Short Note

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Integrating Virtual Reality Headsets in Primary Education: Pedagogical Benefits, KPIs, Software Requirements, and Assessment Design

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Integrating Virtual Reality Headsets in Primary Education: Pedagogical Benefits, KPIs, Software Requirements, and Assessment Design

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Abstract

This study explores the potential of Virtual Reality (VR) to transform primary education. It analyses the pedagogical advantages of VR, such as enhanced engagement, improved learning outcomes, the development of cognitive and socioemotional skills, and increased educational accessibility. Key Performance Indicators (KPIs) for measuring the impact of VR were identified and aligned with Bloom's Revised Taxonomy. This study also provides specifications for the required VR software and content, along with practical guidelines for designing worksheets and assessment tools. Emphasis is placed on the importance of careful planning and adherence to safety protocols for the successful integration of VR in primary schools.

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1. INTRODUCTION

Virtual Reality (VR) is an emerging technology that creates immersive and interactive environments simulated by computers, with which users can explore and interact, mainly through VR headsets [1]. This technology relies on three characteristics: presence (the feeling of physically being "there"), interactivity (the ability to influence the virtual environment), and immersion (the blurring of the boundary between the physical and digital worlds) [2].

Pedagogical Advantages of VR in Primary School

1). Enhanced Engagement and Motivation

VR significantly increases student engagement and motivation, making learning dynamic and interactive [2]. This enhanced engagement stems from VR's ability to create immersive multisensory experiences that reduce distractions and foster emotional connections with the content [5].

2). Improved Learning Outcomes and Knowledge Retention

Students who learn in virtual environments achieve significantly higher academic scores. VR can improve knowledge retention by up to 75% compared to traditional methods, with some studies reporting nearly 80% retention after one year [5].

3). Fostering Cognitive Development

VR aids in the understanding of complex and abstract concepts (e.g., STEM and geometry) by making them tangible and interactive within a three-dimensional environment [2]. It enhances visual thinking skills, spatial awareness, memory retention and problem-solving abilities. VR is particularly effective for procedural knowledge acquisition because it allows students to manipulate virtual objects and conduct experiments [3].

4). Promoting Socio-Emotional Skills

VR is described as an "empathy-inducing medium" [6] that enables users to "step into someone else's shoes," thereby enhancing empathy and cultural understanding [5]. It encourages collaboration and teamwork through shared virtual experiences and multiplayer functions [5].

5). Accessible and Safe Experiential Learning

VR provides risk-free environments for practicing dangerous or costly scenarios [3],[5]. It also offers educational accessibility to students who are unable to attend school in person (e.g., due to illness). Virtual field trips serve as a cost-effective alternative to traditional excursions, ensuring 100% participation and inclusion [7],[5]. Despite these advantages, studies focusing on Primary Education remain comparatively limited [4].

2. Problem Description

Measuring Impact: Key Performance Indicators (KPIs) and Alignment with Bloom's Taxonomy

To measure the true impact of VR in education, it is necessary to define specific, measurable, achievable, relevant, and time-bound (SMART) performance indicators. These indicators should not be limited to academic performance but should encompass a broad range of learning outcomes that VR can influence. Their alignment with Bloom's taxonomy allows us to evaluate not only what students remember but also the depth of their understanding and their ability to apply, analyze, evaluate, and create, as illustrated in Table I.

Table 1

. Bloom Level.	*Cognitive Process*	*VR-Enhanced Learning Activity (Elementary Example)*	*Corresponding KPIs*
Remember	Recall facts, terms, basic concepts.	Virtual field trip to Ancient Egypt, identifying key landmarks and artifacts.	Knowledge Acquisition (e.g., number of correctly identified objects).
Understand	Explain ideas or concepts.	Exploration of the human circulatory system in VR, followed by description of each organ's function.	Understanding Abstract Concepts (e.g., clarity of explanation, correct sequence of blood flow).
Apply	Use information in new situations.	Conducting a virtual science experiment (e.g., safely mixing chemicals), observing reactions.	Acquisition of Procedural Skills (e.g., correct steps followed, accurate measurements).
Analyse	Break information into parts to explore relationships.	Navigating a virtual ecosystem, identifying predator-prey relationships and food chains.	Critical Thinking & Problem-Solving (e.g., accurate identification of relationships, reasoning of observations).
Evaluate	Justify a decision or course of action.	Participating in a VR scenario where a virtual character faces a social dilemma, then choosing and justifying a response with empathy.	Empathy & Perspective-Taking (e.g., action choice, justification of empathy), Collaboration & Communication (if discussed with peers).
Create	Generate new ideas, products, or ways of viewing things.	Using a VR design tool (e.g., CoSpaces Edu) to create a virtual model of a sustainable city or a historical scene.	Critical Thinking & Problem-Solving (e.g., innovative solutions), Acquisition of Procedural Skills (e.g., mastery of design tools).

1). Defining Measurable KPIs

Assessing the effectiveness of VR in education involves monitoring learning outcomes, engagement, and feedback from both students and teachers. KPIs must capture cognitive, emotional and psychomotor development.

2). Mapping to the Revised Bloom's Taxonomy

Bloom's taxonomy provides a framework for classifying educational goals, ranging from the recall of basic knowledge to advanced cognitive skills, such as analysis and creation [8]. Integrating VR with Bloom's taxonomy guides students through progressively complex cognitive tasks [9]. The taxonomy includes cognitive (knowledge, comprehension, application), affective (emotions, values),

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and psychomotor (physical skills) domains, all of which can be related to VR applications [8], as illustrated in Table I.

As illustrated in Table I, the design of VR scenarios should be guided by a clear identification of the specific Bloom's taxonomy skill targeted for development, thereby ensuring the alignment of the corresponding learning activity [10], [11]. Similarly, evaluators or researchers aiming to assess the learning outcomes of an instructional intervention should employ Key Performance Indicators (KPIs) that correspond to the targeted Bloom's skills. Table I presents representative examples tailored for primary education.

VR functions as a catalyst for the development of higher-order thinking skills. Whereas traditional instruction often prioritises the lower levels of Bloom's taxonomy (Remember, Understand), the immersive and interactive nature of VR uniquely facilitates higher-order thinking skills, such as Application, Analysis, Evaluation, and Creation [8]. This shifts learning from passive reception to active knowledge construction, consistent with constructivist and experiential learning theories [12].

3. Proposed Solution

The aim of my research is to measure the effectiveness of VR headsets in Primary Education. For this purpose, I selected appropriate software and hardware resources to assess the student performance. Avantis ClassVR headsets were chosen, with my school owning eight of them. During the experimental process, students were divided into subgroups to engage with the teaching materials.

ClassVR provides teachers with central control over headsets. It also offers its own content through *Eduverse*, an online platform that grants educators immediate access to educational resources. Furthermore, teachers and students can create and upload their own content. This content may include 3D models in GLB or STL format (produced with software such as Paint3D or ThingLink) or 360° photos and videos generated with a 3D camera.

Some software resources were provided by the VR headset company and were available only by subscription. I created the material for the first set of experiments using a 3D camera, which can be accessed via a video link. Additionally, my research team and I developed worksheets to guide the teaching process and assessment sheets to evaluate learning outcomes (available in the VR scenarios link).

For research purposes, students of the same age and learning background were selected and divided into two groups, one serving as the control group.

3.1. First Set of experiments

The first set of experiments was conducted with a fifth-grade class of 24 students divided into two subgroups. This experimental series focused on history, specifically a virtual tour of the Acropolis. This study provided the opportunity to design and implement educational material primarily intended to transmit information to children, with the subsequent objective of evaluating learners' capacity for information recall, corresponding to the first level of Bloom's Taxonomy. This focus was selected because the assessment of information recall represents one of the most straightforward and reliably measurable cognitive skills.One group of students was given six minutes to read a text about the Propylaea and the Erechtheion, as shown in Fig. 1.

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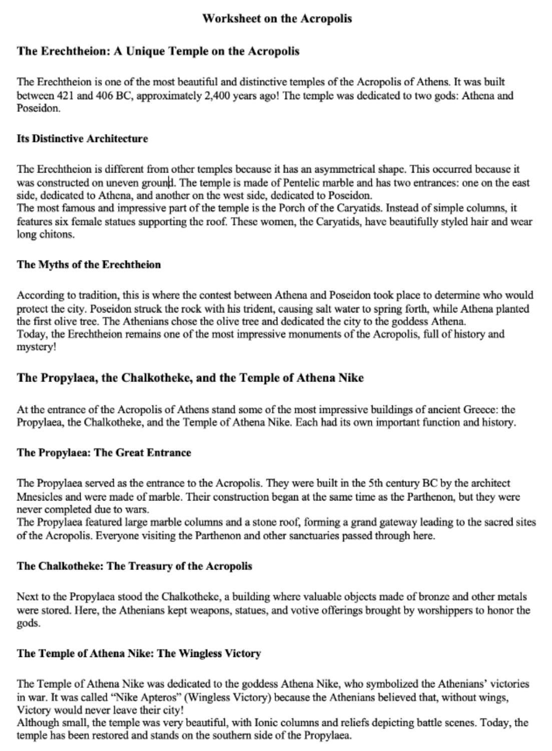

Worksheet on the Acropolis

The Erechtheion: A Unique Temple on the Acropolis

The Erechtheion is one of the most beautiful and distinctive temples of the Acropolis of Athens. It was built between 421 and 406 BC, approximately 2,400 years ago! The temple was dedicated to two gods: Athena and Poseidon.

Its Distinctive Architecture

The Erechtheion is different from other temples because it has an asymmetrical shape. This occurred because it was constructed on uneven ground. The temple is made of Pentelic marble and has two entrances: one on the east side, dedicated to Athena, and another on the west side, dedicated to Poseidon.
The most famous and impressive part of the temple is the Porch of the Caryatids. Instead of simple columns, it features six female statues supporting the roof. These women, the Caryatids, have beautifully styled hair and wear long chitons.

The Myths of the Erechtheion

According to tradition, this is where the contest between Athena and Poseidon took place to determine who would protect the city. Poseidon struck the rock with his trident, causing salt water to spring forth, while Athena planted the first olive tree. The Athenians chose the olive tree and dedicated the city to the goddess Athena.
Today, the Erechtheion remains one of the most impressive monuments of the Acropolis, full of history and mystery!

The Propylaea, the Chalkotheke, and the Temple of Athena Nike

At the entrance of the Acropolis of Athens stand some of the most impressive buildings of ancient Greece: the Propylaea, the Chalkotheke, and the Temple of Athena Nike. Each had its own important function and history.

The Propylaea: The Great Entrance

The Propylaea served as the entrance to the Acropolis. They were built in the 5th century BC by the architect Mnesicles and were made of marble. Their construction began at the same time as the Parthenon, but they were never completed due to wars.
The Propylaea featured large marble columns and a stone roof, forming a grand gateway leading to the sacred sites of the Acropolis. Everyone visiting the Parthenon and other sanctuaries passed through here.

The Chalkotheke: The Treasury of the Acropolis

Next to the Propylaea stood the Chalkotheke, a building where valuable objects made of bronze and other metals were stored. Here, the Athenians kept weapons, statues, and votive offerings brought by worshippers to honor the gods.

The Temple of Athena Nike: The Wingless Victory

The Temple of Athena Nike was dedicated to the goddess Athena Nike, who symbolized the Athenians' victories in war. It was called "Nike Apteros" (Wingless Victory) because the Athenians believed that, without wings, Victory would never leave their city!
Although small, the temple was very beautiful, with Ionic columns and reliefs depicting battle scenes. Today, the temple has been restored and stands on the southern side of the Propylaea.

Figure 1. Worksheet on the Acropolis.

Afterwards, students watched a VR 3D video of a duration of four minutes accompanied by the narrated text. The video, as shown in fig.2, was captured with the school's 3D camera during an excursion.

Figure 2. 3D video of Acropolis.

On the other hand, the control group studied the same text for the same total duration (10 minutes). Both groups then completed the same assessment sheet within eight minutes (Figure 3).

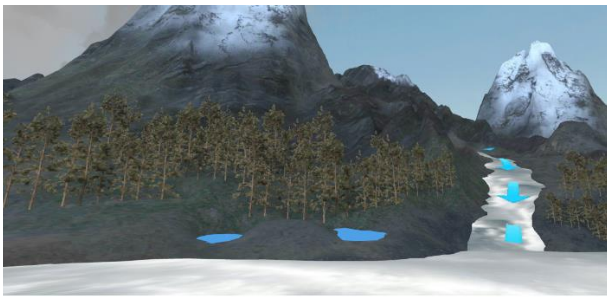

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Figure 3. Assesment sheet on the Acropolis.

During the evaluation phase, the first group, which had the opportunity to use VR during instruction, achieved an average rate of correct responses of 92.3%. The control group, which spent the same amount of instructional time but had access only to the text (note that the text was identical to that accompanying the 3D video presented in VR), achieved an average of 88.6% correct responses. This study revealed a small performance difference of 3.7% on a specific standardized closed-ended assessment (Table II).

Table 2

Method of Teaching	**Mean rate of Correct Answers**		
	Right after	*After 1 month*	*Difference through time*
Without VR	88,60%	68,20%	20,40%
With VR	92,30%	79,60%	12,70%
Difference through method	3,70%	11,40%	

The non-parametric Mann–Whitney U test was applied to investigate whether there was a statistically significant difference in performance between the control group (without the use of VR) and the experimental group (with the use of VR). The results indicated that the difference between the two groups was not statistically significant (U = 62.5, p = 0.61). This finding suggests that, based on a specific student sample, the use of virtual reality did not lead to a measurable improvement in performance compared to conventional teaching.

In the second phase, after an interval of one month, students from both groups were administered the same assessment. As expected, the percentage of correct responses decreased in both the groups. However, the VR group showed a smaller decline, achieving 79.6% correct response. In contrast, the control group demonstrated a significantly greater decrease, achieving only 68.2% of correct responses. Thus, the performance gap between the two groups increased substantially, to 11.4%. This difference was considerably larger than the initial measurement, indicating that the group instructed using VR retained knowledge more effectively. Indeed, correct responses in the non-VR group dropped by 20.4%, whereas in the VR group, the decrease was only 12.7%.

The analysis using the non-parametric Mann–Whitney U test showed that the performance of the students in the VR group was higher than that of the control group; however, the difference did not reach the level of statistical significance (U = 41.5, p = 0.084, slightly above the critical value of p = 0.05). The results indicated a trend in favor of the VR group, which may become statistically significant with a larger sample size.

These initial results are illustrated in Figure 4, where it becomes even clearer that the VR group achieved slightly better outcomes than the other groups. The difference in performance between the two groups became more pronounced when a time gap was introduced between instruction and assessment, indicating that the group taught using VR retained knowledge significantly better.

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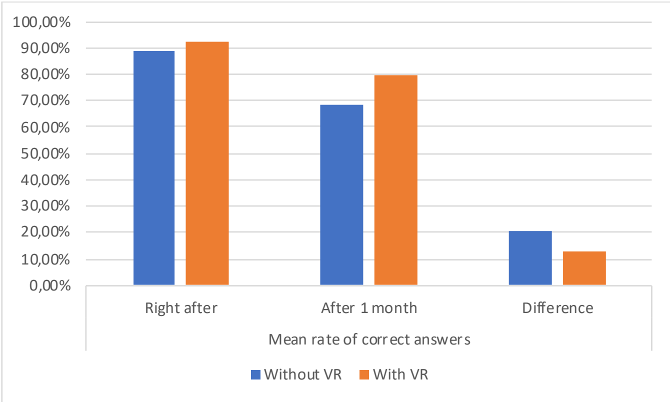
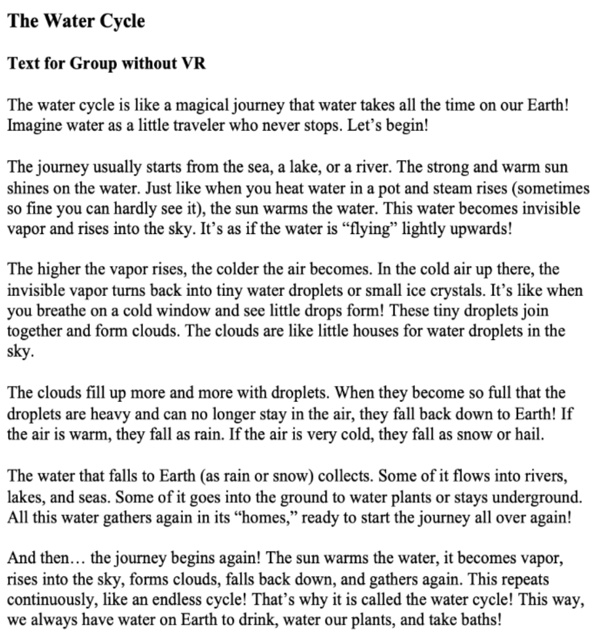


Figure 4. Results of teaching with VR and without VR.

Analyzing this first series of experiments and attempting to interpret why the observed performance difference is noticeable but not striking, we concluded that both the learning material and the assessed skills primarily pertained to the first level of Bloom's taxonomy—information recall. Moreover, the instructional material in both teaching methods (with and without VR) was identical according to our research methodology, which may have limited the comparative advantage that VR could potentially offer.

3.2. Second Set of experiments

Therefore, we are currently developing instructional materials targeting higher-order Bloom skills, such as studying the water cycle. In this phase, two third-grade classes with 17 students each were studied, one serving as the control group. The VR group explored an interactive virtual environment for 10 min, showing water phase transformations in nature, using pre-designed material allowing high interactivity. Students can travel through the scene and observe the transformations of water and the conditions under which every transformation occurs, as shown in fig. 5.



The Water Cycle

Text for Group without VR

The water cycle is like a magical journey that water takes all the time on our Earth! Imagine water as a little traveler who never stops. Let's begin!

The journey usually starts from the sea, a lake, or a river. The strong and warm sun shines on the water. Just like when you heat water in a pot and steam rises (sometimes so fine you can hardly see it), the sun warms the water. This water becomes invisible vapor and rises into the sky. It's as if the water is "flying" lightly upwards!

The higher the vapor rises, the colder the air becomes. In the cold air up there, the invisible vapor turns back into tiny water droplets or small ice crystals. It's like when you breathe on a cold window and see little drops form! These tiny droplets join together and form clouds. The clouds are like little houses for water droplets in the sky.

The clouds fill up more and more with droplets. When they become so full that the droplets are heavy and can no longer stay in the air, they fall back down to Earth! If the air is warm, they fall as rain. If the air is very cold, they fall as snow or hail.

The water that falls to Earth (as rain or snow) collects. Some of it flows into rivers, lakes, and seas. Some of it goes into the ground to water plants or stays underground. All this water gathers again in its "homes," ready to start the journey all over again!

And then… the journey begins again! The sun warms the water, it becomes vapor, rises into the sky, forms clouds, falls back down, and gathers again. This repeats continuously, like an endless cycle! That's why it is called the water cycle! This way, we always have water on Earth to drink, water our plants, and take baths!

Figure 5. Virtual enviroment of water transformations.

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The control group studied the corresponding theory through a text describing water transformations in a playful way (Figure 6).

Worksheet

Name: ____________________________

Describe the journey of water in your own words.

....
....
....
....
....
....
....
....

Evaluation Episodes: 4

1. The Sun-Heater! (Evaporation)
2. The Cloud-Houses! (Condensation)
3. Rain and Snow – Back to Earth! (Precipitation)
4. Back to Water's Homes! (Collection / Runoff)

Figure 6. Worksheet on water transformation.

Both groups then completed the same assessment sheet within eight minutes (Figure 7). The assessment sheet used for this measurement included open-ended responses. To ensure the reliability of the measurement, the research team predetermined specific keywords and phrases, the presence of which in the students' answers awarded points.

The Water Cycle

Text for Group without VR

The water cycle is like a magical journey that water takes all the time on our Earth! Imagine water as a little traveler who never stops. Let's begin!

The journey usually starts from the sea, a lake, or a river. The strong and warm sun shines on the water. Just like when you heat water in a pot and steam rises (sometimes so fine you can hardly see it), the sun warms the water. This water becomes invisible vapor and rises into the sky. It's as if the water is "flying" lightly upwards!

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Figure 7. Assesment sheet on water transformation.

This process is ongoing, but the initial measurements indicate significantly greater discrepancies between the two groups of students, reaching 10.78%, as shown in Table III. This greater difference is attributed to the fact that the assessed skills pertain to the second level of Bloom's taxonomy. Moreover, the instructional material was not identical between the two teaching methods but

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contained the same information. However, VR is more interactive, as the user engages with the environment, providing a comparative advantage for this teaching method.

TABLE III.

Method of teaching	Mean rate of correct answers		
	Right after	*After 1 month*	*Difference through time*
Without VR	55,88%	not mesured yet	not mesured yet
With VR	66,66%	not mesured yet	not mesured yet
Difference through method	10,78%	not mesured yet	

We do not yet have results regarding the percentage of correct answers from the students one month after instruction, as was the case in the first measurement. This measurement will be conducted in the future.

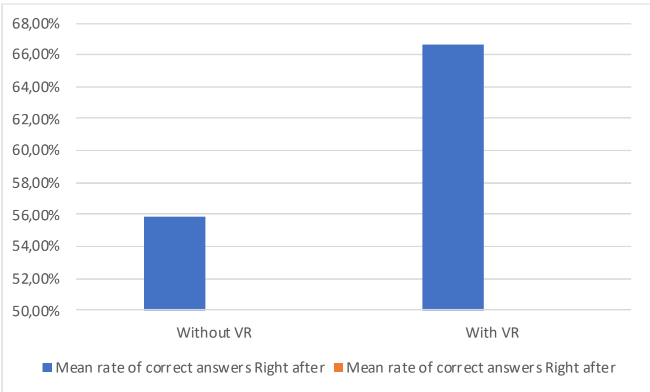

Figure 8. Results of teaching with VR and without VR.

4. Conclusions

The conclusions of this study are still in progress. Several challenges remain in this research. Measuring higher-order skills requires software capable of providing meaningful interactions (e.g., manipulating objects, solving puzzles, and interacting with characters) and a strong sense of presence, which is not always readily available. Both teachers and students require specialized knowledge and content creation skills to maximize VR's educational potential of VR.

Further measurements must also consider age, general student performance, and preferred learning styles. While the sample size used so far is significant, it is not yet sufficient for fully reliable conclusions to be drawn. Adjustments must also align with the Greek national curriculum.

I believe that this scientific field offers fertile ground for new interdisciplinary research.

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