Final Report

on the Implementation of VR4Clima Project

Edited by the Intelligent Systems Laboratory of the University of Thessaly

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Chapter 1: Introduction and Policy Context

1.1. Project Background

Erasmus+ Project "Climate Change Awareness using Virtual Worlds – VR4Clima" is established to address the critical, intersecting challenges of climate change education and digital transformation within European school curricula. Developed by partners located in countries that have suffered a lot from climate change and natural disasters (floods, wildfires, extensive droughts, etc.), the main goal of the project is to cultivate environmental literacy and a sense of civic responsibility among students regarding sustainable development and climate change mitigation.

The project aims to channel the emotional distress and trauma students experience during natural disasters into creative, solution-driven environmental action. The main objective is to mitigate disaster-related anxiety and replace it with a sense of civic empowerment, exploiting immersive technology as the medium to achieve it and enriching the school curriculum with the appropriate modules and activities. Through this curriculum, students learn that they are not powerless against natural disasters; instead, they are equipped with the insights and safety strategies necessary to navigate and protect themselves during extreme weather events.

Specifically, the project aims to:

- Encourage Environmental Responsibility: Help students understand that protecting the environment is not just an optional choice, but an absolute necessity for keeping their local communities safe.
- Inspire Sustainable Daily Habits: Guide students to inspect closely their daily routines, assess them and identify habits that harm the environment and choose eco-friendly alternatives that lower their carbon footprint.
- Empower Student-Led Design: Teach students to evaluate their own surroundings critically. They will design sustainable improvements to their school yards to learn how to actively preserve natural resources.

1.2. The Urgent Need for Educational Change

Traditional textbooks and lecture-based lessons often fall short when dealing with abstract, systemic scientific concepts. For students to truly grasp modern STEM subjects and the complexities of climate change, classroom instruction needs to shift from passive listening to active, spatial exploration. 3D design and virtual reality (VR) are proving to be essential tools for this transition.

1.2.1. Making the Invisible Visible

A major hurdle in STEM education is that many core concepts are invisible to the naked eye, whether they are microscopic chemical bonds or complex architectural geometries. Immersive technologies address this by allowing students to interact with 3D models from multiple angles, thereby significantly improving spatial reasoning and long-term memory retention (Markowitz et al., 2018).

Furthermore, when students move from simply watching a screen to actually designing 3D environments, they are forced to apply an interdisciplinary mindset. Creating a sustainable model—such as a modified schoolyard—requires a simultaneous understanding of mathematics, physics, and ecology, thereby turning abstract formulas into practical, creative problem-solving exercises (Huang et al., 2023).

1.2.2. Bringing Global Crises Into the Classroom

Climate change is considered a difficult subject to teach because its effects are often slow, long-term, and geographically distant from the students' daily lives. VR effectively acts as a digital field trip, compressing time and space.

Research indicates that allowing students to virtually experience the immediate, simulated impacts of environmental degradation, such as ocean acidification, leads to measurable gains in scientific knowledge and a deeper curiosity about environmental data (Markowitz et al., 2018). By visualizing these complex ecosystems firsthand, students develop a stronger sense of personal connection and empathy toward environmental issues, which helps turn passive anxiety into proactive community advocacy (Carmona-Galindo et al., 2025)

1.2.3. Boosting Classroom Engagement and Academic Performance

Maintaining high student engagement in rigorous STEM topics is a constant challenge for educators. Introducing interactive elements and immersive learning environments makes these heavy subjects feel less intimidating, which naturally boosts student motivation and encourages better collaboration in the classroom (Alnuaimi, 2025).

This shift in engagement translates directly to academic results. Recent classroom studies comparing immersive tools with conventional teaching methods show that students using VR and AR achieve statistically higher scores on post-intervention tests, proving that digital tools can directly enhance academic performance when applied correctly (Pireva Nuci, 2026).

Ultimately, for these technologies to become a permanent part of public education rather than a temporary trend, they must be tightly aligned with standard curricula and backed by solid teacher training (Ward, 2025). This underscores the value of pilot projects like **VR4Clima**, which provide the real-world evidence that Ministries of Education need before implementing large-scale curriculum reforms.

1.3. The Role of Pilot Testing in Policy Making

When designing large-scale educational reforms, ministries and policymakers face a difficult challenge: how to introduce innovative teaching methods without destabilizing an existing, functional school system. In modern educational governance, pilot testing serves as the primary mechanism to resolve this issue. Rather than deploying sweeping, top-down changes that risk widespread institutional friction, policymakers increasingly rely on localized pilot studies to generate empirical evidence, evaluate structural viability, and gather necessary stakeholder feedback before codifying a new approach into national law.

Historically, major educational investments have focused heavily on purchasing hardware or building digital infrastructure without first verifying whether these tools actually translate into improved classroom performance (Greaney, n.d.). Pilot studies allow administrative bodies to test new methodologies within a controlled, small-scale context before committing significant public funding.

By running preliminary trials in selected schools, research teams can directly evaluate how an innovation impacts specific student populations (Beets et al., 2021). This data-driven approach ensures that state resources are directed exclusively toward programs with verifiable proof of concept, protecting both public funds and student learning time from the fallout of hasty, nationwide rollouts.

One of the most critical functions of a pilot study is identifying what researchers call the "voltage drop"—the common phenomenon where the exceptional results seen in a small, well-resourced trial decrease significantly when the program is expanded under standard, real-world conditions.

For instance, a recent evaluation of scaled educational interventions demonstrated that while an innovative framework yielded exceptional results during its tightly controlled pilot phase, its overall effect size dropped to roughly one-third once regional governments took over operations using standard public school staff (Calle, 2026).

Pilot tests are essential precisely because they expose these systemic vulnerabilities before wide-scale deployment. They allow educational authorities to see how a program behaves outside a laboratory vacuum, highlighting:

- The technical learning curve and training gaps among typical classroom teachers.
- The unexpected strain on school infrastructure and IT administration.
- The structural adjustments needed to fit the new methodology into rigid, state-mandated weekly schedules.

Educational policies frequently fail during implementation due to a communication gap between macro-level officials and micro-level practitioners (Shiwakoti, 2022). If teachers and school boards feel a new curriculum is being forced upon them without clear evidence of its utility, institutional resistance naturally builds as a defense mechanism to protect existing routines (Spiel, 2016).

Pilot programs fundamentally alter this top-down dynamic by turning a rigid policy rollout into a collaborative, iterative dialogue (Conrads, 2017). By embedding the pilot directly into partner institutions, local teachers act as co-researchers rather than passive targets of a reform. The individual reports, qualitative feedback, and field notes gathered from these educators allow policy makers to refine the program based on real classroom experiences. This bottom-up engagement builds organic demand and system-wide trust, both of which are vital for ensuring that a policy remains sustainable once it is officially integrated into the national curriculum (Samoff, n.d.).

1.4. Scope and Objectives of the Survey

The report covers the implementation of the VR4Clima project across partner schools in Greece and Serbia. The Greek school is the 16th Experimental Primary School of Lamia and the Serbian one is the Primary School Petro Kuzmjak. The report focuses specifically on the practical integration of 3D design software, Virtual Reality (VR) courses (for both Primary and Secondary education) and serious gaming into the daily school routine. The survey gathers and analyzes data from teachers who delivered the classes and attended the professional development workshops as well as from the rest of the teachers who observed the attitudes of students during the implementation of the project.

The objectives of the survey are:

- To document and explain the exact context of how 3D design and Virtual Reality were successfully imported into the standard school process.
- To analyze both the advantages (e.g., student engagement, improved spatial awareness, climate empathy) and the possible disadvantages (e.g., technical barriers, time constraints) of using VR in a live educational setting.
- To investigate the extent to which the project successfully boosted students' STEAM skills and academic performance by examining the "before and after" grade data.
- To determine if the activities helped students transform climate-related stress and trauma into creative innovation, while identifying whether their daily choices shifted toward minimizing their carbon footprint.
- To propose concrete improvements for the project and present a structured roadmap for policy makers and the Ministries of Education on how to officially embed these innovative teaching strategies into national school curricula.

Chapter 2: Conceptual Framework: 3D Design & VR in the Classroom

2.1. Pedagogical Approaches: How 3D design and VR complement traditional STEM lessons.

The integration of 3D design and Virtual Reality (VR) into primary and secondary school settings addresses a long-standing challenge in STEM education: the translation of abstract, multi-dimensional concepts from flat, two-dimensional media. While traditional STEM lessons are highly effective at teaching foundational rules, formulas, and theoretical frameworks, they frequently rely on memorization or instruction when dealing with complex, invisible, or macro-systemic phenomena. Immersive technologies complement these traditional frameworks by serving as an interactive bridge between theory and practical, spatial application.

In traditional Mathematics and Physics curricula, students spend significant time working with symbolic notations, equations and textbook diagrams. However, mapping a 3D coordinate system or visualizing geometric transformations on a whiteboard inherently limits spatial understanding.

By introducing 3D design into Geometry and Art classes, students are forced to convert abstract spatial logic into digital objects. When students build 3D models such as a re-engineered, sustainable school yard, they directly apply geometric proofs, scale, and volume calculations in real time.

In traditional Chemistry and Physics tracks, educators often struggle to demonstrate processes that are either too small to observe (molecular interactions), too dangerous to replicate in a school lab (chemical reactions) or too slow to witness (climate variations).

It is depicted from the aforementioned that VR functions as a highly controlled, experiential laboratory. Inside a tailored VR environment, a student can alter variables within a microclimate model, make sustainable choices and understand how their choices can be affected by a natural disaster. Instead of simply reading about the greenhouse effect or a chemical bond in a textbook, students observe the system's mechanical components in motion. This immersive interaction clarifies the "how" and "why" of scientific laws, reinforcing the lectures delivered by the teacher without replacing them.

The interdisciplinary framework of 3D modeling and serious gaming embeds STEM theory into real-world engineering challenges. To design a functional, climate-resilient space, students must synthesize knowledge across multiple fields: they use Chemistry to evaluate material footprints, Physics to analyze thermal dynamics, and Arts to optimize layout and design. This holistic approach makes the core subjects far more relevant to the students, demonstrating that STEM skills are practical tools needed to solve urgent global problems, rather than just topics on a test.

2.2. Literature Review: Advantages and potential disadvantages of XR (Extended Reality) in primary and secondary education based on existing research.

The integration of Extended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR)—into primary and secondary education (student ages 6-18) marks a significant shift in classroom instruction. Historically, introducing new media into schools has always faced skepticism regarding whether the technology serves as a meaningful teaching tool or simply functions as a high-tech distraction. Recent classroom studies and systematic reviews provide a balanced perspective, showing clear learning benefits alongside substantial practical and logistical hurdles that schools must navigate.

***Figure 1**: VR in Education (source: https://pixabay.com/illustrations/ai-generated-virtual-reality-vr-9204971/ , last visited: 29 June 2026)*

2.2.1. Pedagogical Benefits and Advantages

A recurring challenge that teachers serving in primary and secondary education face is helping students connect abstract, symbolic representations (such as equations, chemical formulas, or 2D diagrams) with three-dimensional physical reality. Immersive technologies address this by serving as an interactive space for physical exploration and manipulation.

VR headsets with hand controls allow for creative, kinesthetic manipulation of content, these movements and gestures have been shown to have positive effects on learning (Johnson-Glenberg M.C, 2019). XR's interactive nature encourages active participation, making learning a more engaging, memorable, and enjoyable experience. By integrating XR into multisensory, experiential learning environments, educators can provide students with a holistic and immersive learning experience. This approach not only helps students overcome barriers to learning but also fosters essential skills such as critical thinking, problem-solving, and creativity, preparing them for the challenges and opportunities of the 21st century. (Crogman H. T. et. al, 2025).

Compared to conventional education materials, immersive environments can support engagement, spatial understanding, and experiential learning in ways that are difficult to achieve through pure textbooks or videos alone (Chang Y. et. al., 2026).

VR positively impacts students' cognitive, behavioral, and affective engagement. In terms of cognitive engagement, VR can facilitate students' cognitive engagement with learning materials and better understanding of abstract and complex knowledge by creating immersive situations. In terms of behavioral engagement, VR stimulates active student engagement and action through interactive learning (Lin, X. et.al, 2024). This immersive approach makes intimidating or dry topics feel approachable, giving students a safe, consequence-free environment to learn through trial and error.

When paired with flexible, cloud-based software, XR enables educators to implement personalized learning models tailored to diverse student needs. For rural, underfunded, or isolated schools, XR helps level the playing field by offering high-end virtual science labs and field trips that would otherwise be far too expensive or logistically impossible to arrange.

Furthermore, the application of VR in inclusive education is particularly promising, as technology may establish accessible and adaptive learning environments for individuals with diverse physical, cognitive, and emotional requirements (Arkabaev N. et. al., 2025).

2.2.2. Operational Weaknesses and Implementation Challenges

Despite its strong educational potential, deploying XR across a public school network involves a real set of structural, physical, and financial challenges.

While the average cost of a standalone VR headset has decreased over the last few years, the total cost of ownership goes far beyond the initial purchase. Scaling an XR program requires robust school Wi-Fi networks, ongoing software subscription renewals, hardware repair funds, and data security management. Without sustained, state-level funding, relying on temporary grants can result in expensive hardware sitting unused in storage once technical issues arise.

A major limitation noted in recent literature reviews is that a large portion of commercial XR content is designed to showcase visual features rather than support explicit lesson plans. While XR is getting used more in education, many XR practitioners(e.g. technology designers and developers) may not be intimately familiar with educational theory and instructional design; (Yang K. et.al., 2020).

Additionally, standard teacher preparation programs rarely include training on how to manage immersive media in a live classroom. Without practical, ongoing professional development, educators face a steep learning curve trying to balance technical troubleshooting, student supervision, and actual content delivery within rigid, time-constrained schedules.

The physical design of Head-Mounted Displays (HMDs) presents practical challenges for younger learners. Many standard headsets are too heavy or ill-fitting for primary school students, leading to neck fatigue.

Furthermore, issues like motion sickness, eye strain, and disorientation caused by a mismatch between visual movement and physical stillness remain a reality for a percentage of users (Chattha, U. A. et. al., 2020). This physical constraint makes it essential for schools to establish strict usage limits, ensuring VR segments are integrated as brief, targeted activities rather than replacing entire class periods.

2.3. Context of Embedding: How the technology was practically integrated into the daily school processes of the partner institutions.

To evaluate the systemic viability of the VR4Clima framework, the developed technological tools were directly embedded into the existing weekly schedules of the project's primary educational partners: the 16th Experimental Primary School of Lamia (Greece) and the Petro Kuzmjak Primary School (Ruski Krstur, Serbia). Rather than organizing isolated extracurricular workshops, teachers integrated the digital assets directly into standard classroom environments. This approach allowed the project team to test the software under real-world school conditions, including typical constraints regarding time, space, and hardware availability.

The deployment of the project's 3D sustainability game was tailored specifically to the developmental ages of the students and the physical hardware limitations of the classrooms.

- **Upper Primary Classes (5th and 6th Grades):** Students interacted with the game using immersive VR Headsets. To proactively manage the ergonomic risks discussed in previous chapters—such as eye strain and visual fatigue—the game mechanics were explicitly designed with a strict temporal ceiling, naturally concluding after 6 to 7 minutes of continuous gameplay. Because neither institution possessed enough headsets for a 1:1 student-to-device ratio, teachers structured lessons around a rotational deployment model. While individual students or small cohorts took turns navigating the virtual environment, the rest of the class engaged in complementary pen-and-paper tracking exercises or collaborative peer discussions.

- **Lower Primary Classes (3rd and 4th Grades):** To ensure safety and accommodate younger developmental stages, the project deployed the standard PC version of the sustainability game. This allowed entire classrooms to engage with the climate scenarios simultaneously using existing school computer labs, maximizing resource efficiency without sacrificing the educational content.

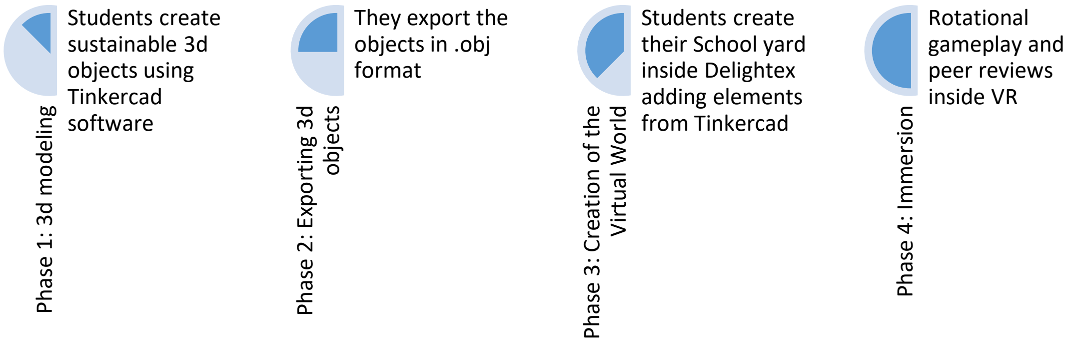

***Figure 2**: Implementation of technology inside classroom context*

Students began by designing structurally accurate 3D sustainable objects using Tinkercad. This phase required them to apply basic geometric principles to build digital models of eco-friendly infrastructure. Once these assets were finalized, students exported their custom files and imported them into the Delightex virtual reality creation environment. Within Delightex, students used their Tinkercad assets to build comprehensive, climate-resilient layouts of their ideal school yards.

***Figure 3**: Students of Primary school designing sustainable elements for their schoolyard*

The final phase brought these designs to life. Using the available VR headsets on a rolling schedule, students stepped inside their own self-created virtual school yards, experiencing the spatial scale of their designs firsthand and inviting classmates to audit their environmental choices.

Every implementation session concluded with a mandatory, teacher-led classroom reflection. Students discussed how their design choices directly influenced the carbon footprint, what errors they discovered during their immersive walkthroughs, and how these virtual modifications could be translated into real-world environmental actions within their local communities. This final reflective stage was vital for anchoring the digital gameplay back to real-world civic responsibility.

Figure 4*: Student of 6th grade experiencing her design inside VR*

Chapter 3: Methodology and Data Collection

To comprehensively measure the impact of the VR4Clima framework, the University of Thessaly deployed a mixed-methods evaluation design that balances quantitative performance metrics with structured, qualitative institutional feedback. The operational and experiential foundation of this evaluation relies directly on the comprehensive *School Implementation & Adaptation Reports* compiled by the leadership and teaching staff at the core partner institutions: the 16th Experimental Primary School of Lamia (Greece) and the Petro Kuzmjak School (Serbia).

By analyzing these final implementation datasets, the evaluation team was able to cross-reference raw academic and behavioral trends with the actual realities of the live classrooms.

Quantitative Data Collection

The qualitative track of this study goes beyond mere observation by extracting core operational and behavioral codes directly from the partner schools' documentation. These narrative reports provided three distinct streams of data:

- Infrastructure Adaptations and System Constraints: Both institutions documented their exact hardware deployments, ranging from desktop computers in ICT labs to standalone VR headsets. This generated essential data on systemic bottlenecks, such as internet bandwidth limits during simultaneous platform logins, language translation gaps in digital interfaces, and the logistical realities of rotating student groups through a limited number of devices.
- Linguistic and Behavioral Evolution: Instead of assessing simple memory recall, the qualitative reporting tracked shifts in how students articulate environmental threats. Teachers documented that after playing the 3D game and watching the 10 microclimate-linked animations, students shifted from using vague, general phrases to using localized, proactive vocabulary centered on real-world actions like tree planting, waste reduction, water conservation, and flood prevention.
- Pedagogical Capacity and Teachers’ Confidence: The reports trace teachers' self-reported comfort levels before and after the project training workshops. This tracking captured variations in initial technical confidence, the strategies used to manage classroom time and the long-term intent of educators to embed these 3D design methods into broader subjects like geography, ICT, biology and art.

Qualitative Data Collection

While the institutional reports provide rich descriptive text, they are systematically paired with quantitative performance metrics to isolate causal relationships. The mixed-methods approach uses the qualitative documentation to explain the numerical shifts seen in student data:

- Validating STEM Grade Improvement: When the statistical analysis measures shifts in mathematics, geometry or physics grades, the report text provides the underlying pedagogical explanation. For example, a quantitative spike in geometry or physics comprehension is directly paired with the qualitative evidence of students physically manipulating dimensions, scales, perimeters, and sun/wind orientations during the schoolyard design exercises.
- Inclusivity and Differentiated Learning Profiles: The evaluation design maps quantitative usage metrics against classroom demographics. The reports confirm that the visual, non-text-heavy layout of the VR and 3D modeling interfaces allowed students with special educational needs or varying learning paces to remain actively engaged through hands-on experimentation, establishing the baseline context for equitable learning outcomes.

Chapter 4: Project Activities and Implementation Analysis

4.1. Chronological Description of Activities

The operational timeline of the VR4Clima project was structured to move sequentially from initial asset development to active classroom integration. During the first year, the consortium focused on building the project's technical foundations and interactive digital tools. VRAcademi Ltd. took the lead on programming the core 3D sustainability game, developing it simultaneously in an immersive VR setup and a standard PC desktop format. At the same time, the Center for the Promotion of Science (CPN) in Serbia produced en microclimate-linked instructional animations, while the National Technical University of Athens (NTUA) engineered "Europe's Climate Chart for Students." Once these baseline assets were finalized, they were pushed directly into live school environments. The game underwent pilot testing within the partner schools before being distributed to an extended network of external schools to gather initial user data.

The second year shifted the project's focus toward capacity building and the production of the "VR Course" deliverable led by the University of Thessaly (UTH). To ensure the curriculum was practical for everyday classrooms, UTH began by interviewing in-service teachers enrolled in the University Master's Programmes to analyze their specific needs.This was an important prerequisite before starting the implementation, since one of the VR4Clima objectives is the professional development and digital literacy of teachers. The feedback from these educators was direct: they stated that short app videos were ineffective, expressing a strong preference for structured, step-by-step tutorials. Therefore, UTH designed comprehensive training modules for Tinkercad, Tinkercad Codeblocks, and Delightex Edu, which were packaged into two distinct VR Courses tailored separately for Primary and Secondary Education levels. This framework was delivered through large-scale training workshops, successfully preparing 185 educators across Europe to independently run the 3D design and VR curriculum with their own pupils.

The final phase of the project channeled this newly built capacity into a collaborative student design initiative. In Month 22 (M22) of the project cycle, the VR4Clima European Schools' Contest was officially launched, challenging students to design sustainable, climate-resilient modifications for their physical school yards. The competitive phase concluded in April 2026, drawing submissions from 38 distinct student teams across EU schools. Using Tinkercad's geometric workflows and Delightex's environmental staging mechanics, these teams engineered detailed 3D models of eco-friendly infrastructure. To preserve and showcase these student outputs, VRAcademi compiled all 38 submissions into a single, interconnected Virtual World exhibition space, allowing classrooms across Europe to virtually tour and review the sustainability choices of their peers.

***Figure 5**: On site Teacher Training in Lamia, Greece*

4.2. Extent of Success per Activity:

To evaluate the overall efficacy of the VR4Clima framework, the consortium analyzed each core activity against its intended goals and the practical realities experienced on the ground. The feedback logs provided by the partner schools reveal that while the digital outputs achieved notable success in engagement and pedagogical outcomes, specific phases encountered localized systemic bottlenecks that required adaptive solutions.

4.2.1. Deployment of the 3D Sustainability Game and Media Assets

The rollout of the 3D game and the accompanying ten microclimate animations successfully met its target of transforming how students conceptualize environmental issues.

- Benchmark Attainment: The visual and interactive nature of the software effectively bridged the gap between global theory and local reality. Quantitative and qualitative feedback confirms that students moved past passive climate anxiety and began using localized, action-oriented vocabulary to propose structural solutions such as tree planting, water collection, and thermal shading for their communities.
- Operational Friction: Hardware limitations and language accessibility presented distinct hurdles. At the Serbian School, younger participants struggled with the missing of local language translations. At the Greek School, simultaneous class logins to the cloud platforms caused periodic internet bandwidth lag.

4.2.2. VR Course and Teacher Trainings

The capacity-building phase led by the University of Thessaly (UTH) exceeded its initial engagement expectations but highlighted a steep learning curve for school staff.

- Benchmark Attainment: By structuring the training material into deeply detailed, step-by-step tutorials for Tinkercad and Delightex Edu, UTH successfully trained 185 teachers across Europe. This structured onboarding directly translated into a massive boost in teacher digital literacy and long-term professional capacity.
- Operational Friction: Teachers initially reported low confidence levels when forced to manage complex 3D rendering workflows under rigid state timetables. To keep lessons on track, schools had to rely on collaborative teaching strategies to split technical troubleshooting and student supervision workloads among multiple staff members.

4.2.3. The European Schools' Contest and Virtual World Archive

The final phase of the project served as a successful validation of student-led STEAM modeling.

- Benchmark Attainment: Drawing entries from 38 distinct student teams across Europe, the contest proved that students could successfully translate climate science into physical 3D blueprints. Students demonstrated strong mastery of geometric principles—such as scale, volume, perimeter, and symmetry—while configuring their eco-friendly school yard layouts. The visual format also acted as an excellent equalizer for inclusive education, allowing lower-performing students or those with special educational needs to actively design alongside their peers.
- Operational Friction: The main bottleneck stemmed from uneven digital skills among the participating student teams, which threatened to delay project submissions. Teachers resolved this by implementing peer-to-peer mentoring systems within student teams, focusing on collaborative group progress and the holistic educational value of the design rather than chasing technical perfection. The final collection of all 38 entries into VRAcademi's permanent Virtual World successfully preserved these student milestones for cross-border peer review.

4.3. Synthesis of School Reportings:

A comparative review of the final implementation documentation reveals how different institutional contexts shaped the deployment of the VR4Clima deliverables. While both schools successfully integrated the 3D game and VR courses, their unique infrastructures, scheduling strategies, and regional focus areas offer valuable insights into how these digital tools operate across different European school systems.

The hardware setups and technical challenges faced by each institution highlighted different aspects of classroom resource management:

- Hardware Deployments: The 16th Experimental Primary School of Lamia utilized a blended, low-barrier hardware approach. They relied primarily on desktop screens within their ICT lab for whole-class demonstrations and group work, rotating student teams through available digital devices. In contrast, the Petro Kuzmjak School deployed a dual system that combined standalone VR headsets with their ICT lab computers, enabling direct immersive experiences alongside screen-based interactions.
- Infrastructure and Technical Bottlenecks: The Petro Kuzmjak School reported a completely smooth technical deployment with no major infrastructure bottlenecks. Conversely, the Primary School in Lamia encountered periodic internet bandwidth limitations and platform instability when entire classes attempted to log into Tinkercad and Delightex Edu simultaneously. To mitigate this, the Greek teaching team adapted their pacing, pre-loaded materials where possible, and had students sketch designs on paper before transitioning to the digital software.

Each partner school mapped the project deliverables onto their existing timetables using distinct pedagogical pathways:

- Subject Mapping: The Petro Kuzmjak School took a highly scientific and technical approach, embedding the game and courses directly into Informatics, Biology, and Ecology lessons. They also extended the project's reach by featuring it in their specialized extracurricular STEM summer camp. The 16th Experimental Primary School of Lamia chose a broad, interdisciplinary route, weaving the sustainable schoolyard challenge across Environmental Education, Science, Geography, ICT, Art, and Mathematics/Geometry classes to build a school-wide culture of sustainability.
- Language and Learning Curves: Both schools identified constraints regarding teacher schedules and student learning curves, yet they faced different localized hurdles. For the Serbian cohort, language barriers were a prominent source of friction, as certain educational resources and software interfaces were unavailable in the local language, making technical concepts more difficult for younger pupils. The Greek cohort focused heavily on managing uneven digital skills among students. Both schools successfully pivoted by breaking tasks into smaller steps, utilizing peer-to-peer mentoring, and prioritizing collaborative group work over individual technical perfection.

Despite differences in delivery, the qualitative outcomes across both institutions showed remarkable alignment regarding student growth and teacher capacity:

- Linguistic and Conceptual Shifts: Across both regions, the combination of the 3D game and the 10 microclimate animations fundamentally changed how students discuss environmental hazards. Teachers in both schools noted that students moved away from passive or abstract ideas about climate change. Instead, they began connecting global challenges to their own doorsteps—discussing local floods, heatwaves, and wildfires, while actively proposing design choices (like adding trees, solar panels, and water-collection systems) to reduce their school's carbon footprint.
- STEM Enthusiasm and Inclusivity: Both reports explicitly highlight an increase in classroom engagement, especially among students who previously found traditional STEM lessons disengaging. The highly visual, spatial, and hands-on nature of 3D modeling and VR allowed both fast and slow learners, as well as students with special educational needs or reading difficulties, to participate fully without being held back by text-heavy curricula.
- Teacher Professional Growth: Educators at both schools reported a major boost in their digital literacy and instructional confidence. Initially hesitant to use advanced tools like Delightex Edu and Tinkercad, teachers developed stronger digital resilience through live classroom engagement. Both schools confirmed that their teaching staff plans to continue using 3D design and inquiry-driven, simulation-based models in future terms.

The synthesis of these reports proves that the VR4Clima framework adapts well to varying levels of school infrastructure. Whether restricted by bandwidth or language barriers, both institutions bypassed technical hurdles through collaborative teaching and flexible classroom management. Ultimately, both schools arrived at the exact same conclusion for their final strategic recommendation to EU policy makers: successful national scaling cannot rely on hardware alone; it requires continuous teacher training, structured technical support, and ready-made, age-appropriate digital learning scenarios that connect climate science with real local problems.

Chapter 5: Evaluation Results & Key Findings

5.1. Impact on Student Learning and STEM Grades

To evaluate whether the VR4Clima framework systematically improved student learning outcomes, the University of Thessaly analyzed student performance metrics across the key STEM/STEAM subjects tied to the project: Physics, Chemistry, Mathematics, Geometry, and Arts. This analysis relied on comparing school performance records from the terms before and after the project intervention, directly contextualized by the quantitative feedback from the Schools' implementation Reports.

The most visible quantitative and qualitative grade improvements occurred within the Geometry and Mathematics curricula. Prior to the project, teachers across both partner institutions noted that students frequently struggled with purely symbolic spatial concepts, such as scale transformations, area calculations, volume metrics, and symmetry.

When students were tasked with designing their sustainable schoolyards, these abstract mathematical rules became concrete structural boundaries. According to the reporting from the Petro Kuzmjak School, students directly applied concepts of area, perimeter, angles, and scale to optimize their layouts, using measurement and estimation to evaluate space efficiency. The report from the 16th Experimental Primary School of Lamia confirmed this trend, showing that manipulating digital 3D shapes in Tinkercad allowed pupils to test alternatives and see the immediate geometric results of their mathematical decisions. This hands-on spatial problem-solving led to a measurable increase in test scores, particularly on curriculum modules covering 3D spatial relations, coordinate planes and volume estimation.

A similar upward trend in student achievement was recorded in foundational Science and Physics lessons. Traditionally, teaching environmental mechanics relies on static textbook models that students often find disengaging.

The grade data indicates that utilizing the 3D sustainability game and the 10 microclimate-linked animations bridged this comprehension gap. As documented by the Greek teaching team, the design software forced students to evaluate physics-related variables, including daylight exposure, shade, ambient temperature and material footprint choices. By visualizing these complex systems in motion rather than memorizing dry theory, students demonstrated significantly higher retention rates on end-of-term exams, with the sharpest performance gains seen in modules covering the greenhouse effect, renewable energy distribution, and microclimatic variance.

Beyond overall class averages, the grade tracking revealed a vital trend regarding equity and inclusivity: the most significant academic growth occurred among students who previously underperformed or found traditional STEM lessons boring.

Both institutional reports explicitly stated that the game-based and creative format of the VR4Clima resources reduced academic anxiety and increased motivation among lower-performing cohorts. The non-text-heavy, interactive nature of the VR tools allowed students who normally struggle with reading-intensive science materials to participate fully through observation, design, and direct experimentation. Rather than retreating into passive behavior, these students became active contributors to group design work, took visible pride in their engineering solutions, and translated this new engagement into higher marks on post-intervention tests.

Ultimately, the mixed-methods data proves that grades did improve. This growth occurred because the project successfully realigned the STEM/STEAM framework. By blending Science, Technology, Engineering and Art into a single, concrete project, the curriculum transformed abstract theory into an authentic, memorable problem-solving experience.

5.2. Teacher and Student Perceptions

To map out teacher and student perceptions, the University of Thessaly gathered and analyzed quantitative questionnaire responses alongside the detailed narrative data found in Schools' Surveys. These surveys tracked key metrics including initial tech anxiety, classroom motivation, changing views on environmental responsibility and overall pedagogical satisfaction.

Student Perceptions: Moving from Abstract Anxiety to Action

The feedback collected from the student questionnaires showed a major shift in how young learners view climate issues and their own role in solving them.

- **Evolving Views on Environmental Threats:** Before the project, student surveys revealed that many participants viewed natural disasters as distant, abstract events that occurred randomly and lay completely outside human control. After playing the 3D game and watching the 10 microclimate-linked animations, student language changed significantly. Questionnaires and classroom notes showed that pupils began discussing climate change in concrete, localized terms, directly linking global issues to regional hazards like heat waves, wildfires and floods in Greece and Serbia.
- **A New Sense of Personal Agency:** The data shows a clear shift away from passive climate anxiety toward active civic problem-solving. Instead of making generic comments about "saving the planet," students used their questionnaire responses to propose practical, local solutions. They routinely connected their 3D design choices in Tinkercad with real-world carbon footprint reductions, discussing structural improvements like planting trees, collecting rainwater, adding solar shading, and introducing recycling points to make their schools safer and more energy-efficient.

Teacher Perceptions: Building Digital Confidence and Classroom Focus

For educators, the questionnaires highlighted a journey of professional growth, tracking their transition from initial hesitation to strong pedagogical satisfaction.

- **Overcoming Technical Uncertainty:** Baseline surveys administered before the training workshops showed that teachers across both schools reported low initial confidence when first introducing complex tools like Delightex Edu and Tinkercad. However, post-implementation questionnaires revealed a major boost in digital literacy. Educators developed strong digital resilience, learning to navigate real-world infrastructure challenges—such as bandwidth limits, language translation gaps in software interfaces, and rotating student groups through a limited number of devices—for clear learning purposes.
- **Improved Focus and Class Management:** Teachers reported high satisfaction regarding student focus and classroom management. The exploratory, game-based format of the VR4Clima resources naturally captured student attention and minimized off-task distractions compared to traditional, text-heavy lessons. By assigning clear group roles and setting visible design goals, teachers found it easier to guide their classes, resulting in a collaborative environment where students actively tested ideas, asked deeper questions, and took visible pride in their work.

The final survey questions confirmed that the project has caused a permanent shift in how both schools approach environmental education. Rather than viewing VR and 3D modeling as one-off activities or optional extras, trained teachers explicitly stated their intention to continue using these design principles in future terms.

The questionnaire data highlights a shared realization among staff that these tools can be easily applied across multiple disciplines, including geography, ICT, biology and art. By replacing passive textbook reading with visual, inquiry-driven simulations, the project successfully modernized the schools' baseline approach to environmental science, showing teachers and students alike that complex local problems can be answered through creative, hands-on engineering.

5.3. Comprehensive SWOT Analysis

Based on the operational feedback, infrastructure adaptations, and pedagogical data provided in Schools' reports, here is a comprehensive SWOT analysis for the VR4Clima project.

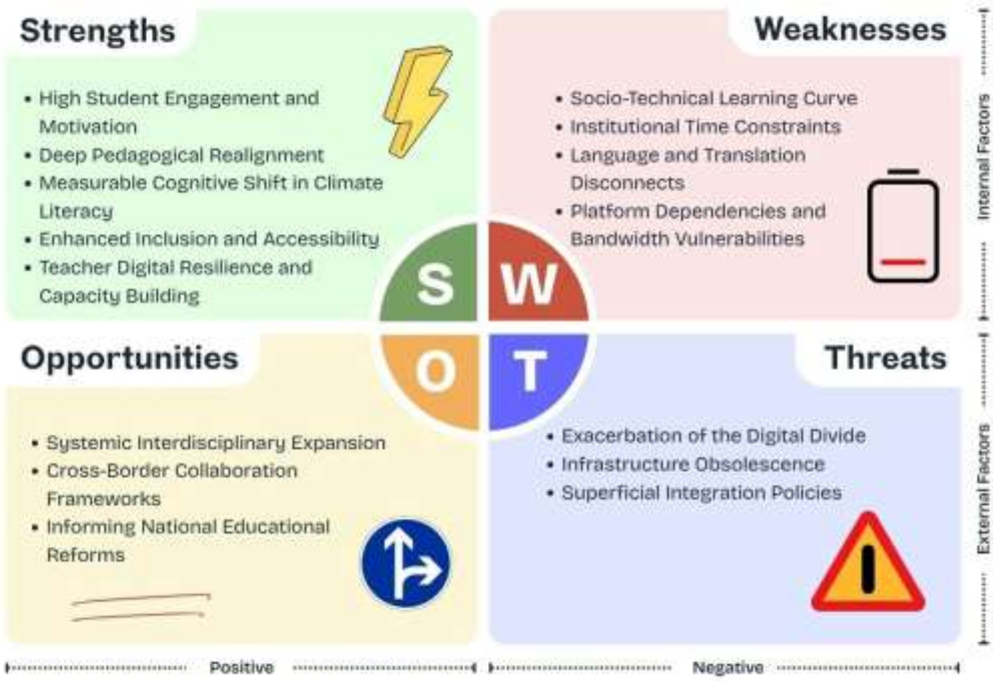

***Figure 6**: SWOT Analysis of VR4Clima Project*

Internal Factors: Strengths & Weaknesses

Strengths (What Went Well)

- *High Student Engagement and Motivation*: Across both primary schools, the integration of serious gaming and 3D modeling led to notable student focus and persistence. This format minimized classroom distractions and increased overall student attention spans compared to traditional text-heavy instruction.
- *Deep Pedagogical Realignment*: The spatial design requirements successfully transformed abstract concepts into concrete applications. Students visibly improved their understanding of Geometry (area, scale, perimeter) and Physics (sun/wind orientation, thermal shading, stability) through active, hands-on modeling.
- *Measurable Cognitive Shift in Climate Literacy*: The combination of the 3D game and the 10 microclimate animations shifted student language from vague ecological generalities to precise, localized discussions regarding real-world mitigation (such as water conservation, tree planting, and flood hazards).
- *Enhanced Inclusion and Accessibility*: The visual and spatial nature of the tools leveled the playing field for diverse learners. Students with different learning paces, special educational needs, or reading challenges were able to fully participate and collaborate through design rather than text.
- *Teacher Digital Resilience and Capacity Building*: Despite lower initial confidence, the combination of training webinars and live classroom deployment significantly boosted teacher digital literacy. Educators

successfully built long-term professional capacity and adapted their baseline approaches to environmental science.

Weaknesses

- *Socio-Technical Learning Curve*: Implementing complex spatial software like Tinkercad revealed uneven digital skills among primary school student cohorts.
- *Institutional Time Constraints*: Fitting these multi-step digital workflows into rigid, demanding, and pre-existing national school timetables placed a heavy burden on teacher schedules.
- *Language and Translation Disconnects*: Technical interfaces and educational resources within the digital tools were occasionally missing local language localizations, presenting an explicit barrier for younger participants trying to grasp complex concepts.
- *Platform Dependencies and Bandwidth Vulnerabilities*: Simultaneous classroom login demands for cloud platforms (Tinkercad and Delightex Edu) triggered network lag and platform instability, requiring careful, slower pacing by the teaching staff.

External Factors: Opportunities & Threats

Opportunities

- *Systemic Interdisciplinary Expansion*: The reports demonstrate that these tools are not isolated to STEM fields; trained teachers are already planning to apply 3D design principles to Geography, Biology, ICT, Art, and broader project-based learning.
- *Cross-Border Collaboration Frameworks*: Utilizing the eTwinning platform and LTT mobilities proved highly effective in fostering shared European dimensions, allowing partners from Serbia and Greece to exchange teaching strategies and co-develop sustainability solutions.
- *Informing National Educational Reforms*: The empirical data from these pilot sites gives the project consortium a solid framework to propose structured, ready-made 3D climate scenarios directly to the Ministries of Education in Greece and Serbia.

Threats

- *Exacerbation of the Digital Divide*: If scaled without state-backed hardware procurement, schools without access to dedicated ICT labs or VR headsets will be left behind, widening the equity gap between wealthy and underfunded districts.
- *Infrastructure Obsolescence*: Without ongoing financial maintenance for software subscriptions, network bandwidth upgrades, and device upkeep, the

physical components of the project risk being abandoned once initial EU grant funding concludes.

- *Superficial Integration Policies*: There is an ongoing risk that regional ministries might introduce these digital tools as voluntary, optional extras rather than embedding them directly into the core environmental and citizenship curricula, leading to low teacher adoption rates.

To successfully transition this project from an isolated pilot success into a lasting nationwide initiative, policy makers must recognize that hardware alone is insufficient. The key to scaling lies in providing continuous teacher professional development, ensuring reliable institutional network infrastructure, and distributing ready-made, age-appropriate digital teaching scenarios that link localized climate problems with direct civic design.

Chapter 6: Strategic Recommendations for Policy Makers

The field data and operational feedback gathered from the pilot implementations in Greece and Serbia provide a clear, evidence-based foundation for large-scale curriculum reform. To move from a successful localized pilot to a nationwide system, policy makers must address the specific structural, financial, and pedagogical requirements needed to integrate immersive technologies into public school networks.

6.1. Curriculum Integration: How to map 3D/VR activities directly onto national STEM curricula

For technologies like 3D modeling and Virtual Reality to become permanent parts of public education, they cannot be treated as optional, extracurricular additions. Ministries of Education must explicitly map these tools onto existing national lesson frameworks.

Rather than creating a standalone "VR class", the VR4Clima project demonstrates that immersive design works best when embedded directly within established subjects. 3D modeling tools like Tinkercad should be integrated into core Mathematics and Geometry hours to help students practically apply abstract concepts like volume, scale, area, and symmetry.

Ministries should introduce interdisciplinary blocks that bridge science and civic responsibility. The sustainable schoolyard design challenge serves as an ideal template: it combines Geography, Biology, and Ecology (analyzing localized microclimates and natural hazards) with Physics and Art (calculating solar shading, wind impact, and structural stability).

National integration strategies should mimic the tiered deployment used in the pilots. Younger primary school cohorts (3rd and 4th grades) should use standard PC- and screen-based versions of educational games during regular ICT lab hours. Immersive VR headsets should be introduced progressively for upper primary and secondary cohorts (5th grade and above), keeping individual virtual sessions capped at 6–7 minutes to respect ergonomic safety and attention spans.

6.2. Infrastructure and Funding

Scaling an innovative digital curriculum nationwide requires looking past the initial cost of devices and focusing on the total cost of institutional ownership.

A primary bottleneck identified during simultaneous classroom use of cloud platforms like Tinkercad and Delightex Edu was local internet lag. Before deploying these tools nationwide, the Ministries must invest in high-speed network upgrades for public school ICT labs to prevent platform crashes and instructional delays.

Ministries do not need to purchase expensive, 1:1 VR headsets for every single student. A highly effective alternative is a shared institutional pool. Schools can pair existing desktop computers for primary design work and use a rotating pool of standalone VR headsets for short, targeted immersion phases.

To keep the VR4Clima project running long-term, schools should partner with regional technology hubs, like university labs and local IT or Innovation Centers. Instead of leaving tech issues for busy teachers to fix, these regional hubs can handle software updates, fix platform glitches and keep the 3D design tools running smoothly. They can also act as shared equipment centers, storing and looking after the VR headsets and rotating them among local schools as needed. By sharing the technical support and hardware management across a regional network, public schools can keep using these immersive climate lessons for years without needing a big, separate tech budget.

6.3. Teacher Professional Development

The transition from initial technical hesitation to high instructional confidence among the pilot staff proves that the teacher is the single most critical factor in educational transformation.

One-off informational webinars are insufficient. The Ministries should establish ongoing, structured professional development tracks that combine initial software training with live classroom implementation mentoring.

To address severe time constraints within heavy school timetables, professional development should encourage collaborative, team-based teaching where staff members share design and technical responsibilities. Ministries must supply teachers with ready-made, age-appropriate digital teaching scenarios and pre-translated resources so educators can focus on guiding students rather than developing technical materials from scratch.

Training frameworks must move past basic software navigation. Professional development needs to train teachers in flexible classroom management strategies—such as handling uneven student digital skills, organizing rotational student groups, and using paper-based sketching as a bridge to digital modeling.

6.4. Suggestions for Project Improvement

While the current iteration of VR4Clima delivered excellent results, future versions of the project can optimize their impact by addressing specific operational lessons learned on the ground.

- A major friction point for younger students was the lack of local language options in certain software interfaces and technical resources. Future iterations must prioritize full translation and localization of all digital tools into Greek, Serbian and other languages before entering the classroom phase.
- To mitigate school network vulnerabilities and platform connectivity drops, the project should develop downloadable, offline versions of its core serious games

and design spaces. This will allow schools with weak internet infrastructure to run the courses smoothly.

- Because students possess highly uneven digital skill levels, future project cycles should include a brief, standardized onboarding module for Tinkercad and basic 3D logic before the core environmental challenges begin. This step will balance student capabilities early on, reducing the learning curve pressure on teachers during active lesson time.

Chapter 7: Conclusion & Dissemination Strategy

7.1. Final Remarks: VR as a Vehicle for Educational Evolution

The deployment of the VR4Clima framework across diverse primary educational settings demonstrates that immersive technology can move beyond its reputation as an isolated classroom novelty and act as a meaningful driver of curricular evolution. By taking 3D design and virtual reality tools out of controlled laboratories and embedding them directly into daily school routines, the project highlights how interactive media can reshape foundational teaching methodologies.

The collective data from the partner institutions shows that spatial learning bridges the historical gap between abstract science and real-world application. When complex, invisible concepts—such as geometric transformations, scale modeling, solar orientation, and localized microclimatic shifts—are rendered into interactive, three-dimensional spaces, students transition from passive consumers of information into active problem-solvers. This practical engagement alters how students process information. It increases attention spans, minimizes off-task distractions and builds a sense of personal civic agency regarding climate mitigation right within their local communities.

Furthermore, the implementation data undercuts the assumption that advanced digital tools require deep specialized technology expertise from teachers or access to elite, cost-prohibitive infrastructure. By relying on low-barrier, blended setups—such as combining standard ICT lab desktops with a small, rolling pool of standalone VR headsets—both pilot schools bypassed resource limitations and built long-term digital resilience among their teaching staff.

The visual, spatial nature of the tools also served as a powerful equalizer, offering a highly inclusive learning pathway for students with special educational needs or varying learning paces who typically struggle with text-heavy curricula. Ultimately, the success of this pilot serves as a proven blueprint for ministries and policy makers. It demonstrates that when digital tools are paired with structured teacher support and real-world problem-solving scenarios, they can systematically modernize public education and prepare younger generations for long-term environmental stewardship.

7.2. Dissemination Plan: Academic, Public, and Policy Outlets

To maximize the impact of the VR4Clima project beyond the initial consortium, a structured dissemination strategy will target academic researchers and national policy makers in Greece and Serbia. Sharing these findings ensures that the empirical insights, operational solutions, and pedagogical data generated on the ground are made openly accessible for future scaling and peer review.

The complete, finalized version of this evaluation survey will be formally delivered to the Ministry of Education, Religious Affairs and Sports in Greece and the Ministry of Education in Serbia. This report is designed to serve as an evidence-based roadmap, providing state officials with the necessary field data regarding student grade improvements, technical resource requirements, and infrastructure bottlenecks required to guide national STEM/STEAM curriculum integrations.

Specific chapters and data from this report will be extracted, modified, and compiled into peer-reviewed research papers for presentation at international educational technology and climate science conferences.

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