

Between Painting and Pixel. Photogrammetry and interactive 3D models for heritage education on Mexican muralism

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This research aimed to develop a digital model of a mural by artist Roberto Cueva del Río, using photogrammetry and interactive 3D visualization as tools for heritage education on Mexican art from the Cardenista era. The methodology began with documentation and a literature review of the mural, followed by in situ digital acquisition consisting of 581 photographs processed with Polycam and subsequently integrated into Sketchfab. The final 3D model incorporates interactive hotspots that reveal contextual information. The creation of this interactive 3D representation demonstrates the value of a precise and non-invasive digital workflow that supports both conservation and educational goals. The study highlights how emerging technologies can foster innovation in heritage education and enhance the aesthetic experience through digital mediation. The results point to new opportunities for future research at the intersection of technology and cultural heritage, particularly within the framework of the digital humanities.

Keywords:

Photogrammetry, 3D models, Muralism, Education, Heritage.

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1. INTRODUCTION

It is consensual at the confluence of digital humanities, heritage education and aesthetic theory; an urgent prompt to not only digitally preserve but also disseminate globally Mexican cultural heritage. The realization of an interactive 3D digital model of the famous mural painting known as "La michoacana Eréndira y el encuentro español" by Roberto Cueva del Río, will help to preserve it and pursuit further research as well as teaching. Additionally, this work will help in assessing what is possible technically using digital tools and bring to light a less known and less studied cultural heritage. This mural was probably commissioned by General Lázaro Cárdenas del Río in 1938, at

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which time he ordered a wooden copy of the group of paintings created by Fermín Revueltas to adorn Quinta Eréndira in Pátzcuaro, Michoacán. Revueltas was already dead, so the work corresponded to Roberto Cueva del Río (López-Argüelles 2009).

1.1 Context

Jiquilpan, Michoacán, a town in the Ciénega region of western Mexico is recognized for its art, culture and historical roots. With its population of around 36,000, the city is best known for being the birthplace of historical figures such as Lázaro Cárdenas del Río and one in which cultural-tourism policies from the Cardenista period were reflected through extensive muralism. The town is culturally famous for its patrimonial urban infrastructure, mostly the murals in its buildings that represent Mexican sensitivities and tendencies. It is also one of the locations where someone made a mural that depicts pre-Hispanic Michoacán and its encounter with the Spanish. Jiquilpan was particularly relevant in this research as the location of such work, created by Roberto Cueva del Río.

1.2 Problem Statement

In this research, cultural management and digital humanities intertwine with the preservation and interpretation of cultural heritage, especially that relating to Mexican muralism. Mexican Muralism is a heritage of 20th century Mexico, that not only praises as aesthetic but also gives us a way to communicate the solid political, social and cultural values of traditional historical aspects of our nation (Rochfort 1994). The works of artists like Roberto Cueva del Río, – who reinterpreted Fermín Revueltas' original murals during the Cardenista era – provide lesser-known but vital clues to understanding Mexico's historical and aesthetic background, a visual narrative of national identity (López-Argüelles 2009, Ettinger 2018).

A major obstacle to viewing and appreciating these art forms is the use of inadequate educational tools capable of integrating digital technology with cultural content. In this case, photogrammetry and interactive 3D models are presented as a solution not only for the digital preservation of this work but also for dissemination and educational use (MacDonald 2006, Kukreja et al. 2024).

The photogrammetry technique has increasingly been used to produce accurate digital 3D models of artworks with fidelity to their materiality (Kasapakis et al. 2018). For an example of this, the creation a 3D model of Cueva del Río's mural is one step for preserve and document, but also opens new forms to teach mexican art through digital content (Means 2017). This idea advanced through the integration of interactive elements, proposing a methodical and competent way to improve our understanding of the mural and providing students and public within an educational experience through different perspectives to give more depth insight into this artistic piece located in its historical context.

In a more theoretical sense, this project takes place at the intersection of cultural management, digital humanities, heritage education and aesthetic theory. Digital Humanities offer ways to incorporate cutting-edge technology into the view, spread and management of cultural heritage, and heritage education focuses on transmitting and preserving cultural knowledge in an innovative pedagogical way (MacDonald 2006). In response, aesthetic theory provides instruments for dissecting the formal

and symbolic components of the artwork, enabling a thorough comprehension of muralism as a social and artistic phenomena (Hoxa 2022).

In terms of the state of art, a great deal of attention was directed towards developments in digital approaches to cultural heritage preservation and education. Numerous projects have proven the value of interactive 3D models in a great range of subjects, with archaeology, architecture and art being among those for which it has markedly raised public engagement and comprehension (Koller et al. 2010).

The scope of this research is related with the creation of a digital mural narrative, and with how that can become integrated into educational practices. Implementing this methodology will yield content that can be used as a pedagogical tool and has the potential to foster a greater appreciation of Mexican cultural heritage (Achille and Fiorillo 2022) and its management, preservation, dissemination, study, and teaching, aligning with current trends in technological integration in the humanities (King et al. 2016).

1.3 Objective

To create a digital model of a mural painting by artist Roberto Cueva del Río using photogrammetry and interactive 3D models as tools for heritage education on Mexican art from the Cardenista era.

1.4 Justification

In terms of convenience and relevance, the suggested study for creating an interactive digital model of Roberto Cueva del Río's murals at Jiquilpan, Michoacan is highly worthwhile. This research has implications for the conservation and analysis of Mexican cultural heritage, specifically Cardenista-era muralism that marks a critical moment in national identity formation. By utilizing technologies, such as photogrammetry and 3D models for online media, the study digitally documents and preserves the artwork creating more interactive and educational materials that challenges traditional methods for teaching cultural heritage at university level.

The significance of this research lies in its capacity to provide an improved and detailed digital access to Mexican art that, in turn, enriches the learning experience and promotes better understanding for it. In a social aspect, the project is important as it preserves the valuable cultural heritage for people to see, thus keeping these cultural goods alive within the history of muralism. Ultimately, students and educators focused on art, history, or culture are the major beneficiaries, gaining access to a fresh and interactive resource. Furthermore, society profits from the democratization of cultural heritage in which everyone has something to do with culture and thus learns to appreciate it and value it more.

In a practical way, this research also provides methodological step forward in the accessible and educational conservation and dissemination of cultural heritage by advanced digital technologies. Producing an interactive digital model not only contributes to the preservation of this work for future generations, but it is also useful in education on heritage and innovation in managing cultural heritage.

This project clearly has theoretical implications for the digital humanities, heritage education and management and aesthetic theory. This paper will document and analyze the process of creating an interactive 3D model for a work of Mexican muralism, seek to generate knowledge about how-to guide that can be replicated in similar scenarios. This reinforces previous understandings about the preservation and transference of cultural heritage, while also suggesting new ways in which digital technologies might contribute to this.

It is expected that the results of this research will provide feedback, serving as a precedent and propose an experimental process to increase the inclusion of digital technologies in heritage education, in the projects of the Cultural Management and Digital Humanities Laboratory of the Bachelor's Program in Multicultural Studies at the Universidad de La Ciénega del Estado de Michoacán de Ocampo, Mexico. This could open new research paths and enrich existing methods of creation, dissemination, teaching and conservation of cultural heritage.

1.5 Background

Mexican muralism, one of Mexico's most emblematic and influential artistic trends is the 20th century movement Mexican muralism that had its roots in social, political and cultural themes (Rochfort 1994). This movement had among its exponents prominent artists such as Diego Rivera, David Alfaro Siqueiros and José Clemente Orozco who used public murals in order to convey the ideals of the Mexican Revolution and create new nationalist identity (Anreus et al. 2012). Other artists less known, as in the case of Roberto Cueva del Río, also participated in this movement in significant form, mainly conformed to revisiting and reproducing murals, as poetic metaphors of great identity and social content which had been created during the era Cardenista by Fermín Revueltas (Cruz-Porchini 2022).

The physical deterioration of materials, exposure to ambient conditions and lack of resources for their conservation are some factors that make preserving these murals challenging (Wang and Wu 2023). In this regard, digital technology has been used for strengthening and spreading culture. Among recent popular techniques used for documentation and preservation of artworks, heritage sites in digital format; photogrammetry has also evolved as an effective tool to create actual 3D models with new details captured geometrically that provided fresh perspectives which aided the study and development of cultural heritage education (Kasapakis et al. 2018).

In the light of previous works, 3D interactive models have proved particularly efficient in heritage learning and constituted a major asset to involve students as well as public in general through engaging and accessible experiences that go along with traditional teaching methodologies (Means 2017). It has been widely documented that these digital tools have proven effect in contributing to the knowledge and appreciation on art and culture, especially when dealing with objects that are either geographically dispersed or are indispensable from a special preservation standpoint (Koller et al. 2010).

Large progress has been made with regards to photogrammetry and interactive 3D models applied to art studies but Mexican Muralism, specially the one of Cueva del Río, is still an underexplored area. This study documents the use of digital technology integration (Achille and Fiorillo 2022) that may also aid in the teaching of Mexican art.

1.6 Theoretical Framework

1.6.1 Mexican Muralism and Cultural Heritage. A powerful social and political content intertwined with aesthetic elements was the prevailing feature of Mexican muralism, an initiative that became an artistic movement that began in the early-mid 20th century under a new post-revolutionary cultural configuration (Rochfort 1994). Famous artists, Rivera, Alfaro Siqueiros and Clemente Orozco sought to encapsulate the spirit of the Mexican Revolution in their monumental mural art, that displayed images of protest, selfhood and heritage (Anreus et al. 2012). Many of these artists had works with high artistic value and were masters at what they did, but perhaps – more importantly – using art to talk to people, using their work as a tool for education and political action. But there were other artists, who were part of this movement.

In this context, and in the case of this research work, it shows how artists like Roberto Cueva del Río become relevant again by re-signifying and creating murals from other muralists as Fermín Revueltas during Cardenismo. This replicas in the building of the Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR IPN), Unidad Michoacán in Jiquilpan, Michoacán are part of the country's cultural heritage that should be saved and studied to help maintain Mexico historical and cultural memory alive.

1.6.2 Digital Humanities and Heritage Education. Digital Humanities, through which humanities scholarship and teaching is advanced with the use of technology has become crucial for all branches of art history in digital century for its preservation and outreach (Burdick et al. 2016). Of particular note is the potential of photogrammetry, a method for generating accurate 3D digital reconstructions from 2D images, to digitally record artworks and heritage sites (Kasapakis et al. 2018) as a means of both conserving these works and engaging with new forms of heritage education.

Digital technologies, e.g. interactive 3D models for heritage education offer new possibilities to both students and the non-specialized public to learn about cultural heritage in a more engaging and accessible way (Means 2017). These tools enhance learning and make visual art and historical sites more accessible while also supporting the dissemination of them.

1.6.3 Aesthetic Theory and Mural Analysis. The opportunity that the Mexican Muralism (MM) gives to dissect the artwork from an aesthetical theory point of view is an open field to develop a study on art in its formal and symbolic components. The philosophy of art and beauty, aesthetics, provides a theoretical background for the way in which color, form and composition either alone or combined enhance the communicative and emotive value of a mural (Hoxa 2022). In the example of Roberto Cueva del Río's mural in Jiquilpan, an attempt to unravel the explicit meanings contained within an aesthetic analysis and its relevance to Cardenista ideation and national identity is made.

2. MATERIAL / METHODS

2.1 Methodological Approach

This research is of a qualitative-exploratory nature and consists of digital heritage preservation, it focuses on the mural education in Jiquilpan Michoacán by Roberto Cueva del Río. The use of photogrammetry and interactive 3D models then enabled the conservation, documentation, and

provided a pedagogical resource for university environments, including digital methodologies to study and promote cultural heritage.

2.2 Research Phases

2.2.1 Documentation and Literature Review: Initially literature survey was around study on the Mexican muralism, Roberto Cueva del Rio's work and photogrammetry techniques in Cultural Heritage field; The objective of this stage was to provide a theoretical framework for the study, and to operationalize best practices for the application of digital technology within art conservation. Additionally, data were gathered about the central figure of the painting, the Michoacán princess Eréndira, who led resistance against the Spanish conquest and later helped evangelize her people (Ruiz 1891).

2.2.2 Data Collection through photogrammetry: Data collection was conducted *in situ* at the Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR IPN), Unidad Michoacán in Jiquilpan, Michoacán. An Apple iPhone 15 Pro Max was selected to capture images of the mural from multiple angles. A total of 581 images were recorded using the Photo Mode capture method with RAW detail to ensure the accuracy of the generated three-dimensional models. The images were processed in photogrammetry mode using the specialized cloud software Polycam, which leverages the LiDAR sensor of the latest Apple devices to quickly generate 3D color scans of objects and spaces, a strategy for heritage registration with 98% accuracy (Da Costa and Rosa Maricato Santos 2023). This process resulted in a 3D mesh with textures and details of the mural in RAW mode, with the object masking option activated, consisting of 1,352.6k vertices. The original file size was 896 MB, reduced to 110.8 MB after processing.

2.2.3 Development of the Interactive 3D Model: Once the data were processed and the 3D model of the mural was generated, an .OBJ file was exported to the Sketchfab platform, a platform for publishing, editing, and displaying 3D models. Clickable hotspots were added, with content generated based on information obtained during the documentation and literature review phase, providing contextual information about the work, its author, and the era in which it was created. The model's interactivity allows users to explore the work in an immersive way, accessing specific details that enrich the educational experience.

2.2.4 Integration and Testing in Educational Settings: The interactive 3D model will be integrated into digital educational platforms such as MOODLE and in sessions of the Cultural Heritage course within the Bachelor's Degree in Multicultural Studies at the Universidad de La Ciénega del Estado de Michoacán de Ocampo. It will be used with university students in courses related to art, history, and cultural heritage. Qualitative methods like interviews and focus groups will then be employed to collect opinions from students as feedback regarding the effectiveness of the three-dimensional model as a teaching material and educational tool. The data collected from the educational sessions will be analyzed to evaluate the 3D model's effectiveness in teaching cultural heritage.

3. RESULTS

Upon completing the search for information in documentary sources, the texts to accompany the 3D model were selected. The digitization process began with generating a 3D mesh using Polycam's software engine.

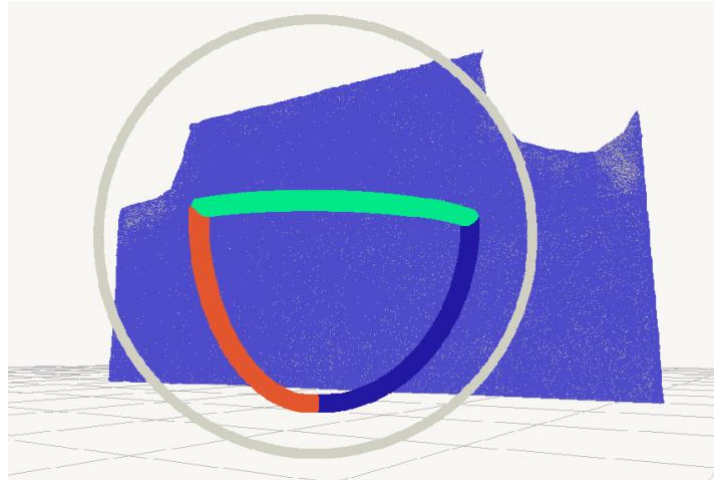


Figure 1. 3D mesh of the mural.

The digital recording process using photogrammetry also captured the details of the wooden frames surrounding the painting. A brief element cropping process was performed to improve the visibility of the artwork. Being graphic content, the final processing phase displayed the painting on the registered structure.

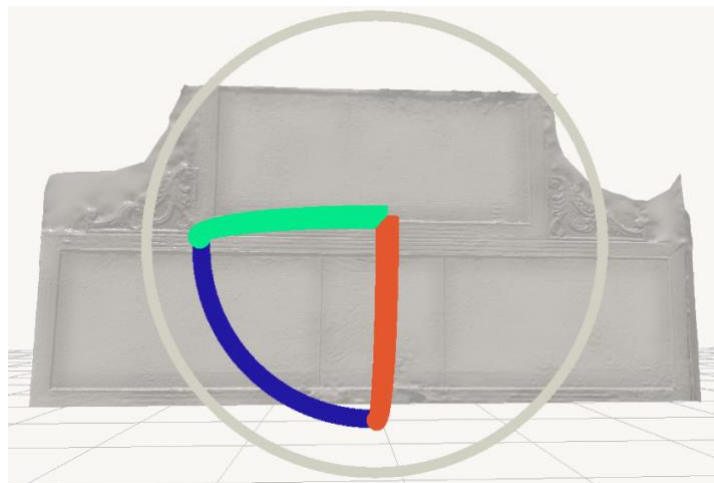


Figure 2. The wooden frames surrounding the painting.

The finalized 3D model allows for detailed observation of the artwork. It enables zooming, rotation, and analysis of specific elements present. The texts are readable, the colors remain faithful to the original work, and measurements of size and area can be performed on the model.



Figure 3. Finalized 3D model.

Finally, after exporting the model and uploading it to the Sketchfab platform, an online viewable 3D model was obtained. During the visualization adjustment process, clickable hotspots were added to the model, featuring information based on the consultation of documentary sources.

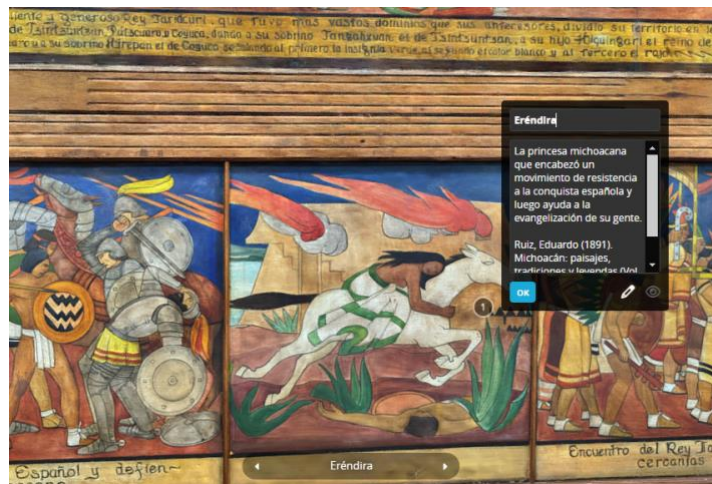


Figure 4. Clickable hotspots featuring information about the mural.

Princess Eréndira was a legendary figure in the history of Michoacán, particularly during the Spanish conquest. Eréndira was the daughter of Tangaxoan II, the last cazonci (ruler) of the Purépecha Empire, one of the most significant civilizations in pre-Hispanic Mexico, whose capital was located in Tzintzuntzan, near lake Pátzcuaro.

Eréndira is said to have stood out for her bravery and leadership during the Spanish invasion in the 16th century. According to legend, after the arrival of the conquerors to Purépecha territory, and in response to her father's apparent submission, Eréndira rebelled against the invaders and led her people in resistance. According to some versions of the story, she even led an army and was trained in riding a horse –an animal unfamiliar to the Purépecha– and part of the equipment used by Spanish soldiers.

The tale of Princess Eréndira has been told for centuries as an epic folktale of indigenous resistance and heroism. Michoacán folkloric history has taken up on this woman, who the years transformed into a figure standing against authoritarian rule at every level, inspiring character whose story of struggle is told and retold in literature, theatre and even in film format.



Figure 5. Surface review using metallic mode visualization to accentuate anomalies.

An advance in analysing surface textures was recently offered with the use of photogrammetric technology, this can lead to extract key data about the artist's painting techniques. For murals painted on wood, the methodology characterizes the actual state of conservation and reveals details its surface as high or low relief areas, tool-marks (eg. chisel marks), irregularities and paint application techniques used in that mural.

The examination of these textures when viewed through photogrammetry provides clues on how the artist made them. Perhaps the grain of the wood influenced how the artist painted, or its imperfections dictated how the style was adjusted. Photogrammetry provides details on how paint interacted with the wood, way in which layers of paint adhere to the surface, and if any manipulation was carried out during execution.

These observations also provide hints as to the artist's "priming" practices. Observation on a more detailed level may give us clues to the initial steps done before painting. The impression of spatulas or other instruments in the wood can reveal what kind of overlay texture (wood grain approximately perpendicular to a spotted area, tablet press through extremely flat wood figure) was recognized by the artist, so that his technique better understood and received. It also allows to analyze the texture of your wood via photogrammetry, unveiling hidden information behind wood processing steps, impossible to be seen with unaided eye. 3D visualization of the metal surface finish can reveal tool marks or the level of wear that researchers can verify directly on the work, providing new insights into how the artist approached various aspects of the mural.

Not only does it be taken to strengthen the understanding of the creative process itself, but further, photogrammetry applied in a texture analysis of murals plays an important role for its conservation. The 3D digital model created through photogrammetry also acts as a diagnostic tool to assess its conservation state, such as cracks, areas of material loss or wear, something that is not always perceptible at first glance. Such detailed observation and diagnostic capability are essential for planning restoration interventions that respect the original work and yield important considerations towards a new approach between conservation (with little or no intervention) and preservation.

4. DISCUSSION

The findings of this research exhibit fundamentally critical and innovative practices at the junction between digital technologies and cultural heritage preservation and management (MacDonald 2006, Kukreja et al. 2024, Kasapakis et al. 2018, Means 2017). Among them are the results on using photogrammetry and 3D models as tools for digital preservation of Cueva del Río's mural, which helps to enrich the learning experience in heritage education (Koller et al. 2010, Achille and Fiorillo 2022, King et al. 2016). These processes being scalable to multiple contexts and works is a non-trivial extension of the capabilities. The content produced, in these cases, allows for a greater depth and context of what the Mexican art at the time of Cardenas offered us and opens an interactive path that permits to obtain data/information that expands the historical comprehension of what it represents (King et al. 2016).

While research has indicated the effectiveness of digital tools and technologies in cultural heritage preservation (Wang and Wu 2023, Da Costa and Rosa Maricato Santos 2023), this study is unique as it focuses on a niche area; Mexican muralism, which is under-researched in terms of digitization and heritage education. Thus, this study projects on how technology can reignite the interest in cultural heritage and allows it to act as a generational bridge to link the past and the future.

The proposed method is an accurate and non-invasive for which a higher level of photorealism can be achieved by adopting conservation technologies in establishing the interactive 3D model, thus enabling new opportunities for innovation in heritage education (MacDonald 2006, Warwick 2012) and constitutes grounds as guiding evidence that motivate further exploration into the use and implementation of tools with a digital humanities approach to preserve and record cultural heritage. This study paves the way for further research on high tech in culture and offers a vision for studying technology-based aesthetic experience (Burdick et al. 2016, Hoxa 2022).

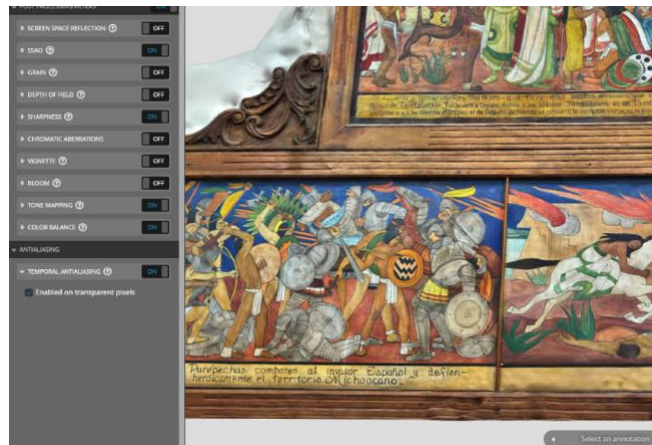


Figure 6. Post-processing parameters to improve visualization quality.

The combination of cultural management with the digital humanities perspective points out how these technologies may contribute to the field, in relation to cultural heritage preservation and population dissemination (Kasapakis et al. 2018, Means 2017, Koller et al. 2010), by showing related processes which might benefit from this kind of approach, such as those classically focused on knowledge production and heritage education improvement (Achille and Fiorillo 2022, King et al. 2016). This is a major progression compared to only preserving cultural heritage in a static way.

Given its high level of fidelity, photogrammetry has been a valuable tool for heritage education to enhance history and art knowledge. In contrast with traditional 3D models, in which students simply observe works passively, as we will see these models are interactive, they allow students to explore details that would be impossible to see with the naked eye and even experiment different rehabilitation policies applied on a digital prototype. This enables a dynamic and contextualized process, making the education more immersive and interactive.



Figure 7. Visualization of the three-dimensional model in a virtual space using immersive virtual reality viewers.

Photogrammetry is playing an increasingly important role in the field of conservation, study and dissemination of cultural heritage. By creating accurate digital records of cultural assets and works of art, it is possible to save vital details about their actual condition, protecting them against the passage of time and possible damage. In other words, a valuable connection with technology and heritage education is established, in which the digital resource can ensure preservation of heritage for future generations as well as spread (learning) links on reasons why it should be appreciated historically and aesthetically.

Through innovation processes related to heritage management and a transdisciplinary approach that integrates digital humanities and aesthetic theory, theoretical-perceptual barriers are expanded and contribute to our knowledge and appreciation, while encouraging collective efforts towards the preservation and dissemination of cultural legacy in a more conscious way.

5. CONCLUSION

The general purpose of elaborating an interactive digital representation of the mural by Roberto Cueva del Río was achieved, integrating the employing photogrammetry and 3D technology as primary mechanisms for educational purposes to disseminate Mexican art of Cardenista era. In doing so, it supported the digital preservation of a work of art and provided a unique educational tool that fosters an expanded learning experience through interaction with cultural heritage.

The interactive 3D model has great educational potential for students and educators, enhancing their relationship with the subject and the permanent significance of Mexican muralism in terms of identity and historical awareness with respect to this work. The research has integrated innovative technologies in both heritage management research and art education practices and is an example to promote the conservation, study and dissemination of muralism as cultural heritage, whose importance is as relevant as the transfer of knowledge for its study.

The results obtained open new opportunities for future studies that explore the intersection between technology and cultural heritage, the study of the technology-mediated aesthetic experience, and its integration with heritage education from the perspective of digital humanities.

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