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INTERACTIVE VIRTUAL ENVIRONMENT FOR SECONDARY SCHOOLS: APPLYING VIRTUAL REALITY TO THE TEACHING-LEARNING PROCESS

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Final Course Project submitted to the Institute of Technology and Leadership (INTELI), to obtain a bachelor's degree in Software Engineering.

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ACRONYM 1 Full name of acronym 1
ACRONYM 2 Full name of acronym 2
ACRONYM 3 Full name of acronym 3

Summary (Required item – NBR14724, item 4.2.1.13; NBR 6027)

1 Introduction

We are living in an era marked by significant technological advances, which have profoundly transformed various aspects of society, including the educational field. The growing integration of technology into people’s daily lives requires us to reflect on the possibilities of its application in the teaching-learning process, especially regarding the potential improvement of traditional methodologies used in the classroom. This transformation aims not only to optimize the teacher's pedagogical practices but also to promote student engagement and motivation in relation to the curricular content established by the Brazilian National Common Curricular Base (BNCC). Various theorists, such as Freire (1996), have long advocated overcoming a banking, traditional, and passive education model, proposing instead a student centered approach based on dialogue, active participation, and the stimulation of knowledge construction.

In this context, it is observed that purely traditional teaching methods no longer effectively meet contemporary educational demands. This is where the concept of Active Learning emerges, proposing student-centered pedagogical strategies that emphasize problem solving, hypothesis formulation, and active participation in the construction of knowledge (ROCHA; LEMOS, 2014).

This demand for new educational strategies has paved the way for innovative approaches capable of making the teaching-learning process more dynamic and appealing to students. These approaches involve the integration of technological resources that support the transformation of pedagogical practices, enabling new forms of interaction and knowledge building. Among these resources, Virtual Reality (VR) and Augmented Reality (AR) stand out.

Virtual Reality is an advanced interface for computer applications that allows users to navigate and interact in real time within a three-dimensional environment, often using multisensory devices for action or feedback (Tori, Kirner, and Siscoutto, 2006). This technology enables interactive and immersive representations of both imaginary scenarios and real-world reproductions, facilitating user engagement in a 3D space. In addition to conventional interaction via menus or buttons, VR allows individuals to directly manipulate three-dimensional elements, enhancing their perceptual and sensory capabilities in both time and space. Through 3D modeling, virtual objects and scenarios are developed, enabling a richer and more immersive navigation experience.

The advancement of multimedia technologies and Virtual Reality has been driven by the increasing processing power of computers, allowing real-time integration between videos and interactive virtual environments. Augmented Reality, in turn, has directly benefited from these advances by enabling the overlay of virtual elements onto the physical environment, expanding its potential applications in various contexts. Its use has become feasible not only on sophisticated platforms but also on accessible devices such as smartphones, democratizing its reach. Unlike Virtual Reality, which completely replaces the real environment with a simulated one, Augmented Reality inserts virtual objects into the user's physical space, fostering a more fluid, intuitive, and accessible interaction experience—often eliminating the need for training or complex equipment (TORI; KIRNER; SISCOUTTO, 2006). Studies such as that by Macedo and Fernandes (2015) highlight that the use of AR in educational contexts provides advantages such as 3D visualization of experiments, opportunities for students to interact with content, and simplicity in the use of the technology, making it a viable and efficient learning tool.

Considering, therefore, the continuous evolution of technological resources and the need for more effective and engaging teaching methodologies, this study analyzes the use of Augmented Reality and Virtual Reality as innovative and promising tools to enhance classroom learning. These digital and interactive technologies are becoming established as important pedagogical resources, not only for the benefits they offer to the teaching-learning process but also due to the urgent need to align educational practices with the technological transformations shaping the contemporary world.

1.1. **Partner Company Context**

MIRAI operates within the educational technology (EdTech) sector, directing its activities toward innovation in teaching through technology. EdTechs, in general, are companies or startups that employ technological resources to transform education, offering solutions ranging from online learning platforms and personalized learning to augmented reality (AR) tools and gamification. By incorporating innovations such as artificial intelligence and AR, these companies seek to enhance the teaching experience and increase student engagement. The central objective of EdTechs is to reinvent learning methods and revolutionize educational processes through technology, thereby overcoming the traditional model of instruction. In this context, MIRAI was created precisely with the purpose of generating a positive impact on the use of technologies to support the educational process, operating as both a consultancy and a developer of customized teaching experiences. In other words, the company develops tailor-made solutions to help educators improve the teaching process and the transmission of knowledge, aligning itself with the trend of placing technology at the service of pedagogy in order to achieve better learning outcomes.

From the standpoint of organizational size, MIRAI can be characterized as a small- to medium-sized company, typical of a technology-based startup focused on education. The educational startup ecosystem is experiencing significant growth in Brazil and worldwide, encompassing companies of MIRAI's size. In Brazil alone, there were more than 500 active EdTechs in 2024, a figure that consolidated the country's position as a leader in educational innovation in Latin America. Founded within this dynamic landscape, MIRAI represents one of these innovative organizations that have emerged to meet the demand for technological solutions in basic and corporate education. Its lean and highly specialized structure allows for agility in the implementation of new ideas, a common characteristic of small companies in the EdTech sector. Thus, MIRAI's field of operation is educational consultancy and technology development applied to education, while its size corresponds to that of a small innovative enterprise—facilitating a focus on specific niches (such as secondary education, in the case of this project) and rapid adaptation to emerging trends in education. It is worth noting that the global EdTech market projects increasing investments in cutting-edge educational technologies; for example, spending on AR and virtual reality (VR) in education is estimated to reach USD 12.6 billion in 2025, a figure that is nearly double the projected investment in artificial intelligence within the sector. These data reinforce that companies such as MIRAI, operating in educational technology, are positioned within a strategic and expanding segment, in which continuous innovation is a critical success factor.

The virtual and augmented reality project applied to secondary education directly impacts MIRAI's core area of educational solution development, specifically the unit focused on creating innovative learning experiences within the context of basic education. In an organization oriented toward educational innovation such as MIRAI, there are no rigid distinctions between technology and pedagogy; therefore, the project will involve an interdisciplinary approach, engaging both the technology/software development department and the organization's pedagogical team. This educational innovation core is responsible for conceiving and implementing customized teaching experiences and will be profoundly influenced by the incorporation of AR/VR into its processes.

More concretely, the AR/VR initiative for secondary education will affect the way MIRAI designs instructional materials and training programs for educators working at this level of education. The company operates by providing consultancy services to schools and teachers, which suggests that its educational consultancy department (responsible for implementing solutions in partner educational institutions) will also be impacted. This department will need to adapt its teacher training methodologies to include the effective use of virtual and augmented reality tools in the classroom. In parallel, MIRAI's technological development team—possibly functioning as an educational R&D laboratory—will have its scope of work expanded to encompass the design and programming of immersive virtual environments aligned with secondary school curricula. Thus, the project touches central areas of the company: from the creation of pedagogical content enriched with immersive technology to the training of teachers and students to use these tools. In sum, the department (or functional area) most directly impacted is the one responsible for developing innovative educational experiences—which, within MIRAI's structure, integrates pedagogical and technological competencies—since it is within this area that the AR/VR solution will be conceived, prototyped, and refined before being delivered to end users (secondary school teachers and students).

MIRAI's decision to support a virtual and augmented reality project focused on secondary education is grounded in several strategic factors, all converging toward the strengthening of its mission of educational innovation. First, there is an imperative of technological leadership: AR and VR have emerged as some of the leading trends in education, offering immersive learning experiences that can shape new ways of teaching. The global education sector has increasingly adopted these technologies in recent years, recognizing their potential to revolutionize pedagogical practices. For MIRAI, active engagement with AR/VR means aligning itself with these cutting-edge trends, ensuring that the company remains competitive and relevant in a market where constant innovation is highly valued. Supporting the present project enables the company to develop internal expertise in immersive technologies and to generate a demonstrable success case, factors that may differentiate it in the eyes of clients (schools and education networks) seeking modern solutions. Indeed, the successful incorporation of AR/VR into basic education would position MIRAI as a reference in technology-mediated active methodologies, creating brand value and intellectual leadership within the educational EdTech niche.

Second, the strategic motivation also derives from the proven pedagogical benefits that AR and VR can bring, particularly in secondary education. Research and practical experiences indicate that AR/VR tools significantly increase student engagement and motivation, facilitating the learning of complex concepts through visualization and interaction. In the context of secondary education—an educational stage in which student disengagement with traditional methods is often observed—the use of immersive virtual environments can transform the abstract into the concrete, allowing students to interact with 3D objects, simulate scientific phenomena, or “travel” to historically relevant scenarios aligned with the curriculum. For example, through VR, a student can explore a virtual replica of Ancient Egypt or conduct a chemistry experiment in a virtual laboratory without real-world risks, experiencing in practice content from History or Natural Sciences. This type of experience provides deep experiential learning, which is difficult to achieve through lecture-based instruction alone, and aligns with the most effective practices in contemporary instructional design (learning based on experience and experimentation). Strategically, MIRAI recognizes value in supporting a project that demonstrates these advantages in practice, as the results may underpin the expansion of its product and service offerings. By mastering the use of AR/VR in secondary education, the company can offer the educational market high-impact innovative solutions, meeting a growing demand for engaging educational technologies. Moreover, involvement in this project allows MIRAI to closely monitor the pedagogical implementation of the technology, obtaining valuable data and insights regarding effectiveness, engagement, and usability, which will inform future strategic decisions and the development of new projects. In sum, the company's support is motivated by the convergence of an opportunity for disruptive innovation—with high potential to improve the teaching–learning process—and the competitive advantage of being among the pioneers in applying AR/VR in Brazilian basic education.

The AR/VR project applied to secondary education directly aligns with MIRAI's fundamental objectives as an organization dedicated to educational innovation. Since its founding, MIRAI has defined as its central purpose "to generate impact through the use of technology to support the educational process," acting to assist educators in improving teaching practices and the transmission of knowledge. This strategic orientation is materialized in the provision of customized and technologically enriched teaching experiences, precisely what the present project seeks to achieve. Virtual and augmented reality represent, in this case, tools capable of enhancing the teaching process, making it more efficient and better aligned with the needs of the current generation of students. By enabling more interactive and engaging classes, the project promotes active learning, in which students assume a protagonistic role—approaches of this nature foster greater student engagement and deeper intellectual connections with content. Such educational outcomes (greater engagement, personalization, and teaching effectiveness) lie at the core of MIRAI's vision, which seeks precisely to transform education through innovative methodologies.

Furthermore, the personalization and customization offered by the project—by creating AR/VR experiences adapted to the secondary school curriculum—reflect the company's philosophy that educational solutions should be shaped according to context and audience. MIRAI, as a consultancy and developer of educational experiences, aims to support each institution and teacher in a unique manner; the application of AR/VR enables complex content to be adapted to the visual and interactive language that resonates with young learners, addressing the new pedagogical demands of the digital era. In this way, the project proposal acts as a natural extension of MIRAI's objectives: it demonstrates in practice how cutting-edge technology can empower teachers and enrich the teaching process, generating the positive impact sought by the company. Strategically, the project serves as proof of concept for MIRAI's mission—that is, it provides evidence that well-applied technological innovation can significantly improve basic education. By supporting and co-developing this initiative, MIRAI not only fulfills its institutional mission but also strengthens its long-term objectives, which include leading digital transformation in education and consolidating itself as a reference in educational innovation. In sum, there is complete alignment between the proposed project and MIRAI's organizational objectives: both converge toward innovating the pedagogical process, enhancing the quality of education through the creative and effective use of technology, to the benefit of secondary school teachers and students.

1.2. **Problem Definition**

In recent decades, education has faced significant challenges, particularly with regard to student engagement. As highlighted by Pozo (2002), one of the main obstacles encountered by educators is the lack of interest and motivation among students—a factor that directly compromises the teaching-learning process. Motivation, according to the author, is associated with psychological processes that influence student behavior in learning situations, and is therefore an essential element to be considered in pedagogical practice. Traditional methods, mostly developed in pre-digital contexts, have increasingly proven insufficient to meet the pedagogical demands of a generation that is growing up immersed in digital technologies (PRENSKY, 2001). This gap between teaching practices and student expectations contributes to demotivation and the consequent decline in academic performance.

Moreover, the Brazilian National Common Curricular Base emphasizes the importance of adopting methodologies that foster the development of socio-emotional competencies and practical skills—aspects that are often not fully addressed in traditional teaching approaches.

Although the benefits of using educational technologies are widely recognized, their implementation in Brazilian school contexts is still at an early stage. Personalized learning, for example, has shown promise, but its implementation faces structural limitations, requiring from teachers not only technical proficiency but also additional time and dedication to identify and address the individual needs of their students (PETERSON et al., 2018). In light of this, several guiding questions arise:

a) How can the creation of interactive virtual environments based on VR and AR impact the teaching-learning process in the context of high school education? With an emphasis on enhancing didactic materials and promoting more engaging methodologies aligned with the technological and pedagogical transformations of the 21st century.
b) What existing applications of VR and AR in education, and what have their outcomes been?
c) Which subjects present greater feasibility for the implementation of these technologies? Are virtual and augmented reality applicable to all areas of knowledge?
d) How do students and teachers perceive and accept the adoption of new tools that complement traditional teaching, especially in subjects that require visual and experiential learning?
e) Do educational institutions have the necessary human, technical, and financial resources to support the implementation and maintenance of VR and AR-based platforms?

1.3. Proposed Solution and Expected Contribution

- Presentation of the proposed computational solution;
- **Contribution Objective: What is the** *quantifiable* result that the project should deliver? (Ex : Reduce time by X%, Increase accuracy by Z percentage points.)

1.4. Business Objectives

In view of the foregoing, the project objectives were delineated from the perspective of the partner company MIRAI, that is, the expected outcomes that the proposed solution should deliver to the business and to its clients in the educational sector. In general terms, the project is expected to contribute to the following results for the company:

a) Pedagogical Innovation within the Portfolio: Development of a functional prototype of an educational platform based on VR/AR, expanding MIRAI's product portfolio with an innovative solution that transforms curricular content into immersive experiences. It is expected that this innovation will make the company's solutions more attractive to schools and education networks seeking to incorporate cutting-edge technologies aligned with the BNCC and with active learning methodologies.
b) Increased Engagement and Effectiveness: Demonstration, through pilot studies or controlled tests, that the use of VR/AR in secondary education increases student engagement and can improve the understanding of complex content when compared to traditional methods. This outcome would provide MIRAI with concrete evidence (data and pedagogical feedback) of the solution's added value, serving as a proof of concept for future implementations on a commercial scale.
c) Customization and Curricular Adaptation: Delivery of a flexible solution, built on the Godot engine, that enables the creation and customization of different immersive educational modules (for example, a virtual science laboratory, an augmented reality visit to a historical site, etc.). This will address the need for frequent customization in MIRAI's solutions, making it possible to adapt the product to the specific demands of each partner educational institution, without reliance on costly licenses or complex infrastructures.
d) Technological Capacity Building and Market Differentiation: Training MIRAI's team in the mastery of new technologies (Godot, VR/AR frameworks, serverless architecture, etc.), strengthening the company's human capital in immersive development competencies. The know-how acquired throughout the project is expected to position MIRAI in a differentiated manner within the EdTech market, enabling it to offer immersive educational solutions competitively and on a proprietary basis (through the use of open-source tools, thereby avoiding licensing costs). It is expected that this will create competitive advantage and potential for new business opportunities, given that the VR/AR market in education is undergoing rapid global expansion.

In summary, the project objectives reconcile academic research on the use of VR/AR in education with the generation of practical value for the partner company. Achieving these objectives will signify not only the fulfillment of a curricular requirement (the completion of the undergraduate thesis), but also the delivery to MIRAI of a solution and a body of knowledge applicable to its operational context, thereby contributing to its mission of innovating teaching–learning processes through technology.

1.5. **Structure of the thesis/dissertation:**

This undergraduate thesis report is organized into chapters that reflect the logical progression of the research, ranging from theoretical foundations to practical application and conclusions. The following presents an overview of the contents of each chapter:

Introduction and Justification: (the present chapter) Provides contextualization of the topic, outlines the relevance of the use of VR/AR in secondary education, presents the partnership with the company MIRAI, defines the project objectives from a business perspective, and describes the overall structure of the study.

Foundations and Applied Justification: Brings together the theoretical and practical framework that underpins the project. Relevant concepts from the educational sector of the partner company are detailed (educational business context and trends in the use of VR/AR in teaching), as well as the technological rationale of the solution (technologies involved, development methodologies considered, and justification for the choice of the Godot engine). The foundations of project management and development methodologies adopted in the corporate environment to enable the implementation of the proposed solution are also reviewed.

Methodology: Describes the methodological procedures adopted in the development of the project. It encompasses the stages of research and requirements elicitation, system planning (including the proposed architecture, data models, etc.), the technologies and tools used, and the manner in which the project was conducted in interaction with the partner company (for example, the use of agile methodologies, development sprints, and continuous validation with stakeholders).

Development and Results: Presents the practical application of the project. It details the implementation of the VR/AR solution, including the integration of components (content authoring front end, serverless backend architecture, Godot-based VR application, etc.). The main functionalities developed are described and illustrated with examples (e.g., a pilot VR-based chemistry teaching experience—construction of a virtual laboratory to explore molecular models). This chapter also discusses the results obtained, both in terms of technical performance and in terms of a preliminary evaluation of the user experience by educators and students involved in the tests.

With this structure, it is expected to provide the reader with a comprehensive understanding of the project—from the why (theoretical, educational, and business justifications), through the what (the proposed solution and technological foundations) and the how (methods and development), and ultimately arriving at the so what? (the results obtained and final reflections).

2 Solution Development

Integrating immersive technologies into the school environment requires grounding from educational, technological, and organizational perspectives. This chapter presents the theoretical and practical foundations that justify the adoption of VR/AR in the context of secondary education, aligned with the business needs of the partner company MIRAI. Initially, the rationale applied to the educational business domain is examined, addressing relevant pedagogical concepts and market best practices in the use of VR/AR in the classroom. Subsequently, the technological rationale is explored, reviewing the technologies and methodologies involved (such as modern software architectures and development paradigms) and providing a technical justification for the choice of the Godot engine for the implementation of the solution at MIRAI. Finally, the foundations of the project management and development methods employed are discussed—for example, agile methodologies and project management guidelines—situating how such frameworks are used within the corporate environment to ensure the success of innovative initiatives in education.

This applied approach seeks to demonstrate not only what should be done, but also why and how to do it in the most effective manner within the given context, thereby providing a solid basis for the decisions made throughout the project.

2.1 Applied Rationale

2.1.1 **Business Area Rationale:**

In this section, the project rationale is discussed from both educational and market perspectives, that is, the reasons why the proposed VR/AR solution is appropriate in light of the demands and trends of the education sector in which MIRAI operates. Initially, relevant concepts from the educational sector that inform the initiative are addressed—including pedagogical principles and curricular guidelines—and subsequently, market best practices regarding the use of VR/AR in education are presented, highlighting how companies and educational institutions have been applying these technologies to improve learning processes.

The partner company, MIRAI, is embedded within the broader context of Brazilian basic education, which means that its solutions must align with national educational policies and contemporary pedagogical theories. A central concept in this context is that of active learning methodologies, which encourage students' direct participation in the construction of knowledge, as opposed to traditional practices centered on teacher exposition. This approach is supported by classical authors in education. As argued by Freire (1970), authentic learning occurs when a dialogical and horizontal relationship is established between educators and learners, valuing students' everyday experiences and prior knowledge. This perspective, which predates the digital era, anticipates the importance of interactivity: both pedagogical interactivity (meaningful exchange between teachers and students) and technological interactivity (students actively engaging with digital tools) are fundamental to the production of new knowledge.

In the case of VR/AR, there is a clear opportunity to concretize this Freirean principle—the student ceases to be a “mere spectator” and becomes an active agent in the process, exploring virtual environments, manipulating 3D objects, and making decisions within a simulated world. This active stance enables new knowledge to be constructed in connection with the learner’s reality (whether physical reality or a virtual reality that simulates real-world situations), rather than in an alienated manner. In summary, from a pedagogical standpoint, the use of VR/AR aligns with the need to break with the “banking” conception of education, promoting educational practices in which “those who teach learn in teaching and those who learn teach in learning,” to paraphrase Freire (1996). Immersive technology, when properly applied, can serve as a mediator of this process, offering means for more meaningful, contextualized, and collaborative learning.

Another relevant concept concerns the profile of new generations of students, often referred to as the Digital Generation or digital natives (Prensky, 2001). These students have grown up immersed in interactive technologies—video games, the internet, mobile devices—and therefore exhibit distinct expectations regarding learning. Prensky and other contemporary authors (such as Katie Davis) observe that today’s students have cognitive styles shaped by the digital world: they are more responsive to multimedia stimuli, prefer experimental and rapid learning, and tend to lose interest in unilateral or overly abstract approaches.

Prensky (2010) argues that twenty-first-century schools must undergo radical change to meet the needs of this new audience of learners, who “spend hours focused on videos, social networks, or video games” yet often show disengagement in traditional lecture-based classes. He proposes a “Partnership Pedagogy,” in which teachers and students act as active co-participants in learning, and suggests that the organic integration of digital technologies into school activities is a fundamental component of this transformation. In particular, Prensky emphasizes that students do not want education to be merely curriculum-relevant—they want it to be real, that is, connected to concrete problems and authentic life experiences.

VR/AR directly addresses this demand, as it literally brings elements of the real world (or simulates real-world scenarios) into the learning process, making content vivid and contextualized. This ability to render learning “real” can reduce many young people’s perception that school is disconnected from their lives—a sentiment that, according to Prensky and also Gee (2004), is common after the early years of elementary education. Therefore, motivating digital learners requires methodologies that integrate playfulness, visual elements, and interactivity, while simultaneously challenging students with real-world problems. Virtual and augmented reality technologies, when employed in a planned manner, can meet these criteria: for example, an educational VR game can engage a student in a scientific mission (playful) within a laboratory scenario (visual and interactive) to solve a problem inspired by real situations (relevant and applied). Thus, from a conceptual standpoint, MIRAI's proposal to invest in VR/AR is grounded in theories that emphasize student-centered, interactive, and reality-connected learning—principles endorsed both by critical pedagogical literature (Freire) and by educational technology literature (Prensky, Davis, etc.).

Additionally, it is important to situate the initiative in relation to curricular guidelines and competencies required in contemporary secondary education. As noted, the BNCC incorporates Digital Culture as a cross-cutting competence, encouraging the critical and creative use of technologies by students. Beyond this, the BNCC advocates, across various subject areas, the use of investigative methodologies, problem solving, and integrative projects. An example can be found in the specific competencies of Natural Sciences and Mathematics, which value students' ability to model real-world problems, analyze data, and understand phenomena through inquiry. AR/VR can be instrumental in this regard—for instance, by simulating a Physics experiment in VR whose results students must analyze, or by using AR to project graphs and information onto the physical world to assist in solving a mathematical problem. Such applications reinforce inquiry skills and critical thinking, aligning closely with the BNCC's expectation of forming students who are protagonists, "authors of their own lives and their own time" (in the terms of the document). Moreover, AR/VR can contribute to Interdisciplinarity, another key concept in modern secondary education: a well-designed immersive experience can simultaneously involve content from history, geography, and the arts (e.g., a virtual visit to an archaeological and cultural site), or integrate chemistry and biology (a virtual laboratory addressing biochemistry). This capacity to articulate multiple disciplines within a single activity reflects the integrated learning pathways proposed by Brazil's New Secondary Education model, suggesting that technology can practically facilitate the transition to more flexible, project-centered educational models.

Finally, it is relevant to understand MIRAI's educational business vision. As a company focused on customized solutions for education, MIRAI operates in partnership with schools and education networks, often developing tailored platforms, digital content, and learning management systems. Concepts such as Education 4.0—which brings the logic of the Fourth Industrial Revolution into education, emphasizing technology, personalization, and the development of future-oriented skills—influence the company's strategies. MIRAI seeks to position itself as a provider of educational innovation, which implies aligning its solutions with market best practices while also addressing the specific needs of its clients (which may range from elite private schools to public education networks in challenging contexts). Consequently, notions such as digital inclusion, personalized instruction, and adaptive learning are part of the company's lexicon and guide the applied justification of the project. A VR/AR solution, for example, must be inclusive (considering access for students with disabilities, such as implementing accessibility features within the virtual experience) and must allow for personalization (e.g., different difficulty levels or exploration paths for students with diverse learning paces). These requirements derive from contemporary educational concepts—such as inclusive education and pedagogical differentiation—which MIRAI adopts in its instructional design policies. Therefore, the project's foundation would be incomplete without considering these concepts from the partner company's educational sector: innovation with pedagogical purpose, adherence to educational policies (BNCC), and commitment to inclusion and personalization. All these elements converge to justify, from a business standpoint, why investing in VR/AR is appropriate: to offer more effective, engaging, and accessible learning experiences that meet student expectations and the demands of an updated and equitable education.

The adoption of virtual and augmented reality in education has moved beyond an experimental phase to become a concrete and growing trend in the global EdTech market. Numerous projects, products, and studies have demonstrated in practice the benefits of these technologies in educational settings, establishing a set of best practices that serve as references for the development proposed by MIRAI. In this subsection, some of these market practices are highlighted, illustrating how VR/AR is being used and for what purposes, as well as the observed advantages and limitations.

From the perspective of successful implementations, examples can be cited across different educational levels. One of the most widespread applications of VR is the use of virtual field trips: schools have employed VR headsets to take students to museums, historical sites, space explorations, or geographically inaccessible locations. These immersive experiences break temporal and spatial barriers, offering rich experiences without the costs and logistics of real-world excursions. For instance, students can “walk” through the streets of Ancient Rome, exploring in 360° what life was like in that civilization, or fly over mountainous systems in geography classes. Forbes (2021) listed “historical tours and space travel” as one of the main ways to use VR in basic and higher education, precisely due to their strong pedagogical and engagement appeal. Similarly, in natural sciences, VR has been used to simulate complex experiments and phenomena: companies such as Labster have developed virtual chemistry and biology laboratories in which students can safely conduct chemical experiments (virtually mixing reagents and observing reaction outcomes) or dissect an organism in virtual reality, all with a high degree of interaction. Such simulations not only reduce costs and risks (e.g., by not using real reagents), but also allow for unlimited repetition—students can attempt experiments as many times as needed, exploring scenarios without fear of failure, something traditional practical classes do not always permit.

This democratizes access to cutting-edge educational experiences, particularly benefiting institutions with limited infrastructure, and has a significant inclusive impact: as noted in a recent report, VR/AR can be a game changer in contexts such as Brazil, compensating for the lack of physical laboratories in many schools and democratizing access to high-quality experiences, despite the initial hardware cost still being a diminishing barrier.

Another emerging practice is the use of augmented reality in the classroom through mobile devices or tablets. AR stands out for overlaying digital information onto the real world, which has been leveraged to materialize abstract concepts within students’ physical environments. For example, biology teachers can use AR applications so that, when pointing a tablet camera at an image in a textbook, a pulsating 3D model of a human heart appears, which students can observe from different angles. There are AR applications that project miniature solar systems in the middle of the classroom or cause geometric figures to “emerge” from printed paper to support mathematics learning. A notable practice is the use of physical objects combined with AR, such as the Merge Cube—a plastic cube with patterns that, when viewed through a tablet or smartphone camera, transforms into different virtual objects (an interactive globe, a rotatable human brain, etc.). This approach provides students with tactile feedback (holding the cube) while they see a hologram over their hands, making the experience multimodal. Best practices in educational AR emphasize the need for a clear pedagogical purpose—the technology should not be a mere embellishment, but rather add instructional value. For instance, using AR to display molecules in 3D in organic chemistry learning is considered beneficial, as molecules are three-dimensional structures that are difficult to visualize mentally; AR helps reveal what is normally invisible to the naked eye, facilitating spatial and functional understanding of chemistry. Conversely, using AR merely to “animate” a textbook character without connection to a specific learning task would be a frivolous application. Therefore, successful market practice always integrates the technological and didactic dimensions: each virtual element introduced must fulfill a learning objective (whether to motivate, explain, or enable practice). Renowned companies, such as Google (with the now-discontinued Google Expeditions and later AR in Search), as well as educational startups, have published exemplary use cases of this nature.

The reported advantages of using VR/AR in education are numerous. In summary, the following stand out:

a) Increased engagement and motivation—students tend to be more attentive and participatory in immersive activities, often describing them as enjoyable and memorable.
b) Meaningful learning and greater retention—by experiencing a situation (even virtually), students associate content with practical experience, which favors information retention and deep understanding, avoiding rote memorization;
c) Visualization and comprehension of complex concepts—abstract, very small, or very large phenomena can be virtually modeled (e.g., visualizing forces acting on a 3D mathematical function in VR, or a magnetic field in AR), making tangible what is difficult to imagine through verbal explanation alone;
d) Safe environments for error and training—VR simulations provide controlled environments where mistakes have no real consequences, allowing students

to practice laboratory procedures, physics scenarios, or even skill training without fear;

e) Inclusion and accessibility—VR can benefit students with certain disabilities, for example by allowing a wheelchair user to virtually "traverse" rugged terrain in geography that might be inaccessible in reality; moreover, accessibility features (audio description, captions, etc.) can be incorporated into virtual environments to support students with visual or hearing impairments.

These advantages support the notion that immersive technology is not merely a "gadget," but rather a transformative tool that, when well utilized, enhances both the quality and equity of education.

Naturally, there are also challenges and limitations associated with the use of VR/AR in education, as identified in market experiences. One of the most frequently cited challenges concerns cost and infrastructure: although the prices of VR devices are decreasing, acquiring a set of VR headsets for an entire class remains costly for many institutions, particularly in the public sector. In addition, compatible computers or smartphones, good connectivity, and adequate physical space are required (in the case of VR, a safe environment for movement is necessary). Thus, logistical concerns are significant. However, trends such as the use of standalone headsets (e.g., Oculus Quest, which does not require a PC) and device-sharing models (student rotation) have partially mitigated this issue. Another limitation involves the learning curve and teacher training: implementing VR/AR requires that teachers be comfortable with the technology and integrate it into lesson planning. Teacher training programs for VR/AR use are therefore critical; without them, there is a risk that the tool will be underutilized or misaligned with pedagogical objectives. Additionally, in the case of VR, some studies report issues of fatigue or discomfort: prolonged sessions may cause motion sickness (cybersickness) in some users or visual strain, indicating that educational use should be moderated (e.g., experiences of 15–20 minutes rather than extended durations). In the case of mobile-based AR, distraction is a concern—if not well managed, tablet use in class can divert attention (students may switch to other applications, etc.). Consequently, best practices always recommend activity designs that keep students focused on the task (goal-oriented gamification, teacher monitoring, etc.). Finally, a technical limitation to mention is that developing VR/AR content can be complex: producing rich 3D environments and virtual models requires specialized knowledge (3D design, programming, VR UX). This constitutes one of the bottlenecks to adoption—many schools would like to use VR/AR but lack curriculum-aligned content. To address this, the market has seen the emergence of immersive content libraries and platforms: marketplaces where teachers can download experiences created by other educators. MIRAI's present project takes this into account by proposing a solution in which teachers can build or customize VR experiences without needing to program, using pre-existing resources (such as 3D objects from a repository). This "open platform" approach is inspired by successful market initiatives such as Immersive VR Education and the Merge EDU platform, which provide collections of reusable educational virtual experiences and objects.

In summary, market practices indicate that VR/AR in education represents a rich frontier of possibilities, already yielding concrete results in various contexts. Best practices emphasize clear pedagogical planning (VR/AR must serve the lesson's objective), curricular integration (alignment with competencies such as those defined by the BNCC), teacher preparation, and outcome evaluation (collecting student feedback and measuring learning impacts). For MIRAI, observing these practices is essential to validate the proposed approach. Growing global investment in the area (with projections of approximately USD 14 billion in the immersive EdTech market by the middle of the next decade) and successful cases suggest that investment in immersive education is well founded. Educational businesses that incorporate these technologies with pedagogical purpose have the potential to lead a transformation in teaching and learning, delivering greater value to their clients (schools, students, and families) while simultaneously contributing to education's response to contemporary challenges—namely, the formation of citizens who are competent in the digital world and capable of applying knowledge critically and creatively.

2.1.2 **Technological rationale for the solution:**

- Review of concepts, technologies, and methodologies (e.g., Serverless Architecture , Natural Language Processing, BI, etc.) that support the proposed solution;

- **Technical Justification:** Why is technology X the most suitable for the partner company's environment/infrastructure?

2.1.3 Fundamentals of Management and Development Methods:

- Review of the development methodologies (Agile , DevOps) and project management methodology (PMBOK) used in the company's corporate environment.

2.2 [Specification and Development :]

[In this section, all technical specifications should be pointed out, which must be aligned with the standards and needs of the partner company.]

2.2.1 Requirements and Specifications:

- **Functional** and **Non-Functional Requirements** of the system;
- User Specifications and Use Cases.

2.2.2 Architecture and Technology:

- **System Architecture** (e.g. , Client-Server, Microservices, *Cloud*);
- How does it integrate into the company's IT ecosystem?

2.2.3 Development and Implementation (MVP):

- Description of the development methodology (*Scrum* , *Kanban* , etc.);

- **Integration** and **Pilot Deployment** Process (or in a test/production environment) on the company's infrastructure.

2.2.4 **Testing and Technical Evaluation:**

- Testing Strategies (corporate: *User Acceptance Testing – UAT* , Performance, Security);
- Results that demonstrate that the solution meets the company's technical requirements and standards.

2.3 [Assessment of Impact and Contribution to the Business]

[In this section, the return on investment of time/resources for implementing the solution should be measured.]

2.3.1 **Defining Corporate Success Metrics:**

- **Project KPIs (Key Performance Indicators):** Clear definition of the metrics used to measure success (based on item 1.3);
- **Measurement Methodology:** How the data was collected to compare the "Before" and "After" of the solution.

2.3.2 **Results and Impact Analysis:**

- Presentation of the results of the solution implementation **versus the** *baseline* metrics (item 1.2);
- **Quantitative Analysis:** Demonstration of results (Ex : "The solution reduced operational costs by 15%, saving R$ X per month").

- **Qualitative Analysis:** Gains in agility, user/internal customer satisfaction, or improved decision-making.

2.3.3 Cost-Benefit Analysis:

- Estimated development/implementation costs (labor, licenses, infrastructure) ;
- Calculation of **Return on Investment (ROI)** or other financial indicators relevant to the company (e.g. , *Payback*).

2.3.4 Critical Success Factors and Lessons Learned:

- What factors contributed to or hindered the implementation and its impact on the company's results?

3 [Conclusion]

[In the conclusion, the author states whether or not the objectives set out in the project were achieved, discusses the impacts on the business, presents recommendations for the company on the evolution of the solution (new features, scalability, maintenance), and the knowledge transfer plan and technical documentation for the company's internal team]

References (mandatory item – NBR14724, item 4.2.3.1; NBR 6023)

(# References must comply with the rules of NBR6023 (Preparation of References;

Only the works consulted and cited in the text should be included in the reference list.

 # font size 12

 # prepared using single spacing;

 # aligned to the left margin of the text and without indentation;

 # separated from each other by a single blank line;

For online documents, the web address must be indicated, preceded by the expression "Available at:" and the access date preceded by the expression "Accessed on:";

The author should be indicated by their last name, in capital letters, followed by their first name and other last names, abbreviated or not; authors should be separated by semicolons.

 # When there are up to three authors, all must be listed;

When there are four or more authors, you can list all of them, or only the first one followed by the expression *et al* .

(# Examples:

Book:

[LAST NAME, First Name. **Book Title** : Subtitle. Edition. Publisher Location: Publisher, Publication Date.]

[PRESSMAN, RS; MAXIM, BR **Software Engineering** : A Practitioner's Approach. 9th ed. Porto Alegre: AMGH, 2021.]

[BASS, L.; CLEMENTS, P.; KAZMAN, R.; Software architecture in practice. 4th ed. Boston: Addison-Wesley, 2022.]

Article:

[LAST NAME, First Name. Article Title: Subtitle. **Journal Name** , Publication Location, Volume, Number, Pages, Publication Date. Available at: [electronic address]. Accessed on: [date of last access]]

[SANTOS, EH; BENITES, CS; STATERI, J. Study of artificial intelligence within the scope of PBL teaching. **Contemporary Journal** . [*S. l.*], v. 4, n. 9, p. 01-18, 2024. Available at: https://ojs.revistacontemporanea.com/ojs/index.php/home/article/view/5781/4271 . Accessed on: Oct. 27, 2025.

[VALENTE, JA; BITTENCOURT, II; SANTORO, FM; GARCIA, M.; ISOTANI, S.; GARCIA, A.; HABIMORAD, M. Project-Based Higher Education in Computing: Inteli on the path to innovation. **Brazilian Journal of Informatics in Education** , [*S. l.*], v. 33, p. 605–642, 2025. Available at: https://journals-sol.sbc.org.br/index.php/rbie/article/view/4320. Accessed on: Oct. 27, 2025.]

[VALENTE, JA *et al* . Project-Based Higher Education in Computing: Inteli on the path to innovation. **Brazilian Journal of Informatics in Education** , [*S. l.*], v. 33, p. 605–642, 2025. Available at: https://journals-sol.sbc.org.br/index.php/rbie/article/view/4320. Accessed on: Oct. 27, 2025.]

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Appendices (Optional item – NBR14724, item 4.2.3.3) (For titles without numerical indicators, see NBR 14724, item 5.2.3)

[Supporting document: text or document prepared by the author, used to support their argument and aid in understanding the main text without compromising the content presented in the body of the work. Ex : tables, reports, questionnaires, programming code, etc.]

Annexes (optional item – NBR14724, item 4.2.3.4)

[Supporting document: text or document not created by the author, but which serves as a basis, proof, or illustration of the content of the work. Ex : tables, reports, laws, manuals, etc.]