extends to educational contexts where it can serve as a diagnostic tool for uncovering potential impediments to technological integrations such as VR [42]. This is particularly crucial in an educational environment that increasingly relies on high-tech interventions for enhanced learning outcomes [21]. Understanding how a technology could potentially introduce new cognitive demands is vital for mitigating any negative impacts on the learning process. In essence, this model provides a comprehensive framework that allows educators and technologists to consider not just the utility but also the usability of technologies. In doing so, it complements CLT by addressing the broader behavioural elements that influence the effective incorporation of VR into various educational paradigms.

2.1.3. Theory of Flow

Flow theory argues that an optimal state of engagement—commonly referred to as a 'flow'—arises when there is a delicate balance between the level of skill a person has and the challenges that a task presents [43]. In educational VR settings, the capacity for inducing these flow states becomes increasingly important as it can serve as a potent catalyst for academic success. This is achieved through the optimal allocation and focus of cognitive resources which, in turn, mitigate the impact of both the intrinsic and extraneous cognitive load [44].

The intrinsic interactivity and immersion of VR make it particularly conducive for fostering flow states. Unlike traditional learning environments, VR platforms can provide real-time adjustments to the level of challenge and complexity, ensuring that learners consistently operate within their Zone of Proximal Development [45], a concept closely related to the flow state. This not only augments learners' intrinsic motivation but also maximises their engagement with the educational content. Moreover, when flow states are successfully induced, the educational experience itself can become intrinsically rewarding, thereby enhancing both retention and the transfer of knowledge. As such, the incorporation of flow theory into the VR design process can significantly elevate the efficacy and engagement levels of educational experiences.

2.2. Technical Design

2.2.1. System Architecture

The architectural cornerstone of the present VR application resides in its utilisation of an innovative spherical layout (Figure 1). This layout incorporates prefabricated inverted spheres which serve as the substrate for projecting 360° photographs of the virtual and real environment (Figure 2). However, this complex architectural design presented its own challenges, particularly in the realm of navigation. To mitigate difficulties in transitioning between distinct spheres, a custom navigation mechanism was developed. This mechanism employs a sequence of arrow buttons and custom scripts, activating a 'fading in' functionality that incrementally turns the display opaque and subsequently darkens the image. This operational choice was implemented with the intent to minimise disorientation and physiological discomfort during shifts in viewpoint.

Figure 1. Indicative examples of the gamified assessment scenarios.

Figure 2. Comparative view of the real (**left frame**) and the virtual (**right frame**) representation of the castle's gate.

In addition to addressing navigational complexities, the application prioritises user engagement by enhancing information accessibility. This has been achieved by providing information cues in the form of 'blue buttons' integrated throughout the virtual environment. By interacting with these cues, participants are able to access a deeper layer of contextual information regarding specific aspects within each sphere. This may, on the one hand, add an additional layer of complexity but, on the other, it increases the engagement with the virtual experience.

Recognising the needs of the school context, the application was also designed to extend its functional scope. A 'narrative override' mechanism was introduced to accommodate the time-sensitive constraints often present in educational settings (i.e., the classroom teaching timeframe). By introducing this feature (activated by engaging a specific joystick control) users can accelerate the pacing of the narrative which, accordingly, unlocks subsequent modules.

Finally, to facilitate learners' understanding of the abovementioned features, an instructional digital guide was formulated to provide insights into the application's operational and pedagogical underpinnings.

2.2.2. Gamification

By considering the fact that game-oriented experiences are especially pervasive among younger generations, the experiential structure of the application also resembles a level-based progression, like those commonly found in traditional gaming paradigms. In greater detail, within each sphere, participants are presented with tasks that necessitate varying degrees of interaction, comprehension, and the application of knowledge. These tasks adhere to a dualistic design framework; some are rooted in tangible realism for direct interaction while others deploy metaphorical constructs to encourage a more profound level of cognitive engagement.

2.3. Instructional Design

The Castle of Rta (Greece) constitutes the central focus for the pedagogical content within the application. Users navigate through an array of specific points of interest, each of which has been carefully curated to represent the historical and architectural facets of the castle. Salient features of the castle include:

- the iconic 'Main Gate' which serves as an entryway into the castle's rich history;
- the 'Palace of the Despots', an emblematic structure echoing tales of past rulers;
- the 'Chapel of All Saints', representing the religious significance of the castle over the course of time;
- and the castle's 'Acropolis', showcasing the zenith of its defensive architecture.

Upon launching the application, users are greeted with a language selection feature where they can choose their preferred language (Greek or English). Following this, a dedicated menu enables them to teleport to the castle's areas. As they progress, they encounter various educational stations, each dedicated to different aspects of castle's lifespan including its architecture, daily life, and governance. These stations employ gamified elements such as quizzes and problem-solving tasks to foster engagement. Below, we present a breakdown of the key experiential modules that comprise the application's virtual tour:

- Participants begin their journey at the "castle's main gate" where they are introduced to the historical context through voice narrations. For the completion of this stage the users are required to complete a 'hangman' challenge which examines the retention of generic information related to the castle's founding history.
- The next station is "Xenia's Prison", a remarkable example of modernist architecture, nestled beside the historical castle of Rta, on the grounds of what was once an ancient fortress. Following the completion of the historical narrative, a picture-based puzzle game is presented to the users. Progression to the next stage requires that the user successfully places all the puzzle pieces together in order to virtually reconstruct the build.
- The exploration continues with the "Palace of the Despots", situated within the precincts of the castle. This architectural marvel dates back to the Byzantine period and served as the administrative and residential hub for the rulers of the Despotate of Epirus. As in the previous cases, this stage also includes storytelling narratives. However, the interplay within this level is further enhanced by enabling users to interact with 3D

models of the knights, who symbolise different ruling families of the castle, in order to learn about the history of the past dynasties.

- The journey continues at the "north side" of the castle, which is built upon the ancient Ambrakia, one of the most important cities of ancient Greece. As users traverse this sector, they are immersed in the rich tapestry of Ambrakia's history—from its founding to its role in various historical epochs. Following the historical overview, participants are then presented with a multiple-choice quiz designed to test their knowledge retention. This part concludes the virtual tour of the inner area of the castle and moves the users to the exterior grounds.
- As the virtual tour transitions to the castle's exterior, an insightful outlook is offered regarding the historical and cultural significance of the "Chapel of All Saints", situated within the castle's grounds. The chapel serves as a silent witness to the castle's long history, embodying the religious devotion and artistic expression of the eras it has survived. The narration enriches the visitors' understanding of the chapel's role through the centuries, its architectural features, and its importance to the community. To engage users further and consolidate their learning, a matching game is introduced, requiring participants to pair images of the chapel and other significant artifacts with their respective historical dates.
- The VR experience culminates at the outskirts of the castle, where users are tasked with correctly matching points of interest to corresponding photographs. Upon the successful completion of this task, they receive commendation and are offered the option to 'immortalise' their names on the custom leaderboard. This final quiz marks the end of the virtual journey through the Castle of Rta and its associated landmarks.

2.4. Research Design

Figure 3 provides an overview of the procedures followed for the preparation of the study, whereas Figure 4 illustrates the dual-phase approach adopted during the conducting of the experiment.

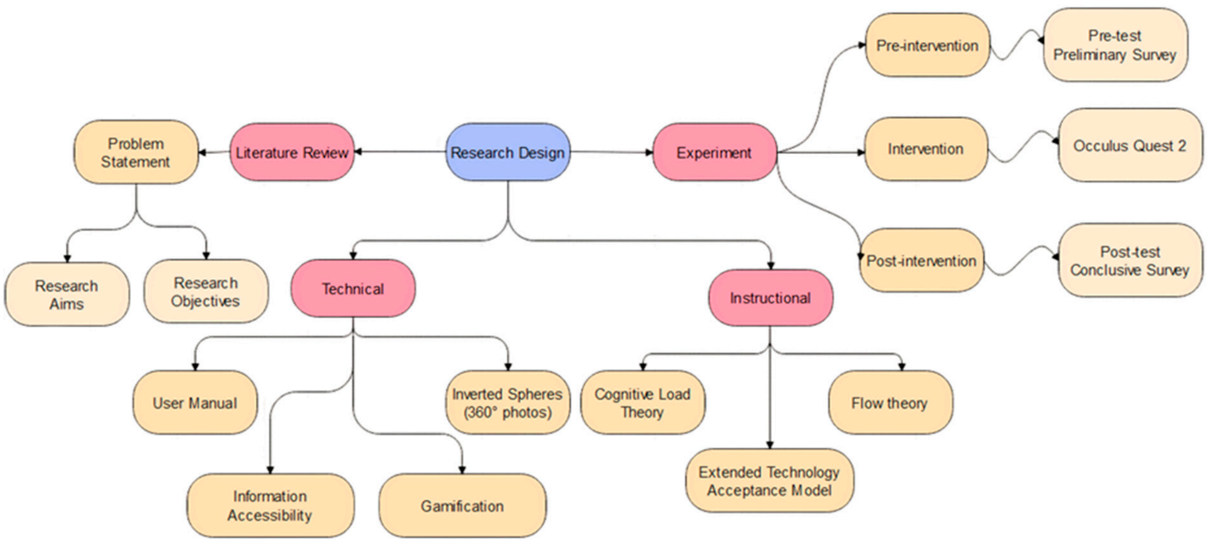

Figure 3. Overview of the research design procedures.

Figure 4. Photographs taken during the experimental session (**upper frame**) and the respective data collection phases (**lower frame**).

In light of the small cohort size, partitioning participants into groups—such as control and experimental groups—would dilute the data's potency [46]. Instead, we chose to administer the VR-based educational experience to all available participants to harness the full power of the within-subject comparisons. The intervention process lasted approximately 45 min, in line with a conventional classroom session length. Below we summarise the procedures followed:

- Pre-intervention stage: Before the VR educational session, each participant underwent though a preliminary knowledge assessment and completed a self-reported psychometric instrument. The knowledge assessment quiz (herein referred to as the "pre-test") comprised questions intended to gauge participants' existing knowledge of the cultural subjects in question (Appendix A). Likewise, to gauge their preconceptions of the use of VR in education, a preliminary survey was administered (Appendix B). These baseline assessments provided a clearer understanding of each participant's initial academic standing as well as their preconceptions and attitudes toward educational VR.
- Intervention stage: Participants were equipped with VR headsets (Oculus Quest 2) and engaged with the VR experience for approximately 20 min.
- Post-intervention stage: After the completion of the VR experience, participants' knowledge was evaluated once again using a knowledge assessment form, identical to the one used in the pre-intervention stage, with the aim to detect any changes in knowledge comprehension (Appendix B). To mitigate the effects of rote memorisation and counterbalance any potential order-related biases, the sequence of the questions was

randomised as recommended by [47]. Additionally, a post-intervention psychometric survey was administered to explore participants' reception of the VR intervention.

2.5. Data Collection

2.5.1. Psychometric Instruments

For the needs of this study, two psychometric instruments were distributed with the aim of assessing students' perceptions of VR in education. Both surveys employed a 5-point Likert scale format (Strongly Disagree–Strongly Agree).

The pre-intervention survey was based on the instrument developed by [48] and was slightly adjusted to fit the context of this experiment. The survey revolved around three main dimensions:

- Satisfaction (α = 0.86): These items were evaluated the extent of satisfaction experienced by learners in previous encounters with VR applications. Positive prior experiences can enhance learners' motivation and diminish the cognitive load associated with negative emotions.
- Anxiety (α = 0.82): These items identified potential stress levels encountered by learners in prior engagements with VR applications. Elevated anxiety can increase extraneous cognitive load, thereby impeding the learning process.
- Willingness (α = 0.64): These items assessed learners' readiness to participate in VR-based learning environments. Increased willingness can reduce the cognitive load associated with resistance to new technologies.
- The post-intervention survey, inspired by the work of [49], aimed at measuring factors relevant to cognitive load after the VR experience:
- Presence (α = 0.8): These items assessed the level of immersion, noting that a heightened sense of presence can diminish the extraneous cognitive load by minimising distractions.
- Enjoyment (α = 0.87): These items measured the level of pleasure derived from the experience, which, as previously mentioned, can have a positive effect on cognitive load.
- Perceived Usefulness (α = 0.84): These items evaluated the extent to which VR was deemed to be helpful for learning, observing that perceived usefulness can alleviate the cognitive load associated with mastering a new tool.
- Perceived Realism (α = 0.84): These items gauged the authenticity felt during the VR experience, indicating that greater realism can reduce the cognitive load by lessening the distractions attributable to the simulation's artificiality.
- Adequacy of Educational Material (α = 0.85): These items probed the quality of the content, with the understanding that well-crafted content can lower the extraneous cognitive load by simplifying information processing.
- Perceived Ease of Use (α = 0.84): These items investigated the technology's user-friendliness, suggesting that the ease of use can decrease the extraneous cognitive load associated with navigational difficulties.
- Incentive (α = 0.85): These items evaluated the motivational impact on learning, positing that a strong motivation can counterbalance the cognitive load presented by complex materials.

2.5.2. Academic Performance

To evaluate participants' understanding before and after the VR experience, a structured knowledge quiz was administered, spanning the following categories:

- Historical figures and rulers: There were questions focusing on key individuals and monarchs who played pivotal roles in the past.
- Geographical locations: There were questions about significant places, regions, and landmarks.
- Historical events and periods: There were questions centred on major occurrences and eras that shaped history.

- Structures and architecture: There were questions about prominent buildings, structures, and the principles of their designs.
- Military and occupation history: There were questions about important battles, military strategies, and periods of occupation or colonisation.

2.6. Data Analysis

For the analysis of the primary data, the *R* programming language (v. 4.3.1) was employed. Before any statistical analysis, the dataset was examined for missing or incomplete values. The preliminary analysis confirmed that there were no missing values. For outlier detection, both graphical (e.g., boxplots) and analytical methods (e.g., Z-scores) were utilised to identify and handle anomalous data points. For the evaluation of internal consistency, Cronbach's alpha score was calculated for each survey. Coefficients nearing or exceeding 0.7 were considered to be 'satisfactory' [50]. Subsequently, the data was subjected to the Shapiro–Wilk test to evaluate normality [51]. The test revealed that the data did not exhibit a normal distribution, therefore necessitating the need to adopt non-parametric tests for further analyses.

As the academic performance data emerged from the same cohort, the Wilcoxon signed-rank test [51] was utilised to analyse differences in scores before and after the VR session. Concerning the psychometric instruments, Spearman rank-order correlations [51] were employed to examine the interrelationships both within the constructs of the surveys and within the evolving perceptions of utilising VR for educational purposes (i.e., shifts in attitudes and perceptions before and after the conducting of the intervention).

3. Results

3.1. Demographics

The study involved students (N = 52) from secondary schools in the city of Rta, Greece. The participants' ages ranged from 13 to 15 years, which corresponds to the typical age distribution across the three grades of the national lower secondary school system. Selection was unbiased by variables such as socio-economic status, prior VR exposure, or academic prowess. The gender distribution among the participants exhibited a commendable balance with boys and girls each constituting 44.2% of the total sample. The remaining participants (11.6%) opted not to disclose their gender. With regard to the age distribution, a significant skew towards the older aged cohort was observed. Specifically, the overwhelming majority (96.2%) fell within the age range of 14–15 years, while a marginal subset (3.8%) was categorised in the 13–14 years-old age bracket.

3.2. Academic Performance

In the preliminary analysis of student performance, we noticed a significant upshift in both the mean and the median scores between the pre-test and the post-test assessments (Table 1, Figure 5). While this points to an overall improvement in academic achievement, the broader dispersion in scores suggest a greater heterogeneity in student performance during the post-test phase. Moreover, when examining the distributional attributes of the scores, the post-test results display a leftward skew, indicating that the majority of students not only improved but also scored above the mean. This contrasts with the pre-test scores, which are more symmetrically distributed, indicating a more unified performance among the cohort.

The Shapiro–Wilk test confirmed these observations, as the pre-test scores mildly deviated from normality (W = 0.942, p = 0.01), whereas the post-test scores showed a significant deviation (W = 0.874, $p < 0.05$). On these grounds, the Wilcoxon signed-rank test was utilised to further explore these differences. In the 'Historical Figures and Rulers' category, a statistically significant difference (W = 157.0, $p < 0.01$) was observed with a large effect size (r = 0.886). Similarly, for the 'Geographical Locations' category, a significant difference was noted (W = 57.0, $p < 0.01$), also with a large effect size (r = 0.959). In contrast, the 'Historical Events and Periods' category showed no significant variation (W = 213.0,

$p = 0.207$). However, the 'Structures and Architecture' category revealed a significant difference ($W = 128.5$, $p < 0.01$) with a pronounced effect size ($r = 0.907$) and so did the 'Military and Occupation History' category ($W = 121.0$, $p < 0.001$) with a large effect size ($r = 0.912$). Given the significant improvements observed across multiple categories, it can be safely concluded that the VR educational session influenced participants' understanding, and therefore, knowledge gains.

Table 1. Descriptive statistics for academic performance.

Statistics	Pre-Test	Post-Test
Mean	0.43	0.69
Median	0.4	0.75
Std. dev.	0.15	0.26
Skewness	−0.13	−1.04
Kurtosis	−0.21	0.28

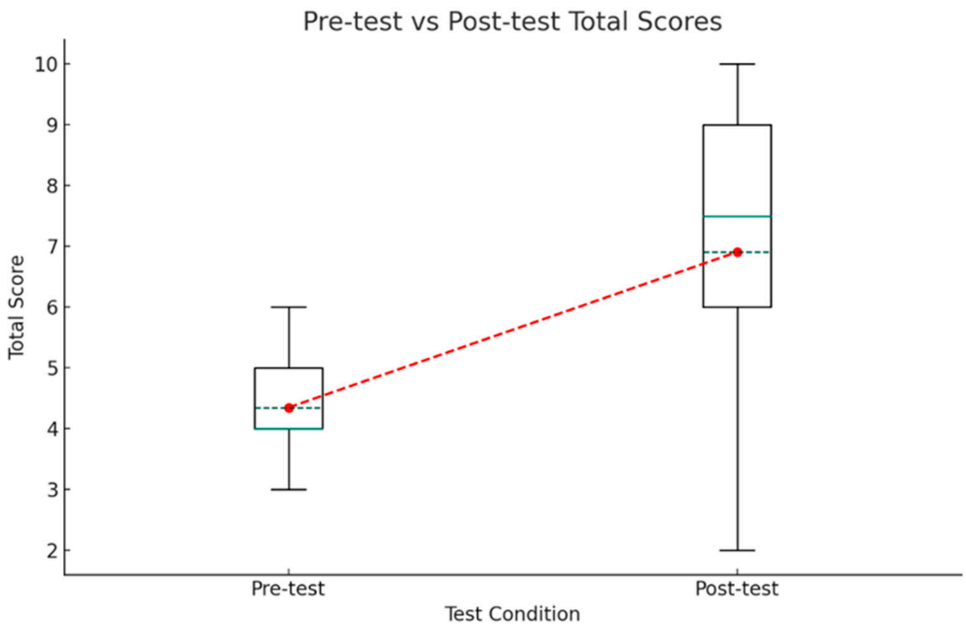

Figure 5. The distribution of the quiz scores (pre–post-test).

Concerning the influence of the demographic characteristics, a negative correlation is identified between gender and academic performance ($r = -0.047$, $p = 0.736$) in the pre-test. Although this correlation suggests a minor inverse association, the result lacks statistical significance. In a similar vein, the post-test measurement indicated a negative correlation also ($r = -0.226$, $p = 0.106$), though this relationship does not attain the threshold for statistical significance either. Thus, while there may be a perceptible divergence in performance based on gender, the evidence is insufficient to substantiate this. Age-related correlations were not performed due to the limited sample size across different age groups.

3.3. Instructional Experience

3.3.1. Perceptions and Preconceptions toward Educational Virtual Reality

The preliminary survey results provide a baseline understanding of how students perceive VR-based educational interventions (Table 2). Participants demonstrated surprisingly low anxiety levels regarding the use of VR, suggesting that they may be more receptive to this learning modality than educators often assume. Satisfaction scores followed a normal distribution, reflecting a generally positive response to VR without overwhelmingly high expectations. Finally, while the willingness to engage with VR was positive, it was slightly less pronounced. This finding indicates a cautious optimism among students towards adopting VR in their learning. Although students show a general openness toward VR, their willingness to engage with it, while positive, suggests that there may be underlying concerns or reservations that need to be addressed. A possible explanation for this discrepancy could stem from a variety of factors including unfamiliarity with the technology, concerns about its effectiveness as a learning tool, or potential discomfort.

Table 2. Descriptive statistics for the preliminary survey.

	Mean	Median	Std. Dev.	Skewness	Kurtosis	Cronbach's α	Shapiro–Wilk
Satisfaction	3.38	3.28	0.76	−0.01	−0.56	0.84	$W = 0.982$, $p = 0.622$
Anxiety	2.03	1.75	0.89	1.18	1.26	0.9	$W = 0.892$, $p < 0.05$
Willingness	3.25	3	0.96	0.31	−0.67	0.75	$W = 0.938$, $p < 0.05$

Interestingly, the survey also reveals connections between these different perceptions (Table 3). Specifically, students who hold more favourable views toward VR's potential in the classroom tend to experience significantly reduced anxiety about using it in their studies. Furthermore, it highlights a deeply intertwined relationship between student satisfaction with VR's educational potential and their willingness to engage with it. In other words, those who view VR favourably are demonstrably more open to incorporating it into their learning. This result reinforces the importance of emphasizing the potential advantages and effectiveness of VR-based learning to drive student adoption.

Table 3. Spearman rank correlations within the preliminary survey.

Construct	Satisfaction	Anxiety	Willingness
Satisfaction	1		
Anxiety	−0.312 *	1	
Willingness	0.709 **	−0.223	1

* Significant for $p < 0.05$; ** Significant for $p < 0.01$.

3.3.2. Evaluation of the VR Instructional Experience

The focal point of the post-intervention survey was to discern how students perceived this alternative instructional approach. The conclusive survey results (Table 4) offer encouraging insights into the participants' overall experience with the VR intervention. The strong sense of presence that participants experienced suggests that the learning environment was successfully designed to foster deep engagement. Furthermore, students generally reported high levels of enjoyment and motivation, highlighting the intervention's ability to create a positive and stimulating learning experience. While there is room to explore how to improve the perceived learning effectiveness, the content seems generally well-aligned with learner needs. Most participants felt that the learning materials were highly adequate, indicating that resources were relevant and supportive. Finally, the positive responses regarding the perceived ease of use of the VR and the students' sustained motivation point to a user-friendly and engaging VR experience.

The secondary analysis also revealed several significant correlations (Table 5) that shed light on the factors contributing to the effectiveness of VR-based learning.

A strong link exists between students' enjoyment of the VR experience and their sense of presence within the virtual environment. This highlights the importance of creating immersive and engaging VR environments to foster positive learning experiences. Similarly, students who felt more immersed (more present) also perceived the VR tool itself to be more useful for learning, underscoring how an authentic design enhances the perceived educational value. One of the most notable findings was the strong positive correlation between enjoyment and perceived learning effectiveness, suggesting that when the VR experience is enjoyable, students are more likely to believe it has educational value. Additionally, the ease of use was closely tied to a better overall experience, which can be attributed to the intuitive navigation. Interestingly, participants also associated realism in the VR environment with ease of use.

Table 4. Descriptive statistics for the conclusive survey.

Construct	Mean	Med.	Std. Dev.	Skew	Kurt	Cronbach's α	Shapiro–Wilk
Presence	2.91	3	0.81	−0.17	0.39	0.71	$W = 0.976$, $p = 0.4$
Enjoyment	3.06	3	0.56	0.41	1.56	0.61	$W = 0.958$, $p = 0.06$
Learning Effectiveness	3.49	3.5	1.13	−0.45	−0.46	0.94	$W = 0.941$, $p = 0.01$
Realism	3.09	3.12	1.16	−0.14	−0.67	0.94	$W = 0.944$, $p = 0.01$
Adequacy of Learning Material	1.95	1.66	0.95	1.82	3.89	0.86	$W = 0.797$, $p < 0.05$
Ease of Use	2.94	3	0.6	0.57	3.04	0.66	$W = 0.877$, $p < 0.05$
Motivation	2.12	2	1.1	1.09	0.86	0.91	$W = 0.867$, $p < 0.05$

Table 5. Spearman rank-order correlations within the conclusive survey.

	Presence	Enjoyment	Learn. Effect.	Realism	Adeq. of Learn. Mat.	Ease of Use	Motivation
Presence	1						
Enjoyment	0.312 *	1					
Learn. Effect.	0.377 **	0.742 **	1				
Realism	0.371 **	0.592 **	0.669 **	1			
Adeq. of Learn. Mat.	0.137	−0.109	−0.1	−0.084	1		
Ease of Use	0.357 **	0.56 **	0.559 **	0.485 **	0.018	1	
Motivation	0.106	−0.238	−0.327 *	−0.335 *	0.431 **	0.003	1

* Significant for $p < 0.05$; ** Significant for $p < 0.01$.

However, our analysis also revealed potential challenges. The negative correlation between motivation and perceived learning effectiveness suggests the need for careful consideration when integrating VR for use in long-term educational objectives. Likewise, the negative connection between motivation and realism indicates that hyper-realistic elements might have a diminishing return on student engagement over time, perhaps due to sensory overload.

3.3.3. Evolving Attitudes before and after the Intervention

The final objective of this study was to understand how participants' initial attitudes toward educational VR might change after participating in the intervention (Table 6). The analysis revealed several compelling and unexpected relationships. Learners who initially expressed high satisfaction subsequently reported lower levels of enjoyment, perceived usefulness, and perceived realism than anticipated. This finding underscores the importance of fostering realistic expectations to optimize long-term engagement with the educational experiences. Interestingly, students who reported initial anxiety about the learning experience perceived the VR environment to be more realistic than their less-anxious peers. This suggests that a degree of initial apprehension might potentially amplify the perceived realism of the learning environment. Furthermore, participants with high initial perceptions reported lower perceived learning effectiveness, revealing a possible disconnect between initial expectations about the technology's utility and the actual learning gains achieved. Finally, we observed that the initial scepticism toward the experience tended to diminish after engagement. However, this outcome may imply that the novelty effect might influence early attitudes but may not be a reliable predictor of sustained involvement.

Table 6. Spearman rank-order correlations between the preliminary survey and the conclusive survey.

	Presence	Enjoyment	Per. Learn. Effect.	Per. Realism	Adeq. of Learn. Mat.	Per. Ease of Use	Motivation
Satisfaction	−0.082	−0.284 *	−0.369 **	−0.378 **	−0.02	−0.104	0.07
Anxiety	−0.028	0.052	0.126	0.331 *	−0.034	0.031	−0.212
Willingness	−0.058	−0.212	−0.238	−0.372 **	−0.062	0.012	0.064

* Significant for $p < 0.05$; ** Significant for $p < 0.01$.

4. Discussion

In this study, we investigated the impact of a VR-based cultural education program on student academic performance (RQ1) and further explored their perceptions toward this alternative instructional approach (RQ2). The findings offer various insights into the potential of VR in education while highlighting the importance of careful design and expectation management to maximize its effectiveness.

With regard to academic performance, the evidence strongly supports the proposition that VR-based cultural education programs can positively impact knowledge gains, as shown from the significant enhancements observed across several subject-specific categories. These outcomes can be attributed to VR's distinctive immersive qualities and its capacity to facilitate experiential learning. By situating learners within contextually rich virtual environments, VR activates multiple sensory modalities which contribute to the development of a more holistic learning experience [52]. This multisensory stimulation aligns with the principles of CLT, suggesting that the distribution of information processing across visual and auditory channels can reduce the overall cognitive load and, consequently, enhance learning outcomes [53]. Furthermore, the ability of VR to present information spatially and to allow learners to directly interact with virtual representations of concepts aligns with theories of embodied cognition. This theoretical perspective argues for the importance of sensorimotor experiences in shaping abstract understanding [54,55]. Additionally, our findings resonate with the growing body of research that demonstrates the efficacy of VR for learning across a variety of scientific domains [56,57] and for the development of empathy [58]. Importantly, the immersive experiences generated by VR are instrumental in fostering a state of flow, where students feel fully engaged and absorbed by the learning activity, minimizing distractions and enhancing their focus on the content presented.

However, the findings also reveal a deficiency in one subject category (namely, 'Historical Events and Periods'), where the VR intervention did not significantly improve academic performance. This outcome may partly reflect the limitations of our assessment approach, which utilized binary-based assessments. Such questions are unlikely to trigger a higher cognitive load and thus may not adequately measure the depth of understanding required to grasp complex historical events and their interconnectedness. Consequently, this highlights the need for an alternative approach not only to the designing of VR content but also to how we assess its impact. In addition, it also underscores the need for an alternative approach to designing VR content. Indeed, conceptualising complex historical events and their interconnectedness presents unique cognitive challenges for learners. Therefore, VR experiences designed to convey such abstract concepts might benefit from incorporating elements from the field of gamification more intensively. For instance, integrating interactive timelines or cause-and-effect scenario visualisations could potentially provide learners with the scaffolding necessary to navigate the complexities of historical narratives [59]. In doing so, the management of an intrinsic cognitive load, which is heavily influenced by the inherent complexity of the learning material itself, may be more effectively optimized [60]. Additionally, research suggests that collaborative VR experiences that encourage learners to discuss and negotiate understandings within the virtual environment can be particularly effective in supporting the learning of complex and abstract concepts [61]. By leveraging the immersive properties of VR to create a flow state, these collaborative settings can enhance the effectiveness of learning abstract and complex content by maintaining continuous engagement and interest. These approaches, while requiring further investigation within the context of cultural education, could offer promising avenues for addressing the limitations observed in our study.

Concerning student perceptions toward educational VR, the study uncovers a largely positive attitude toward the adoption of this instructional approach. The reportedly low initial anxiety levels among participants are encouraging as they defy common preconceptions about VR's potential to induce apprehension. Moreover, the high satisfaction scores post-intervention, coupled with the high degree of experienced presence, and enjoyment levels further reinforce VR's capacity to create highly engaging and experiential learning experiences [62].

These findings resonate with the core tenets of the TAM, underlining how the perceived usefulness and ease of use play a pivotal role in fostering the adoption of new technologies [63]. The high degree of enjoyment expressed by participants aligns also with the Self-Determination Theory, which posits that intrinsically motivated activities that satisfy needs for competence, autonomy, and relatedness are more likely to persist across time [64]. Importantly, the positive student perceptions echo broader trends in educational technology research, where VR is increasingly recognised for its potential to enhance motivation, engagement, and overall learning satisfaction [29].

Finally, the study also highlights the significance of managing student expectations with respect to VR's capabilities. The observed discrepancy between those with initially high expectations and the subsequent levelling-off of post-intervention satisfaction underscores this point. Educators integrating VR into their classrooms must proactively frame VR experiences as a powerful learning tool while being acutely aware of its current limitations. Setting realistic expectations serves a two-fold purpose: on the one hand, it mitigates the risk of disillusionment that can negatively impact student engagement and, on the other, it allows users to focus on the unique strengths and opportunities that VR presents. Furthermore, it is important to recognize that the novelty effect associated with new technologies, such as VR, can initially inflate perceptions [65]. Therefore, incorporating VR into regular and ongoing instruction can help mitigate this phenomenon.

5. Conclusions

The present work highlights the transformative potential of VR to enrich education, particularly in the realm of cultural studies. For teenage learners, VR offers a uniquely powerful way to engage with historical and cultural concepts. The findings demonstrate that VR interventions aimed at this target group can improve academic performance and reshape attitudes, fostering increased motivation, cultural sensitivity, and a more positive outlook on the subject matter. To maximise these benefits, instructional designers must carefully tailor VR experiences to the specific interests and needs of the target group [66]. This involves balancing VR's unique strengths with pedagogical strategies, such as gamification, to mitigate cognitive overload. Additionally, providing proper orientation and technological support is essential to ensure student comfort. However, educators must remain mindful of potential challenges, such as decreased motivation or misaligned perceptions of learning effectiveness. These challenges underscore the need for ongoing research and the optimization of both VR content and its delivery methods.

6. Limitations and Recommendations for Future Research

The empirical nature of our study inherently presents several limitations that merit attention. Firstly, our study was constrained by a small sample size, which may limit the generalizability of the findings. Future research could address this by incorporating larger and more diverse samples to substantiate the conclusions drawn. Additionally, while our findings suggest demographic variations, the study does not conduct an exhaustive demographic analysis that includes factors such as socioeconomic statuses or cultural backgrounds. A more comprehensive exploration into these areas could significantly deepen our understanding of the differential impacts of educational technologies across diverse groups.

Another limitation concerns the environmental and temporal scope of the research. The physical context and the study's duration may hinder our ability to draw causal inferences. Longitudinal studies could offer more detailed insights into how VR is adopted over time and its long-term educational effects. Moreover, our assessment methods primarily focused on factual recall, which might not adequately capture deeper knowledge acquisition or the cognitive processes facilitated by VR. This is particularly pertinent as the cognitive load induced by VR interventions was only evaluated at the basic recall level of Bloom's taxonomy.

Additionally, the immediate testing following the VR intervention may amplify the observed benefits, a phenomenon known as the "intervention-testing effect", suggesting that recent exposure to an educational intervention could enhance the performance on subsequent assessments irrespective of the medium used [67]. Comparative analysis with non-VR interventions, such as educational videos, could further clarify VR's unique advantages. Future studies should include a control group and integrate assessment methods that evaluate higher-order cognitive skills, thus providing a fuller understanding of VR's educational potential.

The novelty effect also poses a limitation; as the initial excitement of using VR diminishes, the sustained impact on learner engagement and cognitive load management remains uncertain. Future research should explore the long-term effectiveness of VR-based educational strategies to determine their enduring pedagogical value.

Lastly, the study's focus on specific cultural domains restricts its applicability to other subjects, pointing to the necessity for a more interdisciplinary approach in future research to offer a more holistic perspective on technology-mediated education.

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Institutional Review Board Statement: This study was conducted in collaboration with the educational institution and facilitated through a planned visit to the university's campus. The school's principal and teaching staff reviewed and approved all research procedures to ensure the well-being of the participants. The content and nature of the Virtual Reality (VR) experience were chosen to align with age-appropriate guidelines, with considerations for the emotional and psychological well-being of the participants. Robust measures were instituted to protect the anonymity and confidentiality of all individuals involved.

Informed Consent Statement: Informed consent was obtained from the parents/guardians of all subjects involved in the study.

Data Availability Statement: Anonymised data that support the findings of this study are available from the corresponding author upon request.

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Appendix A

The knowledge assessment quiz involved 10 multiple-choice answers.

A. Historical figures and rulers

1. Who was the founder and first ruler of the so-called "Despotate of Epirus"?
2. In the year 1318, the city of Arta and the castle came under the rule of Carlo I Tocco?

B. Geographical locations

1. Where is the Castle of Arta located?
2. When did Arta and its castle surrender to the Ottoman Empire?

C. Historical events and periods

1. In the 13th–14th centuries, Arta was attacked only by Byzantine rulers?
2. In 1736 and 1737, the city of Arta was hit by plague epidemics?

D. Structures and architecture

1. Are there parts of the ancient defensive wall of Amvrakia incorporated into the structure of the Castle to this day?
2. When was the Xenia Hotel built?

E. Military and occupation history

1. How many times was the Castle of Arta occupied?
2. Who expanded, fortified, and upgraded the Castle of Arta to its present form?

Appendix B

The psychometric instruments utilised in the pre-and-post-intervention phase.

A. Preliminary survey

C1. Satisfaction

1. I enjoy the lessons instructed with VR applications.
2. The demonstration of 3D objects, videos, and animations about the book in VR applications increases my curiosity.
3. I study harder for the lesson thanks to VR applications.
4. The 3D objects in VR applications give a sense of reality to the environment.
5. I come to the class more eagerly when VR applications are used.
6. I can concentrate better on the lesson when VR applications are used.
7. I enjoy studying lesson at home with VR applications.

C2. Anxiety

1. VR applications do not attract my attention.*
2. VR applications make my learning difficult because they confuse my mind.*
3. There is no need to use VR applications in classes.*
4. Using VR applications in classes causes a waste of time.
5. I get bored while I am using VR applications.*
6. It is difficult to use VR applications.*

C3. Willingness

1. I want VR applications to be used in other lessons, as well.
2. I want VR applications to take place regarding course books in the future

* Denotes reversed item

B. Conclusive survey

C1. Presence

1. I was deeply concentrated in the application.
2. If someone was talking to me, I couldn't hear him.
3. I forgot about time passing while using the application.

4. I felt detached from the outside world while using the application.

C2. ***Enjoyment***

1. I think the application was fun.
2. I felt bored while using the application.*
3. I enjoyed using the application.
4. I really enjoyed studying with this application.
5. It felt good to successfully complete the tasks in this application.
6. I felt frustrated.*

C3. ***Perceived Learning Effectiveness***

1. I felt that this application can ease the way I learn.
2. This application was a much easier way to learn compared to the usual teaching.
3. This application made learning more interesting.
4. I felt that the application increased my knowledge.
5. I felt that I caught the basic ideas of what I was taught with this application.
6. I will definitely try to apply the knowledge I learned with this application.

C4. ***Perceived Realism***

1. When interacting with the virtual objects, these interactions seemed like real ones.
2. There were times when the virtual objects seemed to be as real as the real ones.
3. The virtual objects seemed like real objects to me.
4. When I used the application, the virtual world was more real than the real world.

C5. ***Adequacy of Learning Material***

1. In some cases, there was so much information that it was hard to remember the important points.*
2. The exercises in this application were too difficult.*
3. I could not really understand quite a bit of the material in this application.*
4. The good organization of the content helped me to be confident that I would learn this material.

C6. ***Perceived Ease of Use***

1. I think it was easy to learn how to use the application.
2. I found the application unnecessarily complex.
3. I imagine that most people will learn to use this application very quickly.
4. I needed to learn a lot of things before I could get going with this application.
5. I felt that I needed help from someone else in order to use the application because it was not easy for me to understand how to use it.
6. It was easy for me to become skilful at using this application.

C7. ***Motivation***

1. This application did not hold my attention.*
2. When using the application, I did not have the impulse to learn more about the learning subject.*
3. The application did not motivate me to learn.*

* Denotes reversed item

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