Enhancing Educational Outcomes and Well-being through Technology-Supported Object-Based Learning: The RESTART Project at the University of Tor Vergata[*]

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Abstract

The RESTART project at the University of Tor Vergata represents a significant advancement in the application of innovative educational methodologies through Object-Based Learning (OBL). This initiative aims to utilize cutting-edge technologies to enrich the educational landscape, prioritizing the development of key transversal skills—the 4Cs: Creativity, Communication, Collaboration, and Critical Thinking (Bialik et all, 2015)—and assessing participants' well-being levels. The project features interactive totems that facilitate access to immersive virtual reality (VR) environments specifically designed for OBL workshops. These workshops will take place within the Virtual Museum of Tor Vergata, which houses 20 carefully curated artifacts that narrate the history of the region. By engaging with these VR environments, participants can interact deeply with the cultural and historical content presented as reported in (Poce et all, 2020). Additionally, RESTART employs a haptic glove that simulates tactile sensations, such as heat and cold, and provides feedback mimicking physical contact with virtual objects. This integration of multisensory technology is designed to enhance both the learning experience and the emotional and psychological well-being of the participants. All the experiences related to the virtual museum are adapted by an AI capable of recognizing the needs of visitors through initial profiling. A central component of RESTART is its commitment to inclusivity and accessibility. Workshops are specifically designed to cater to a diverse group of participants, including those with physical or sensory disabilities, ensuring that all have equal access to these innovative educational tools. This approach not only enriches the educational experience for learners across all ages but also fosters greater social inclusion. RESTART also places a strong emphasis on evaluating both the educational outcomes and the well-being of its participants. By monitoring these aspects, the project aims to document the effectiveness of technology-supported OBL in boosting student engagement, understanding, and overall well-being. This dual focus on skill development and well-being assessment positions RESTART as a pioneering model for future educational initiatives that seek to integrate advanced technology with progressive pedagogical strategies

Keywords

education, VR, heritage, adaptive learning, 4C

1. Introduction

The digital revolution has significantly transformed the landscape of education, particularly in the domain of cultural heritage. Innovative methodologies, such as Object-Based Learning (OBL), have emerged as powerful tools for fostering deeper and more meaningful engagement with historical, scientific, and cultural artifacts. OBL, which centers around the use of physical or digital objects to facilitate learning, has gained widespread popularity, especially in Anglo-Saxon educational contexts (Durbin et al., 1990; Paris, 2002; Lane & Wallace, 2007). The integration of digital technologies has expanded the possibilities of OBL beyond traditional classroom settings. Digitization of artifacts, coupled with immersive technologies like virtual and augmented reality (VR/AR), enables learners to access and interact with objects that would otherwise be inaccessible or difficult to study. These technologies offer new avenues for exploration, allowing users to manipulate objects virtually, enhancing both conceptual understanding and sensory experiences. Gamification, the application of game-like elements to non-game contexts, has proven to be a particularly effective tool in education. By incorporating elements of

fun, challenge, and rewards, gamification can enhance engagement, motivation, and learning outcomes. Research has demonstrated that gamification can:

- Facilitate progressive and gradual learning (Ryan & Deci, 2000)
- Foster active user engagement and build trust (Kapp, 2012)
- Improve memorization and comprehension through positive experiences (Johnson et al., 2016)

Storytelling, a key component of many gamified experiences, can further enhance learning by stimulating creativity, communication, and critical thinking skills. It can also foster emotional engagement, which is essential for deep and meaningful learning (Giakalaras, 2016). Immersive technologies, such as VR, have been widely used to recreate historical and cultural environments, providing users with a first-hand experience of past epochs or distant places. Museums around the world have adopted these technologies to offer virtual tours, allowing visitors to explore collections without physical presence. The interactive nature of VR can enhance engagement and make learning more enjoyable and effective (Antonioli et al., 2014). Beyond cognitive development, OBL can also foster the development of transversal skills, such as creativity, communication, collaboration, and critical thinking (Poce, 2018). These skills are essential for success in today's world, and OBL provides opportunities for learners to practice and develop them in authentic contexts. In addition to its cognitive and social benefits, OBL can also have a positive impact on users' well-being. Experiential and participatory learning can reduce stress and improve emotional engagement. The interactive nature of OBL requires active participation, which can encourage critical reflection and deeper understanding. Despite these advantages, challenges remain. The integration of advanced technologies requires significant resources, and effective evaluation frameworks are needed to measure the impact of OBL in digital contexts. The Restart project, as outlined in the accompanying document, seeks to address these challenges and harness the potential of OBL for cultural heritage education. By combining innovative technologies, gamification, and storytelling, the project aims to create engaging and meaningful learning experiences for users of all ages.

2. METHODOLOGY

This study aims to address two main research questions that guide the research within the RESTART project:

How digital Object-Based Learning activities, can supported by VR and haptic technologies, promote transversal skills, particularly critical thinking?

This research question aims to explore how the integration of digitized objects, combined with immersive technologies such as virtual reality and haptic gloves, can foster more engaging learning experiences. The goal is to stimulate the development of transversal skills such as creativity, critical thinking, and communication. The RESTART project aims to create innovative and dynamic learning environments where users can interact immersively with cultural heritage, promoting a deeper understanding of historical and scientific content.

Is it possible to promote the well-being of the local population through interaction with the totem?

The second question investigates whether interaction with the totem, supported by artificial intelligence, can contribute to improving the well-being of the local community. In particular, the empathetic chatbot Romolo, developed within the project, will provide personalized responses that can reduce anxiety and promote a sense of inclusion and support. The goal is to create a digital environment that not only delivers information but also promotes the psychological well-being of users, especially in an urban context like that of Tor Vergata.

The main objectives of using the virtual museum and the 5G totems installed on the Tor Vergata campus can be summarized as follows:

- Promote the development of transversal skills through the exploration of cultural heritage and the use of immersive technologies such as VR and haptic technology;

- Offer more immersive and rewarding educational experiences that stimulate critical thinking and creativity;
- Foster the psychological well-being of the community through personalized and empathetic interaction with the totem, improving the sense of belonging and inclusion

The methodology adopted by the project is based on open and diversified interaction, aiming to engage both university students and school audiences through advanced immersive technologies. Students from the University of Tor Vergata will have the opportunity to interact freely with an interactive totem, allowing them to explore digital content of cultural and historical significance, including materials related to the RESTART project. On specific days, students will also be able to experience virtual adventures using VR headsets and haptic gloves, enabling immersive experiences within the virtual museum of Tor Vergata. In this environment, characters from a comic created to share RESTART's content will serve as guides, and the comic itself will also be accessible via the totem. During these immersive experiences, specific questions designed to stimulate critical thinking will be posed, encouraging participants to reflect on the historical and cultural implications of the represented objects and characters. Additionally, the project includes pathways for transversal skills and orientation (PCTO) with local schools, inviting various institutions to explore the museum and participate in digital Object-Based Learning activities. During these visits, students from nearby schools will have the opportunity to interact with the virtual museum and digital objects, using tools that facilitate active learning and enhance understanding of historical and cultural heritage. In this context as well, the experiences are designed to include thought-provoking questions, fostering critical thinking in young participants and inviting them to reflect on cultural and historical themes. This approach not only facilitates learning but also promotes dialogue between schools and the university, encouraging greater cultural awareness and the active involvement of young people in the appreciation of digital heritage.

3. THE TOR VERGATA VIRTUAL MUSEUM: A DIGITAL PLATFORM FOR HERITAGE VALORIZATION AND SOCIAL INCLUSION

The Tor Vergata Virtual Museum is designed to serve as a tangible and intangible heritage valorization, communication, and education tool. Grounded in theories and models of education concerning tangible and intangible heritage, the museum aims to promote social inclusion and well-being for a diverse range of users, including students, university staff, and members of the local community, especially those with cognitive or physical disabilities, children, and the elderly. The museum's content focuses on the historical and cultural development of the Tor Vergata neighborhood, emphasizing the University's significant role in the area's cultural and social evolution. By providing a diachronic perspective, the museum seeks to enhance users' understanding of the local heritage and foster a sense of belonging. The underlying hypothesis of the museum's design is that increased knowledge of one's territory fosters a critical awareness of its cultural and social resources, thereby promoting inclusion and well-being. To achieve this, the museum's content is structured around several key themes, including:

- The early settlements in the area
- The Roman era and its legacy
- The decline of the Roman Empire and the ruralization of the area
- The rise of towers and castles
- The history of the University and its significant scientific contributions (e.g., Marconi's radio experiments)
- The surrounding neighborhoods and their activities

To deliver this rich content, the museum employs a Digital Object-Based Learning (OBL) approach. A selection of heritage objects, chosen by a team of researchers and industry experts, forms the core of the museum's experience. These objects are presented through 3D digital models and interactive

Figure 1: The virtual museum, hight definition museum for desktop and VR applications

pathways, enabling users to explore the history and significance of the Tor Vergata area in a dynamic and engaging way. Inspired by MacGregor's (2012) concept of "A History of the World in 100 Objects," the museum's content is organized around a narrative of "The History of Tor Vergata in 20 Objects." This approach allows for a focused and coherent exploration of the area's heritage. Furthermore, the museum incorporates digital storytelling techniques to enhance the user experience and foster emotional connections with the content. By combining historical facts with personal narratives, the museum aims to create a more immersive and meaningful learning experience. To further enhance the educational potential of our object-based approach, we have selected a group of participants who will be able to experience the WEART haptic glove. This cutting-edge technology will allow users to perceive digital objects in a tactile manner, simulating a wide range of temperatures from 15 to 42 degrees Celsius and various textures. This will enable in-depth study of archaeological artifacts, scientific instruments, or works of art, allowing for a direct and engaging analysis of their physical and material characteristics. The WEART experience will prove to be a valuable tool for stimulating curiosity and creativity, fostering deeper and more lasting learning. In addition to haptic technology, which will enrich users' tactile experiences, the virtual museum will also integrate Leap Motion technology. This advanced motion-tracking system will enable precise tracking of participants' finger movements, allowing for more natural and intuitive interactions with virtual objects. For instance, users will be able to open an ancient chest, turn the pages of an old book, or even compose a melody on a virtual instrument, simply by moving their fingers as they would in the real world. This combination of haptic and optical technologies will provide an immersive and engaging experience, bringing the public closer to cultural heritage in an innovative and accessible way. In a previous experiment, the project presented promising preliminary results regarding the use of virtual reality for museum experiences. Specifically, the prototype of the E-Trouria app was developed, a virtual exhibition that uses objects from the Etruscan Museum of Villa Giulia. The experiment involved a group of 20 postgraduate students in museum education and demonstrated how the integration of VR technologies can foster greater emotional engagement and stimulate critical thinking through personalized educational paths.

Participants completed a satisfaction survey covering various aspects of the experience, averaging a 4.23 out of 5 on a Likert scale. The survey included five items: overall satisfaction with the experience, appreciation of multimedia content, enjoyment of the gamification elements, evaluation of the digital replicas of the artworks, and ease of use of the museum access system. Additionally, a System Usability

Figure 2: The virtual museum, hight definition museum for desktop and VR applications

Scale (SUS) questionnaire was administered, resulting in a score of 89 out of 100, indicating a high level of usability and user satisfaction with the system. Furthermore, emotions such as "pleasure" and "wonder" were among the most frequently reported, with a strong correlation between these emotions and preferences for specific objects or narratives. These results highlight the potential of virtual reality not only in creating more engaging educational experiences but also in promoting transversal skills such as critical reflection. These findings provided the foundation for the project, demonstrating how immersive technologies like virtual reality and digital storytelling can be successfully applied to promote both learning and user well-being.

4. THE ROMOLO CHATBOT

The chatbot Romolo, developed within the RESTART project, represents an innovative opportunity to improve the well-being of users of the interactive kiosks that will be installed at the University of Tor Vergata. Thanks to its advanced artificial intelligence capabilities and its ability to interact in an empathetic manner, Romolo is particularly suited to serve not only students but also local residents.

Research on current GPT models, such as those reported in the document "Large Language Models (LLMs) and Empathy-A Systematic Review", has shown that these models have a strong capacity to recognize emotions and generate empathetic responses, which often surpass human capabilities. This ability to generate empathetic responses, tailored to a variety of users and their unique needs, makes Romolo ideal for a context as diverse as that of Tor Vergata, where a population as varied as students and residents can find a connection. The possibility of having an empathetic interaction through the kiosks can foster a deeper connection between the user and the system, leading to a more comprehensive experience. Specifically, in the case of the Tor Vergata kiosks, Romolo will be able to respond to a wide range of requests, from academic and administrative inquiries to those related to mental health and personal well-being. Empathetic interactions, which are a key characteristic of GPT models, help to create a welcoming and supportive environment for students, stressed or residents seeking information or emotional support. This is particularly relevant in an urban context like Tor Vergata, where the kiosks will become points of reference for quick and personalized interactions. The integration of Romolo in the kiosks can also be seen as a way to promote psychological well-being. Research on

Figure 3: The virtual museum, hight definition museum for desktop and VR applications

Romolo has shown that empathy, even if simulated by an artificial intelligence, can reduce users' anxiety and improve their overall satisfaction with complex responses to interactions. For example, a study that compared the responses of ChatGPT with those of neurologists has shown that users perceived the AI's responses as more empathetic, even if not always more accurate, which demonstrates the positive impact that empathetic communication can have on the user's well-being (Maida et al., 2024)." The Romolo chatbot, in addition to its previously described functions, assists users in interacting with the totem and navigating its various features, acting as a virtual guide or tutor. This support enhances the accessibility of the system and promotes a smoother user experience. By providing empathetic and personalized guidance throughout the interaction, Romolo contributes to increasing users' emotional well-being, fostering a supportive and engaging environment within the digital museum.

5. DISCUSSION

The extensive research endeavors conducted over the past years have culminated in the creation of the Tor Vergata Virtual Museum, an innovative and multifaceted project that brings together the latest advancements in education and technology. This 5G-enabled totem strategically located across the University of Tor Vergata campus, has been integrated within an initiative representing a significant milestone in the application of digital methodologies for cultural heritage education, particularly through the use of Object-Based Learning (OBL). The Virtual Museum creates a dynamic and accessible platform for students, faculty, and the broader community. Previous research has shown that psychometric variables such as introversion and extroversion are correlated with specific preferences in the fruition of virtual museum experiences. Based on this evidence, our project aims to implement a highly sophisticated personalization system. This system, through the analysis of individual user profiles, will be able to adapt the virtual museum experience in real time. For example, for a more introverted user, we could propose more intimate virtual environments and less frenetic interactions, while for a more extroverted user we could offer more dynamic and socially engaging experiences. Furthermore, the choice of interaction tools, such as the haptic glove or the Leap Motion system, could be personalized based on individual preferences, guaranteeing an ever more immersive and satisfying experience. One of the most innovative aspects of these totems is their ability to facilitate seamless interaction with a chatbot powered by GPT-4. This AI-driven virtual guide, named Romolo, enhances the learning experience by providing users with personalized responses, guiding them through the virtual exhibitions, and offering detailed information about the historical and cultural heritage of the Tor Vergata area. The integration of such advanced technology ensures a more engaging, immersive, and active learning environment, where users can explore historical artifacts, understand their significance, and gain deeper insights into the area's cultural evolution. With the start of a large-scale data collection process, every interaction will automatically generate valuable data, which will be critical for validating the approach proposed by the project. The data will provide a wealth of insights into how effectively the virtual museum and related activities promote transversal skills such as creativity, communication, collaboration, and critical thinking. These skills are increasingly recognized as fundamental for both personal and professional development, making the evaluation process essential for understanding the broader impact of the museum on student growth and learning. The evaluation will not be limited to skills development. It will also assess the well-being of participants, exploring how engaging and immersive learning environment that incorporates haptic technology, 3D object interaction, and VR, offered by the totems foster a sense of connection with the material, which research has shown can significantly reduce stress and improve cognitive engagement. Additionally, the collected data will enable a thorough assessment of the knowledge students acquire regarding the history of the Tor Vergata area. The Virtual Museum offers a comprehensive historical journey, from ancient settlements to modern-day developments, highlighting key moments in the region's evolution. The project's alignment with the RESTART initiatives aimed at enhancing local urban heritage and fostering social inclusion, knowledge with ongoing innovative programs further enriches this experience, as it ties together historical knowledge. The use of precise evaluation tools will ensure that all aspects of the project, from skill development to well-being and knowledge acquisition, are rigorously measured and analyzed. This will provide quantitative evidence of the museum's effectiveness, offering a solid foundation for potential future expansion of the model. By continuously monitoring user interactions and feedback, the project can adapt and refine its approach, ensuring that it remains at the forefront of educational innovation. The Tor Vergata Virtual Museum represents a unique fusion of cultural heritage, education methodology, and cutting-edge technology. It not only enhances the learning experience for students and the wider community but also serves as a powerful tool for promoting social inclusion and well-being. By offering an interactive, data-driven, and user-centered platform, the project sets a new standard for how universities can leverage digital innovation to enrich both academic and social engagement. This initiative, with its integration of 5G, AI, and virtual reality, not only validates the research that led to its creation but also opens up new possibilities for the future of education and cultural heritage preservation.

REFERENCES

[1] Sorin, V., Brin, D., Barash, Y., Konen, E., Charney, A., Nadkarni, G. and Klang, E., 2023. Large language models (llms)

[2] Maida, E., Moccia, M., Palladino, R., Borriello, G., Affinito, G., Clerico, M., Repice, A.M., Di Sapio, A., Iodice, R., Spiezia, A.L. and Sparaco, M., 2024. Chatgpt vs. neurologists: a cross-sectional study investigating preference, satisfaction ratings and perceived empathy in responses among people living with multiple sclerosis. Journal of Neurology, pp.1-10.

[3] Al-Malah DK, Majeed BH, ALRikabi HT. Enhancement the educational technology by using 5G networks. International Journal of Emerging Technologies in Learning (Online). 2023;18(1):137.

[4] Baratè, A., Haus, G., Ludovico, L.A., Pagani, E. and Scarabottolo, N., 2019. 5G technology and its application to e-learning. In EDULEARN19 Proceedings (pp. 3457-3466). IATED.

[5] Kizilkaya, B., Zhao, G., Sambo, Y.A., Li, L. and Imran, M.A., 2021. 5G-enabled education 4.0: Enabling technologies, challenges, and solutions. IEEE Access, 9, pp.166962-166969.

[6] Poce, A.: Il patrimonio culturale per lo sviluppo delle competenze nella scuola primaria. FrancoAngeli, Milano (2018).

[7] Durbin, G., Morris, S., Wilkinson, S.: Learning from objects: A teachers guide. English, London (1990).

[8] Lane, J., Wallace, A.: Hands On: Learning from Objects and Paintings. A Teacher's Guide. Glasgow: Scottish Museums Council (2007).

[9] POCE, A. (a cura di) (2020). Memoria, inclusione e fruizione del patrimonio culturale. Primi risultati del progetto Inclusive Memory dell'Università Roma Tre. Memory, Inclusion and Cultural Heritage Fruition. First results from the RomaTre Inclusive Memory Project. Napoli: ESI

[10] Kador, T. and Chatterjee, H. eds., 2020. Object-based learning and well-being: Exploring material connections. Routledge.

[11] Duhs, R., 2019. "HANDS ON" LEARNING FROM MUSEUMS AND COLLECTIONS IN HIGHER EDUCATION. Studi avanzati di educazione museale. Lezioni Advanced Studies in Museum Education. Lectures, p.37.

[12] Wiley II, D.A., 2000. Learning object design and sequencing theory.

[13] Antonioli, M., Blake, C. and Sparks, K., 2014. Augmented reality applications in education. The Journal of technology studies, pp.96-107.

[14] Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

[15] Kapp, Karl. (2012). The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Eduction.

[16] Giakalaras, Marios. (2016). Gamification and Storytelling

[17] Paris, S.G. (2002). Perspectives on Object –Centred Learning in Museums. Mahwah, NJ: Routledge.

[18]   Johnson, D., Deterding, S., Kuhn, K.A., Staneva, A., Stoyanov, S. and Hides, L., 2016. Gamification for health and wellbeing: A systematic review of the literature. Internet interventions, 6, pp.89-106.

[19]   MacGregor, N. (2012). A History of the World in 100 Objects. Londra, Penguin Books

[20]   Bialik, M., Fadel, C., Trilling, B., Nilsson, P. and Groff, J., 2015. Skills for the 21st century: What should students learn. Center for Curriculum Redesign, 3(4), p.29.

[21]   Poce, A., Caccamo, A., Amenduni, F., Re, M.R., DE MEDIO, C., Valente, M. (2020). A Virtual Reality Etruscan Museum Exhibition–Preliminary Results Of The Participants' Experience.. In Enhancing the Human Experience of Learning with Technology: New challenges for research into digital, open, distance & networked education (pp.40-49) [10.38069/edenconf-2020-rw-0005].