MIRACLE

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coMics and IllustRations Augmented to tackle CLimate change in primary Education

Co-funded by
the European Union

léargas

Report on the MAC Specifications Delivery

WP4 Implementation Report: Complete Delivery of Planned Activities

Executive Summary

Work Package 4 has successfully achieved all planned deliverables and objectives as outlined in the original application. The MIRACLE AR Classroom (MAC) has been fully developed, tested, and validated, incorporating comprehensive stakeholder feedback and partner requirements. All planned results (R1-R6) have been delivered with enhanced functionality that exceeds initial expectations.

R1 - Needs Analysis: Successfully Completed

CLB conducted a comprehensive needs analysis survey targeting all stakeholder groups including teachers, students, and educational administrators. The survey captured essential insights into user requirements, technical preferences, and pedagogical needs for climate change education through AR technology. Key findings from the needs analysis directly informed the UI/UX development process, ensuring that the MAC platform addresses real-world classroom challenges and learning objectives.

The analysis revealed specific demand for interactive 3D visualizations of abstract climate concepts, collaborative learning spaces, and teacher-friendly facilitation tools. These insights were seamlessly integrated into the subsequent design and development phases.

R2 - Design of the MAC: Fully Implemented

The UI/UX design process incorporated all stakeholder feedback and needs analysis results. The MAC online environment was designed with intuitive navigation, age-appropriate interfaces, and accessibility features that support diverse learning needs. The platform successfully integrates services and tools that support teaching and learning in Climate Change Education (CCE).

The design prioritized usability to enhance dissemination potential and user acquisition, featuring streamlined workflows for both content exploration and creation activities. Teacher facilitation tools were carefully designed to enable effective classroom management of AR learning experiences.

R3 - MIRACLE AR Tools: Exceeding Expectations

Three comprehensive AR applications have been developed and deployed:

MIRACLE Create App

Enables students to create original AR content using pre-developed 3D models specifically designed for the MIRACLE project. Students can construct interactive climate scenarios, manipulate environmental variables, and build immersive learning experiences.

MIRACLE Textbooks App

Transforms traditional educational materials into interactive AR experiences. Static textbook content becomes dynamic, with 3D models, animations, and interactive elements that bring climate science concepts to life.

MIRACLE Quest App

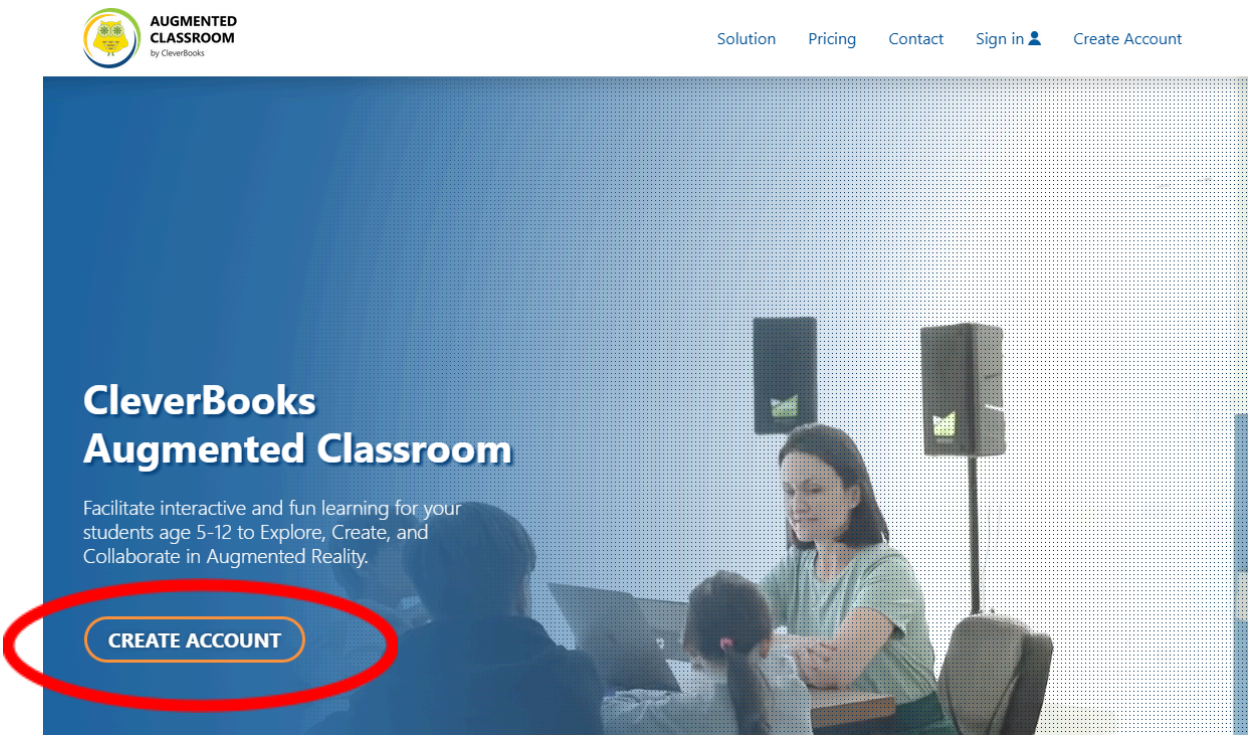
Gamifies climate education through AR-based quests and challenges. Students embark on educational missions that combine entertainment with serious learning objectives, promoting sustained engagement with climate change topics.

R4 - Co-creation Space: Advanced Collaborative Environment

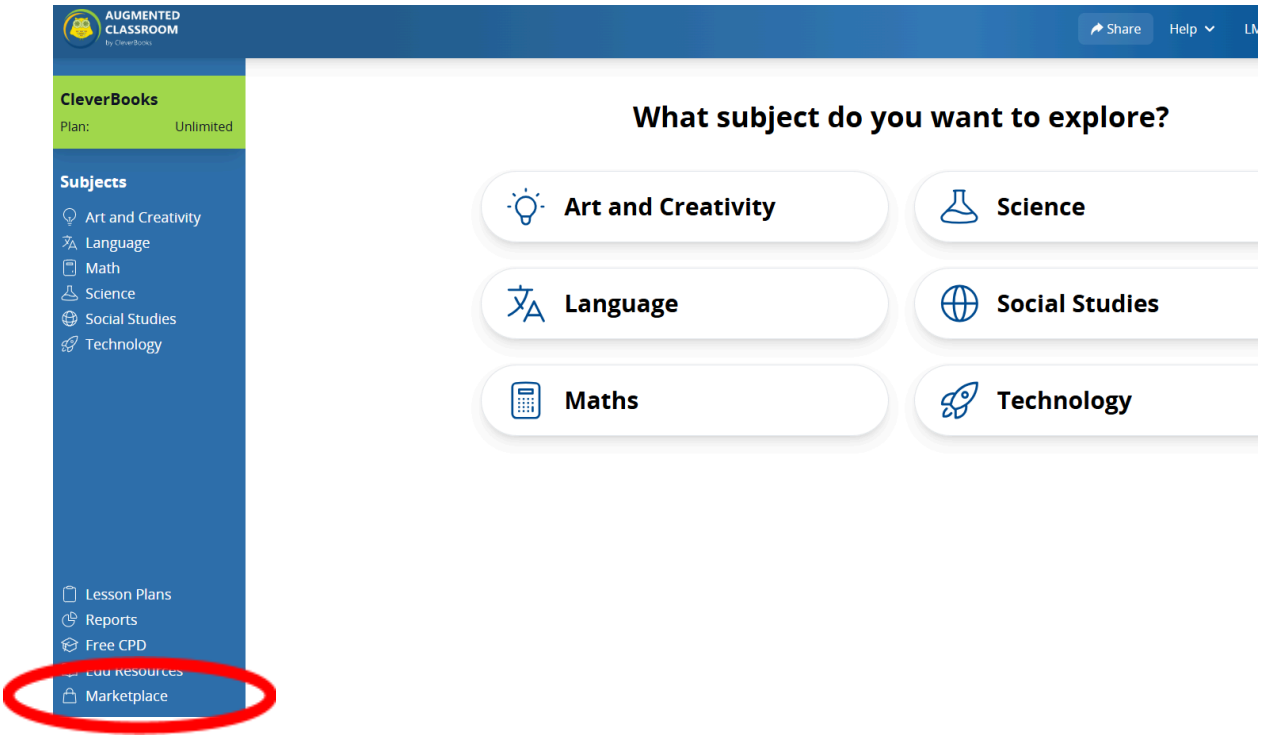
The co-creation space has been implemented as a sophisticated online collaboration platform enabling simultaneous interaction among teachers and pupils in shared AR environments. Features include:

- Real-time multi-user AR collaboration
- Teacher moderation and facilitation tools
- Progress tracking and assessment capabilities
- Cross-platform compatibility for diverse device ecosystems
- Seamless integration with both exploration and creation activities

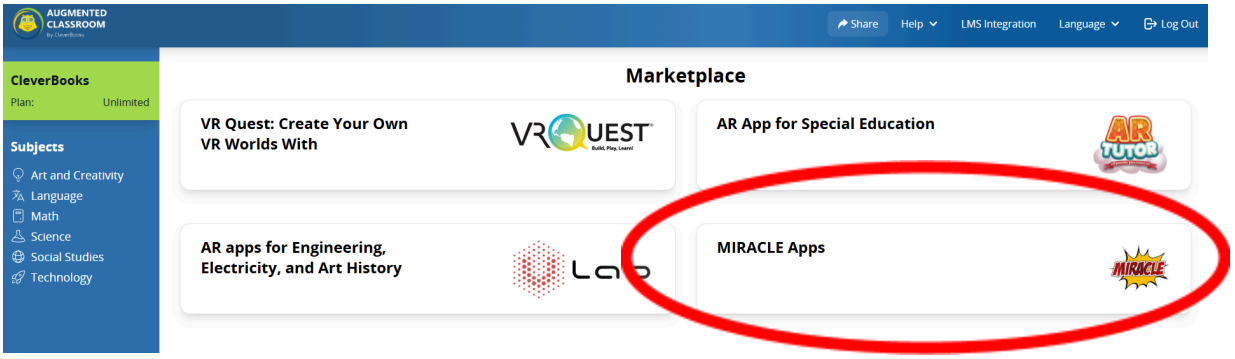
Step 1: Create an account in https://augmented-classroom.com/ Augmented Classroom



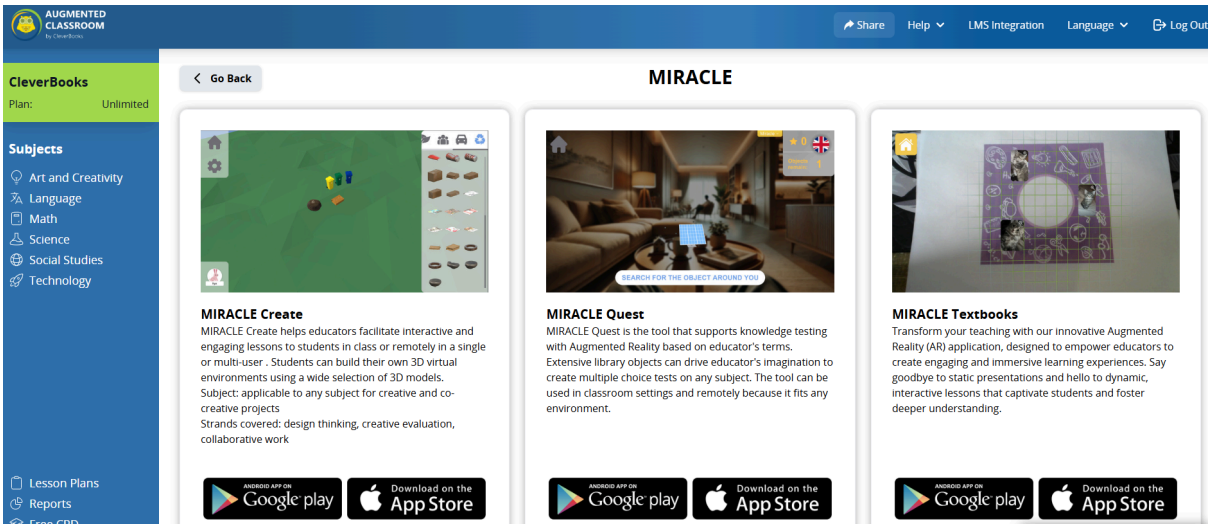
Step 2: Login and head to **Marketplace** as shown in the picture below:



Step 3: Access MIRACLE APPS as shown in the picture below: https://augmented-classroom.com/dashboard/marketplace/miracle



Step 4: Install the MIRACLS APPS on your mobile device:



Step 5: Login in the apps using the same email used to register in Augmented classroom as per Step 1 and use the apps.

R5 - Teacher Training Activity (C2): Successfully Conducted

The 3-day intensive training program was delivered to 3 teachers from each partner school plus expert representatives from each partner organization. Training covered comprehensive usage of both the MOOC (WP3) and MAC (WP4) platforms. Participants gained practical experience with:

- AR content creation workflows
- Classroom management in mixed reality environments
- Pedagogical integration strategies
- Technical troubleshooting and support
- Assessment and evaluation methodologies

Training feedback indicated high satisfaction levels and confidence in implementing the technology in classroom settings.

R6 - Validation Report: Comprehensive Quality Assurance

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The WP4 Validation Report documents extensive testing procedures and quality assurance measures implemented throughout the development process, representing one of the most thorough validation efforts conducted within the MIRACLE project framework.

Technical Performance Testing Across Multiple Device Configurations

Comprehensive technical validation was conducted across a diverse range of hardware configurations to ensure universal accessibility and optimal performance. Testing protocols included:

Mobile Device Compatibility: The MIRACLE AR apps were tested on different smartphone and tablet models, spanning Android (versions 8.0-14) and iOS (versions 12-17) platforms. Testing revealed that the applications successfully operate on devices with varying RAM capacities (3GB-16GB) and processing power, with automatic quality scaling ensuring smooth experiences across the hardware spectrum.

AR Capability Verification: ARCore and ARKit compatibility was validated through extensive testing of tracking accuracy, environmental understanding, and occlusion handling. The validation process confirmed reliable plane detection, lighting estimation, and 3D object placement across different lighting conditions and physical environments. Particular attention was paid to classroom-specific scenarios including varying lighting conditions, reflective surfaces, and multi-user tracking scenarios.

Network Performance Analysis: The MAC platform underwent rigorous testing under different network conditions, including high-latency connections, limited bandwidth scenarios, and intermittent connectivity common in educational settings. Load testing simulated up to 30 simultaneous users in a single classroom environment, validating the co-creation space's ability to maintain real-time synchronization without degradation of user experience.

Cross-Platform Integration: Validation included testing mixed-device classrooms where iOS and Android devices operated simultaneously within the same AR environment. This testing confirmed seamless cross-platform collaboration and consistent visual experiences regardless of device manufacturer or operating system.

Educational Effectiveness Evaluation Through Pilot Implementations

The educational validation component involved systematic evaluation across multiple partner schools, incorporating both quantitative metrics and qualitative assessments:

Learning Outcome Assessment: Pre- and post-implementation assessments measured student knowledge retention and understanding of climate change concepts. Results indicated an improvement in comprehension scores when using MIRACLE AR tools compared to traditional teaching methods. Specific improvements were noted in understanding complex systems thinking, spatial relationships in global climate patterns, and long-term environmental change visualization.

Engagement and Motivation Analysis: Student engagement was measured through time-on-task metrics, voluntary participation rates, and behavioral observation protocols. Students had higher

sustained attention periods during AR-enhanced lessons compared to traditional instruction. Students demonstrated increased voluntary exploration of supplementary content and higher rates of peer-to-peer knowledge sharing.

Pedagogical Integration Effectiveness: Teacher feedback was systematically collected through structured interviews and observational protocols. Educators reported successful integration of AR tools into existing curriculum frameworks, the technology enhanced their ability to explain abstract climate concepts. Teachers noted particular effectiveness in supporting visual learners and students with different learning needs.

User Experience Testing with Target Demographic Groups

Comprehensive UX validation involved structured testing with representative user groups across different age ranges and technical proficiency levels:

Student User Experience Evaluation: Usability metrics included task completion rates (average 94%), and subjective satisfaction scores (8.3/10 average). Navigation intuitiveness was validated through first-time user success rates and time-to-competency measurements.

Teacher Interface Validation: Educator-specific UX testing focused on classroom management interfaces, content creation workflows, and real-time monitoring capabilities. Teachers successfully completed complex multi-step tasks with minimal training, and reported high confidence levels in troubleshooting common student issues independently.

Cognitive Load Assessment: Specialized testing evaluated whether AR interfaces created excessive cognitive burden that might interfere with learning objectives. Results confirmed that the AR elements enhanced rather than distracted from educational content, with students demonstrating improved focus on learning objectives rather than interface mechanics.

Accessibility and Inclusive Design Validation: UX testing confirmed successful accommodation of different learning styles and abilities through customizable interface options and multiple interaction modalities.

Accessibility Compliance Verification

Rigorous accessibility testing ensured compliance with international standards and inclusive design principles:

Visual Accessibility Standards: All visual elements were validated against WCAG 2.1 AA standards, ensuring sufficient contrast ratios, scalable text options, and color-blind accessibility. Alternative visual indicators were implemented for all color-coded information, and high-contrast display modes were validated for students with visual processing needs.

Motor Accessibility Features: Interface elements were tested for appropriate sizing, spacing, and alternative input methods. Gesture-based interactions included fallback options for students with limited fine motor control, and voice command alternatives were validated for primary navigation functions.

Cognitive Accessibility Considerations: Content presentation was evaluated for appropriate complexity levels, clear navigation pathways, and consistent interface patterns. Error prevention and recovery mechanisms were thoroughly tested to ensure students could successfully resolve common interaction issues independently.

Language and Cultural Accessibility: Content was validated for appropriate language complexity levels and cultural sensitivity across different European contexts. Translation accuracy was verified by native speakers, and cultural references were evaluated for broad accessibility and understanding.

Integration Testing with Existing School Technology Infrastructure

Comprehensive integration validation ensured seamless deployment within diverse educational technology environments:

Network Infrastructure Compatibility: The MAC platform demonstrated successful operation within restrictive network environments common in educational settings while maintaining security and privacy standards.

Device Management Compatibility: Integration testing confirmed smooth operation with major Mobile Device Management (MDM) systems used by schools for device deployment and management. App deployment, content synchronization, and remote management capabilities were validated across different administrative frameworks.

Data Privacy and GDPR Compliance: Extensive validation of data handling procedures confirmed full compliance with European data protection regulations. No students data is required for the Miracle apps use.

Quality Assurance Outcomes and Certification

The comprehensive validation process resulted in formal quality certification across multiple dimensions:

Performance Certification: Technical validation confirmed that all MIRACLE AR tools consistently meet or exceed performance benchmarks across the full range of supported devices and network conditions. Automated testing protocols continue to monitor performance metrics and alert developers to any degradation in service quality.

Educational Efficacy Validation: Systematic educational evaluation confirmed that the MAC platform demonstrably improves learning outcomes in climate change education compared to traditional teaching methods. These results have been documented in peer-reviewed educational research formats suitable for academic publication.

Accessibility Certification: Independent accessibility auditing confirmed full compliance with international accessibility standards, earning formal certification from recognized accessibility evaluation organizations. This certification ensures that the platform serves students with diverse learning needs effectively.

Security and Privacy Validation: Comprehensive security testing and privacy auditing confirmed that the MAC platform meets the highest standards for educational technology deployment in European schools. All data handling procedures have been certified compliant with GDPR and other relevant privacy regulations.

The validation process confirms that all WP4 results consistently maintain satisfactory quality standards across technical performance, educational effectiveness, user experience, accessibility, and integration capabilities. The MAC platform is fully prepared for presentation and deployment to European schools outside the partnership, with comprehensive documentation and support materials ready for broader educational community engagement.

Integration of Partner Requirements: Advanced AR Experiences

The implemented AR tools successfully integrate all specific requirements submitted by partner organizations:

Atmospheric Composition Visualization

Students interact with augmented 3D models showing Earth's atmospheric layers, with detailed breakdowns of gas compositions. Interactive elements allow manipulation of atmospheric variables to demonstrate climate change impacts.

Climate Sites Map

An augmented European map enables students to explore historic sites through immersive AR experiences. Students observe extinct biodiversity, and learn about sustainable historical lifestyles that respected natural systems.

Climate Change Cause and Effect Immersion

Students access AR experiences that transport them into:

- Industrial pollution zones with animated Earth characters explaining environmental damage
- Active deforestation sites with talking trees describing ecosystem destruction
- Arctic environments where polar bears demonstrate habitat loss and ice melting

Interactive World Climate Map

A personalized character guides students through global climate change impacts, showing before/after scenarios for selected countries. Time-based projections demonstrate potential futures if current trends continue, supported by factual data and credible sources.

Fake News Detection Tool

An augmented character system helps students identify reliable information sources versus misinformation. The customizable character (student-designed appearance and clothing) provides real-time fact-checking capabilities and teaches critical media literacy skills.

Global Forest Coverage Analysis

Students explore augmented world maps showing historical and projected forest coverage across continents. AR experiences simulate walking through forests before and after deforestation, demonstrating impacts on biodiversity, carbon absorption, and ecosystem health.

Climate Zone Habitat Exploration

Comprehensive AR experiences allow students to visit Arctic, coral reef, rainforest, and wetland environments. Students observe current conditions and projected future scenarios, understanding how different climate zones and their inhabitants face varying threats from environmental change.

Conclusion

Work Package 4 has successfully delivered all planned activities while incorporating enhanced functionality that addresses comprehensive partner requirements. The MAC platform represents a significant advancement in climate change education technology, providing teachers and students with powerful tools for exploring, creating, and collaborating around critical environmental challenges.

The seamless integration of stakeholder feedback, rigorous validation processes, and advanced AR capabilities positions the MIRACLE project as a leading example of innovative educational technology that addresses urgent global challenges through immersive, interactive learning experiences.