Implementation of an Immersive Environment with 360º Video at SENAI CIMATEC: an Experience Applied to Engineering

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This article presents the experience of conception, development, and implementation of CIMATEC 360º, an immersive environment based on 360º videos conceived to support the teaching of engineering. In this context, the aim was to analyze the development and application of 360º videos as an immersive resource for engineering education, based on practical experience conducted at SENAI CIMATEC. This is a qualitative research study, outlined as a case study, that followed all stages of the process, from the definition of the theme and the preparation of the scripts, through the capture and editing of the material, to the structuring of the interface together with the availability of the solution. In summary, the development integrated, in an articulated manner, pedagogical objectives related to contextualized learning and technological requirements focused on compatibility and usability on multiple devices, including computers, mobile devices, and virtual reality (VR) headsets. The resource allows the student to virtually explore laboratories and institutional facilities, fostering the understanding of processes, the connection between theory and practice, engagement, and autonomy in learning. The results obtained indicate that the use of 360-degree videos represents a viable and scalable strategy to enrich engineering education, although it still faces challenges related to the need for a stable connection, variations in performance depending on the device, and the absence of complementary interactive elements. The evidence gathered points to prospects for improvement, such as the adoption of adaptive streaming techniques, optimization of file compression, and incorporation of interactive resources that expand the possibilities of navigation and conceptual deepening.

Keywords: 360º Video. Immersive Technologies. Engineering Education.

The current educational landscape, marked by the increasing migration of teaching and learning practices to digital spaces, calls for a reevaluation of the principles guiding the organization of informational and pedagogical spaces, as well as the strategies for content creation and curation. From this perspective, adopting immersive technologies is no longer merely following an emerging trend in education but has become an urgent necessity. These technologies enable the design of formative experiences that foster greater student engagement, promote cognitive and emotional immersion in learning processes, and enhance, in an integrated manner, the relevance, dynamism, and effectiveness of proposed activities [1].

Immersive technologies have been occupying an increasingly significant space in the educational field, especially within pedagogical approaches that aim to integrate innovation, engagement, and experiences closer to practical reality, in areas such as engineering that demand an articulation between theory and practice. Rather than assuming a deterministic migration to the digital, these media are understood here as context-dependent options, whose pedagogical value varies according to objectives, learner profiles, and the available infrastructure.

In this context, the use of 360º videos constitutes an accessible and effective strategy to provide more engaging, realistic, and student-centered instructional experiences. By enabling the visual exploration of environments recorded in all directions, these videos foster an intensified sense of presence, promoting both cognitive and

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emotional immersion in the presented content [2].

The choice of the engineering field, focusing on 360° videos as an interactive and immersive resource, is supported by the contemporary need to bring future engineers closer to practical and complex contexts, even when access to laboratories and industrial environments is limited [3]. This technology allows immersion in realistic scenarios, fostering interactive and meaningful learning, while enhancing students' understanding of processes, structures, and equipment, and developing technical and cognitive skills [3].

We emphasize that 360° video is not intended to replace the tactile, olfactory, and thermodynamic materiality of laboratory practice; rather, it serves as preparatory visualization and spatial orientation before hands-on sessions, not as a substitute for embodied experimentation.

In engineering education, the incorporation of immersive technologies aligns with pedagogical needs that value active learning and contextualized experiences. As Bolkas and colleagues [4] observe, practical classes often devote significant time to overviews, reducing opportunities for field experimentation, which can leave students underprepared for lab sessions [4].

In this context, the use of 360° videos in engineering education helps align instructional practices with emerging Industry 4.0 trends, which demand professionals skilled in working with advanced technologies and understanding complex systems holistically [5]. By delivering near-professional experiences, even in virtual format, this resource enhances both teaching-learning possibilities and the theory-practice connection, while simultaneously preparing engineers to tackle real-world challenges in their professional field.

Therefore, considering the context of engineering education and the transformations characterizing contemporary educational demands, challenges surrounding teaching and learning processes have been extensively examined in scholarly literature [6-8]. Research demonstrates that the need for professionals equipped to work in dynamic, interdisciplinary environments necessitate restructuring traditional training models historically rooted in one-dimensional and linear approaches.

The lack of immersive experiences may weaken the theory-practice connection, limiting knowledge transfer to professional contexts. Research by Xie and colleagues (2023) [9] demonstrates that virtual reality simulations enhance the practical application of theoretical concepts. Similarly, that immersive technical tours improve interactivity and comprehension in educational projects [1]. However, studies like Nyaaba and colleagues (2024) [10] identify persistent challenges in this interactive process, particularly regarding content development, instructor training, and technological infrastructure requirements.

According to Reyna (2018) [11], the educational use of 360° videos may encompass several applications, including: conducting virtual tours of complex environments that are difficult to fully understand when presented solely through static images, text, or standard audiovisual recordings.

The panoramic perspective offered by 360° video intensifies the user's sense of presence, while encouraging immersion that involves both cognitive processing and emotional engagement. [2]. In their systematic review, Rosendahl (2022) [12] identified three primary pedagogical applications of 360° videos in education: presenting and observing content in authentic environments, mediating interactively between theoretical concepts and practical situations, and stimulating self-reflection through contextualized observation of experiences. The authors further emphasize that 360° video can boost student motivation by promoting autonomous content exploration and learning through multiple visual perspectives, thereby supporting active knowledge construction.

Following the pipeline described by Naef and colleagues (2023) [13], 360° video production requires consideration of successive, complementary stages. The initial stage involves content planning and design, where key variables are established including subject matter, duration, visual elements, and integrated audio components. The subsequent stage focuses on selecting appropriate audiovisual recording equipment and defining capture procedures. The third stage encompasses material creation and processing, involving both the stitching of captured footage into a cohesive 360° video and necessary post-production work. The final stage concerns hardware specifications for content implementation and viewing, covering both technical parameters and experiential requirements.

At SENAI CIMATEC, an institution renowned for its innovative approaches, initiatives have been developed to explore 360° videos' potential as pedagogical mediation tools in engineering education. The experience documented in this study forms part of these efforts, demonstrating the implementation of 360° video immersive environments within a didactic-technological strategy designed to enhance contextualized learning and develop competencies aligned with contemporary engineering challenges.

Within this context, the present study aims to examine the development and implementation of 360° videos as immersive educational resources in engineering education, drawing on practical experience at SENAI CIMATEC. The research proposes to analyze the pedagogical, technical, and institutional dimensions of this technological integration, evaluating its educational potential while addressing the challenges encountered and lessons derived from the implementation process.

Materials and Methods

This study adopts a qualitative research methodology following a case study design. As Silveira (2009) [14] emphasizes, qualitative research focuses on developing an in-depth understanding of social groups rather than statistical representativeness. In our investigation, this approach enabled detailed exploration of participants' perceptions and experiences regarding 360° video implementation, examining both the technical dimensions and pedagogical potential for enhancing engineering education.

Regarding methodological design, this study employs a case study approach, which Yin (2010) defines as an empirical research strategy for developing a comprehensive understanding of contemporary phenomena within their real-world contexts, particularly when boundaries between phenomenon and context remain ambiguous. This method proves especially valuable for investigating educational technology implementation processes, as it facilitates multidimensional analysis (technical, pedagogical, and organizational) of the study object's unique characteristics through evidence gathered in authentic application settings.

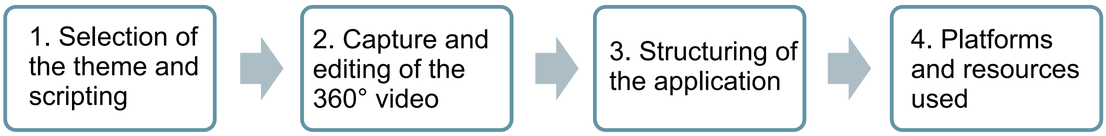
Within this specific context, the case study methodology enabled systematic documentation of all phases in developing and implementing the 360° video immersive environment at SENAI CIMATEC, encompassing the entire process from initial conceptualization to final delivery to end users. This research design facilitated integration of multiple data sources, including direct observations, technical documentation, development team interactions, thereby ensuring a holistic and contextually grounded understanding of the implementation process.

The development of the application - implemented as a didactic resource in an introductory course module of the Engineering program - was structured into four interdependent stages (Figure 1), each with specific objectives and procedures aimed at designing an immersive solution that is both functional and pedagogically aligned.

In the first stage, topic selection and scripting, the institutional environments to be presented in the 360º format were defined, prioritizing strategic spaces for engineering education. Descriptive scripts were prepared to guide the image capture, indicating points of interest as well as narrative sequences aligned with the learning objectives.

The second stage, 360º video capture and editing, involved the use of omnidirectional cameras to record high-resolution images,

Figure 1. Application development stages



ensuring full coverage of the environments, followed by processing and editing in specialized software for distortion correction, stabilization, and adjustments of brightness and color.

In the third stage, application structuring, an interactive interface was developed that brought together the videos in a simple and intuitive navigation library, with support for multiple devices (desktop, mobile, and VR headsets), enabling exploration experiences suited to different access contexts.

In the stage of platforms and resources used, 360º video editing software, responsive web development tools, and hosting servers optimized for high-resolution media were specified and applied, in addition to conducting tests on various devices and browsers to ensure compatibility, responsiveness, and adequate loading times. The process was conducted collaboratively, integrating pedagogical, technical, and instructional design teams, in order to ensure that the decisions made met both the educational demands and the technological requirements for the feasibility and scalability of the solution.

Finally, to support reproducibility, we provide a brief reproducible materials and methods note: a metrics overview comprising average load times under varied network conditions, frame rates across device classes, and post-use usability and presence ratings; and artifacts and documentation including codec and bitrate settings for adaptive streaming, interface screenshots, and the device and browser matrix used in testing.

Results and Discussion

The evidence reported here is descriptive and exploratory. We refrain from causal claims about learning gains. Observed benefits relate to orientation and engagement during pre-lab preparation; they do not generalize to skill acquisition without subsequent guided practice.

Figure 2. 360º video application.

The developed application (Figure 2), titled "CIMATEC 360°," constitutes an interactive virtual environment incorporating 360° videos for immersive exploration of laboratories and facilities at both SENAI CIMATEC and CIMATEC Park. Designed for cross-platform accessibility, the resource accommodates diverse devices including desktop computers, mobile devices, and VR headsets, ranging from advanced systems to cost-effective solutions like cardboard viewers.

The interactive library of 360° videos provides access to various institutional environments, enabling immersion in spaces that represent distinct academic and technological domains. These include the Brazil Model Factory, specializing in simulating integrated industrial processes; the Creative Resources Laboratory, which facilitates prototyping and experimentation for innovative projects; the Energy Laboratories, dedicated to researching renewable energy sources and energy efficiency systems; the Automotive Engineering sector, focused on developing and testing mobility solutions; the Precision Mechanics sector, specializing in high-accuracy machining processes; and the Networks, Robotics, and Autonomous Systems sector, concentrating on automation and artificial intelligence applications.

This variety of environments enables students to acquaint themselves with the institution's physical infrastructure while comprehending each area's practical context. Consequently, it strengthens the theory-practice connection, enhancing opportunities for contextualized learning and demonstrating real-world knowledge application, particularly for interactive processes like 360° video utilization. This approach proves especially valuable for hybrid and distance learning students, providing immersive exposure to engineering practice environments early in their academic training.

The intuitive, responsive interface was designed for universal accessibility across user profiles, enabling straightforward navigation that includes video selection, full-screen playback, and free environmental exploration. Computer-based navigation utilizes cursor movements to adjust viewing perspectives according to user interest. Mobile device interaction (smartphones and tablets) employs built-in gyroscopic sensors to track physical movements and rotations in real time. When using VR headsets - ranging from advanced systems to cost-effective cardboard solutions - the interface delivers enhanced spatial presence and immersion, closely approximating real-world environmental engagement.

This solution facilitates virtual technical visits, extending access to the institution's physical facilities for students and professionals when on-site presence is unfeasible. By doing so, it enhances knowledge dissemination regarding available infrastructure and resources while reinforcing the theory-practice nexus. Application analysis revealed three key educational benefits: (i) immersion, the panoramic 360° view enables realistic spatial comprehension of environmental layouts, equipment configurations, and operational processes; (ii) engagement, autonomous scenario exploration stimulates learner interest and curiosity, fostering more active participation; and (iii) instructional effectiveness, the integration of high-quality visual media with contextual narratives improves information retention and strengthens conceptual-practical linkages.

During implementation, several limitations were identified: (i) dependence on stable internet connectivity to ensure uninterrupted video streaming, particularly on mobile platforms; (ii) performance variability contingent on device specifications, potentially causing rendering delays on lower-capacity hardware; and (iii) lack of supplementary interactive features, such as informational hotspots, which could otherwise enhance the educational experience.

The application's architecture demonstrated effective multiplatform compatibility across major operating systems (Windows, macOS, Android, iOS) and educational browsers (Google Chrome, Mozilla Firefox, Microsoft Edge, Safari). This cross-platform functionality significantly enhances accessibility, enabling content delivery across diverse devices ranging from high-performance workstations to entry-level smartphones. However, evaluation revealed that 360° video loading times are network-dependent, potentially impairing experience quality in low-bandwidth environments. These findings underscore the necessity for optimization strategies including: (i) efficient video compression, (ii) high-performance codec implementation, and (iii) adaptive streaming technologies that dynamically adjust playback quality based on available bandwidth.

Regarding responsiveness, the application consistently preserved visual and functional integrity across desktop, tablet, and smartphone platforms. However, iOS device limitations preclude cardboard mode compatibility, thereby partially restricting user access to the virtual reality format.

Conclusion

The implementation of the "CIMATEC 360º" application demonstrated the potential of 360º videos as an immersive educational resource for the field of engineering, integrating technical, pedagogical, and technological accessibility aspects. The experience showed that, by enabling the free exploration of real environments, the solution contributes to strengthening contextualized learning, expanding the possibilities for student interaction and engagement.

From a pedagogical perspective, the resource proved effective in bringing theoretical content closer to the practices developed in laboratories, fostering the understanding of processes, equipment, and layouts that, in many cases, would only be experienced through in-person visits. This feature is particularly relevant to the field of engineering, where contact with real environments is necessary for skill development.

From a technological standpoint, the application achieved good compatibility with multiple devices and browsers, maintaining an intuitive and responsive interface. However, the identified limitations, such as the dependence on a stable internet connection and performance variations depending on the device, indicate the need for future improvements, such as the implementation of adaptive streaming, optimized file compression, and the inclusion of additional interactive elements, such as hotspots with information, check questions, or complementary links.

As a proposal for future studies, it is suggested to investigate students' perceptions of the use of the CIMATEC 360º application, analyzing its effects on motivation, engagement, and competence development. Furthermore, it is recommended to integrate the solution with artificial intelligence systems to personalize navigation and suggest pathways aligned with the user's profile and interests, as well as to incorporate augmented reality resources and interactive simulations. Such enhancements could expand opportunities for active learning and guide immersive experience toward specific pedagogical objectives, thereby enhancing the use of immersive technologies in engineering education and other educational contexts.

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