UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

ROSÂNGELA DE FRANÇA BAIL

THE USABILITY OF IMMERSIVE TECHNOLOGY: A TEACHING PROPOSAL FOR THE TECHNICAL AND TECHNOLOGICAL TRAINING OF THE FIRE DEPARTMENT OF PARANÁ STATE, BRAZIL

PONTA GROSSA

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A usabilidade da tecnologia imersiva: uma proposta de ensino para a capacitação técnica e tecnológica do Corpo de Bombeiros do Estado do Paraná, Brasil

Thesis presented as a requirement for obtaining the title of Doctor in Production Engineering, from the Post-Graduate Program in Production Engineering, at the Federal University Technology of Paraná (UTFPR).
Advisor: Prof. Dr. Ariel Orlei Michaloski.

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Trabalho de pesquisa de doutorado apresentado como requisito para obtenção do título de Doutor Em Engenharia De Produção da Universidade Tecnológica Federal do Paraná (UTFPR). Área de concentração: Gestão Industrial.

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I dedicate this work to my Lord Jesus Christ, for all the wisdom, strength, and health bestowed upon my life. I dedicate it to my daughters, Jade, Nicolle, and Kamila, for their love and patience with me.

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Whatever you do, work at it with all your heart, as working for the Lord, not for human masters, since you know that you will receive an inheritance from the Lord as a reward. It is the Lord Christ you are serving. (Colossians 3:23-24).

ABSTRACT

The usability of Immersive Technologies, represented in this work by Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), has become essential in several activities, gaining greater prominence after the SARS-CoV-2 pandemic. Since then, the use of these technologies for training has increased considerably and has become fundamental in the teaching-learning process. In specific scenarios, such as disaster management, for example, these technologies allow the simulation, study and early application of risk events and emergencies, enhancing the quality of saving lives in real situations. This study investigated the usability of the FLAIM Trainer Virtual Reality (VR) tool as an Immersive Technology for additional training of the Military Fire Department of the State of Paraná. Initially, a systematic review of the literature was carried out, using software and methodologies for organizing, classifying, and filtering bibliographic material, followed by data collection, analysis, and action research. The results of this research demonstrated that Immersive Technology is essential for a continuous, efficient and effective training of firefighters, allowing the simulation of environments and practical occurrences, providing realistic experiences, such as fires and risk situations, assisting in training for future actions, enhancing preparation for face risk situations more effectively, thus, contributing to develop a proposal for a teaching approach for technological technical training of the Military Fire Department. This research may be relevant to the following areas: production engineering, education, artificial intelligence, simulations and training, and cognitive psychology.

Keywords: disaster management; immersive technologies; virtual reality; technical and technological training; Military Fire Department.

RESUMO

A usabilidade das Tecnologias Imersivas, representadas nesse trabalho pela Realidade Virtual (VR), Realidade Aumentada (RA) e Realidade Mista (RM), tornou-se essencial em diversas atividades, ganhando maior destaque após a pandemia do SARS-CoV-2. Desde então, o uso dessas tecnologias para treinamentos para a formação aumentou consideravelmente e tornou-se fundamental no processo de ensino-aprendizagem. Em cenários específicos, como a gestão de desastres, por exemplo, essas tecnologias permitem a simulação, estudo e aplicação antecipada de eventos de risco e emergências, aprimorando a qualidade de salvaguardar vidas em situações reais. Este estudo investigou a usabilidade da ferramenta de Realidade Virtual (RV) FLAIM Trainer como uma Tecnologia Imersiva para o treinamento complementar do Corpo de Bombeiros Militar do Estado do Paraná. Inicialmente, foi realizada uma revisão sistemática da literatura, utilizando software e metodologias para organizar, classificar e filtrar material bibliográfico, seguida pela coleta, análise e pesquisa-ação de dados. Os resultados desta pesquisa demonstraram que a Tecnologia Imersiva é essencial para um treinamento contínuo, eficiente e eficaz de bombeiros, permitindo a simulação de ambientes e ocorrências práticas, proporcionando experiências realistas, como incêndios e situações de risco, auxiliando no treinamento para futuras ações, melhorando a preparação para enfrentar situações de risco de forma mais eficaz, contribuindo assim para o desenvolvimento de uma proposta de abordagem de ensino para o treinamento técnico tecnológico do Corpo de Bombeiros Militar. Esta pesquisa pode ser relevante para as seguintes áreas: engenharia de produção, educação, inteligência artificial, simulações e treinamento, e psicologia cognitiva.

Palavras-chave: gestão de desastres; tecnologias imersivas; realidade virtual; capacitação técnica e tecnológica; Corpo de Bombeiros Militar.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAPES	Coordination for the Improvement of Higher Education Personnel
CAO	Officer Enhancement Course
CBMPR	Paraná Military Fire Corporation
CFP	Enlisted Personnel Training Course
COCI	Firefighting Specialization Course
(VR)	FLAIM Trainer Reality Virtual
GB	Battalion of Firefighters
Health-EDRM	Health-Related Emergency Disaster Risk Management
IA	Artificial Intelligence
IoT	Internet of Things
OMS	World Health Organization
ONU	United Nations National Organization
PHEIC	Public Health Emergency of International
POPs	Standard Operating Procedures (SOPs)
RA	Augmented Reality (AR)
RM	Mixed Reality (MR)
RV	Virtual Reality (VR)
RSL	Systematic Literature Review
TICs	Information and Communication Technologies

SUMMARY

1 INTRODUCTION

1.1 Contextualization of the research

From 2019, in the city of Wuhan, China, the SARS-CoV-2 virus was first detected (Baker; Peckham; Seixas, 2020; Vaishya *et al*., 2020; Bail *et al*., 2021a), rapidly spreading worldwide, causing one of the most significant pandemic disasters known to humanity. Consequently, this event shattered established paradigms within health organizations, government, and various sectors of society (Singh, 2020a).

In an attempt to support the response to SARS-CoV-2, the priority was to create unprecedented treatment protocols due to it being an unknown disease at the time, both in its effects and levels of contagion. Another measure was the use of safety Personal Protective Equipment (PPE) for mass population care (high rates of hospitalizations and deaths) (Singh, 2020a).

Suddenly, there was a need to create governmental strategies through competent organizations such as the United Nations (UN) and the World Health Organization (WHO). Consequently, multidisciplinary teams comprising researchers, physicians, healthcare professionals, and industry experts (Polenta *et al*., 2020) were summoned to organize a 'task force' to better understand the virus and act efficiently (Nasajpour, 2020).

Digital technologies and tools such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, and 5G have immensely contributed throughout the SARS-CoV-2 response process. They enabled the collection of data, including the number of infections, hospitalizations, and daily deaths (Siriwardhana *et al*., 2020). Consequently, there was a need to readjust healthcare systems for databases, encompassing virus forms and mutations, telemedicine, self-service supports, patient monitoring and tracking systems, bed management centers, emergency services, and transportation activities.

Thus, emergency health protocols were developed to adopt restrictive measures on people's movement, such as lockdowns, health checkpoints, airport closures, shutdowns of industries, businesses, and the suspension of various services (Batty, 2020). All measures taken through digital technologies had a primary purpose: to mitigate the virus's spread among the population and safeguard healthcare professionals directly involved in the response efforts (Jahmunah *et al*., 2021; Popkova; Sergi, 2021; Rathee *et al*., 2021).

The world's population had to adapt to the so-called 'new normal,' meaning getting used to long periods of confinement in their homes (Al-Ogaili *et al*., 2020), avoiding contact with other family members and friends. Consequently, remote work or telecommuting, online shopping, virtual classes, and training became widespread (Hoosain; Paul; Ramakrishna, 2020). Digital technologies became essential for the daily lives of the planet's inhabitants, involving governmental, healthcare, industrial, commercial, and educational sectors (Bail *et al*., 2022).

However, according to Cui (2020), amidst the pandemic, a critical view of data organization and information - captured by integrated and interconnected healthcare systems - is crucial. In this field, the prominent highlighted technologies include IoT, AI, Big Data Analytics, and 5G (Gaire *et al*. 2020; Bail *et al*., 2020; Adeel *et al*., 2019; Sinha *et al*., 2019; Qin *et al*., 2018; Xu *et al*., 2018a; Ray; Mukherjee; Shu, 2017; Yang *et al*., 2010). Furthermore, within this context, another set of digital technologies refers to Immersive Technologies, primarily employed in the assimilation and dissemination of knowledge across different domains (Chamola *et al*., 2020b; Kumar; *et al*., 2021a; Nadian-Ghomsheh *et al*., 2021).

In healthcare, the use of digital technologies extends to patient care, logistics, and transportation of supplies, equipment management, training, and overall monitoring (Kim, 2021; Zahedi *et al*., 2021; Elavarasan *et al*., 2021; Kong *et al*., 2021).

Among the agencies capable of responding to pandemic situations and disaster cases is the Fire Department, responsible for urgent and emergency responses. Together with its Central Military Command, it develops distinct Standard Operating Protocols (SOPs) for its teams (Oskouei *et al*., 2020; Awais *et al*., 2020). But, how useful are these resources, i.e., what is the usability of such technologies, more specifically the immersive ones, for the Fire Department?

1.2 Research problem

In practical terms, how can Immersive Technology, specifically the usability of the FLAIM Trainer Virtual Reality (VR), effectively contribute to the training of students in high-risk operations within the Military Fire Brigade of the State of Paraná?

1.3 Objectives

1.3.1 General objective

The objective of this work is to investigate the usability of Immersive Technology, specifically the FLAIM Trainer Virtual Reality, in teaching for the training of the Military Fire Brigade of the State of Paraná, aiming to propose a teaching approach to complement the teaching-learning process.

1.3.2 Specific objectives

1 - Identify applications and contributions of Immersive Technologies, specifically the FLAIM Trainer Virtual Reality, for the training of the Military Fire Brigade of the State of Paraná;

2 - Assessing how immersive technologies contribute to disaster management.

3 - Identifying the usability and perceptions of Military Firefighters regarding teaching and training in VR technology;

4 - Evaluating the Curriculum Matrix of the Fire Department, proposing the integration of Immersive Technology in supplementary training;

5 - Suggesting a teaching approach for technical and technological training in the Curriculum Matrix for the Fire Department, based on this action research in the Military Fire Brigade of the State of Paraná.

1.4 Justification

The work of the Military Fire Brigade in Brazil is responsible for addressing various emergencies of different natures, such as fires, high-rise rescues, aquatic rescues, collapsed space rescues, pre-hospital care, among others.

The training of these professionals is of utmost importance due to the complexity and challenging nature of the activities they perform. In all the incidents they respond to, technical knowledge, accurate decision-making under pressure, and physical and mental aptitudes are required.

The ongoing and quality technological education of the Fire Department is essential to ensure that these professionals are prepared to face these challenging situations efficiently and safely. This is essential for the absorption of theoretical and practical teaching through pertinent actions in rescuing and aiding victims, utilizing state-of-the-art vehicles and equipment. So, it is imperative to investigate the usability of these technological resources in specific contexts such as the Fire Corporation.

1.4.1 Research delimitations

This research aims to develop and implement an immersive technology approach, integrating it into the curriculum of the Military Fire Brigade, aiming for continuous improvement in training and troop formation. This significantly fosters cognitive knowledge, aligning with military engagement in sharing practical experiences, providing timely and relevant feedback, along with metacognitive learning.

Due to the virus's lethality and rapid spread, it brought about the necessity for quick adaptation (protocols) presented by leading global health organizations and frontline professionals in attending to patients infected with the disease.

Similarly, digital technologies, initially prevalent across various sectors of society such as Government, Industry, University, and Society (Li *et al*., 2021; Bail, 2019), were initially created with characteristics focused on industrial processes, logistics, and databases. Subsequently, they were redirected towards gaming, entertainment, and well-being (Henry *et al*., 2021; Kim *et al*., 2014). After the pandemic, they underwent restructuring to accommodate and serve areas such as healthcare, education, among others.

Thus, digital technologies (IoT, AI, Big Data Analytics, 5G, VR, and AR) have contributed to Disaster Management in the COVID-19 Pandemic. Initially, these were directed towards major global health organizations and frontline professionals in the care of patients infected by the disease. As a result, the potential benefits of each technology will be mapped, focusing on the contribution of immersive technologies to firefighters' training.

During the research, a shortage of articles exploring the correlation between Internet of Things, Digital Technologies, Disaster Management, Virtual Reality Equipment, and the Fire Department was observed. None of these articles specifically highlights immersive technologies aimed at training military firefighters.

This project was submitted to the Research Ethics Committee of UTFPR through the Plataforma Brasil. It was approved under the number CAAE 53739221.7.0000.5547, as shown in Figure 1.

Figure 1 - Approval of the research project on the Plataforma Brasil

LISTA DE PROJETOS DE PESQUISA:

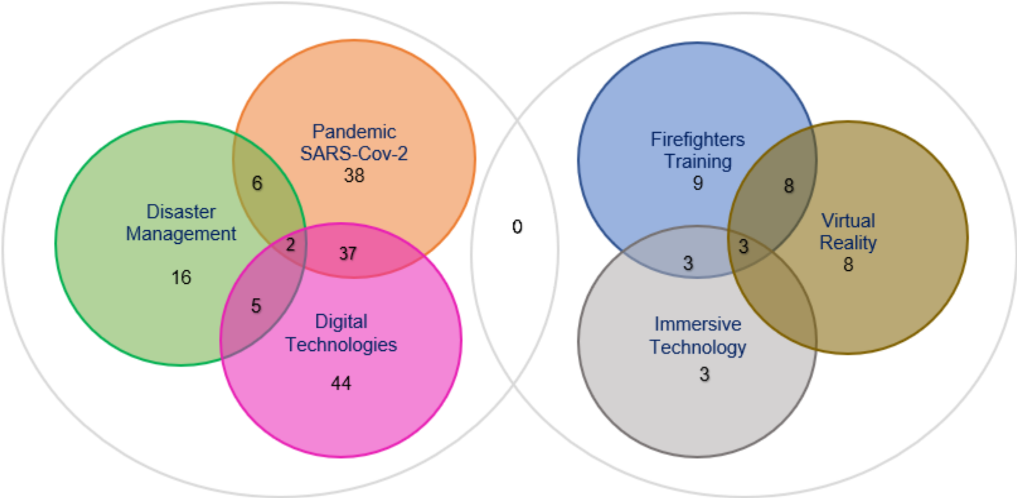
ipo	CAAE	Versão	Pesquisador Responsável	Comitê de Ética	Instituição	Origem	Última Apreciação	Situação	Açã
›	53739221.7.0000.5547	2	Ariel Orlei Michaloski	5547 - Universidade Tecnológica Federal do Paraná		PO	PO	Aprovado	

Source: Own authorship (2023).

1.4.2 Originality, innovation, and relevance of the study

The uniqueness of this research is validated by the peculiarities not found in other works during the systematic literature review (Figure 2), confirming the research's originality. Searching the keywords Disaster Management, SARS-CoV-2 Pandemic, Virtual Reality, Immersive Technology, Fire Department in databases such as Web of Science, Scopus, and Science Direct yields a significant number of articles. However, when combined, this number of works substantially decreases the results. Searches were also conducted in CAPES directories of Theses and Dissertations in a complementary manner.

Figure 2 - Research results on different topics



Source: Own authorship (2023).

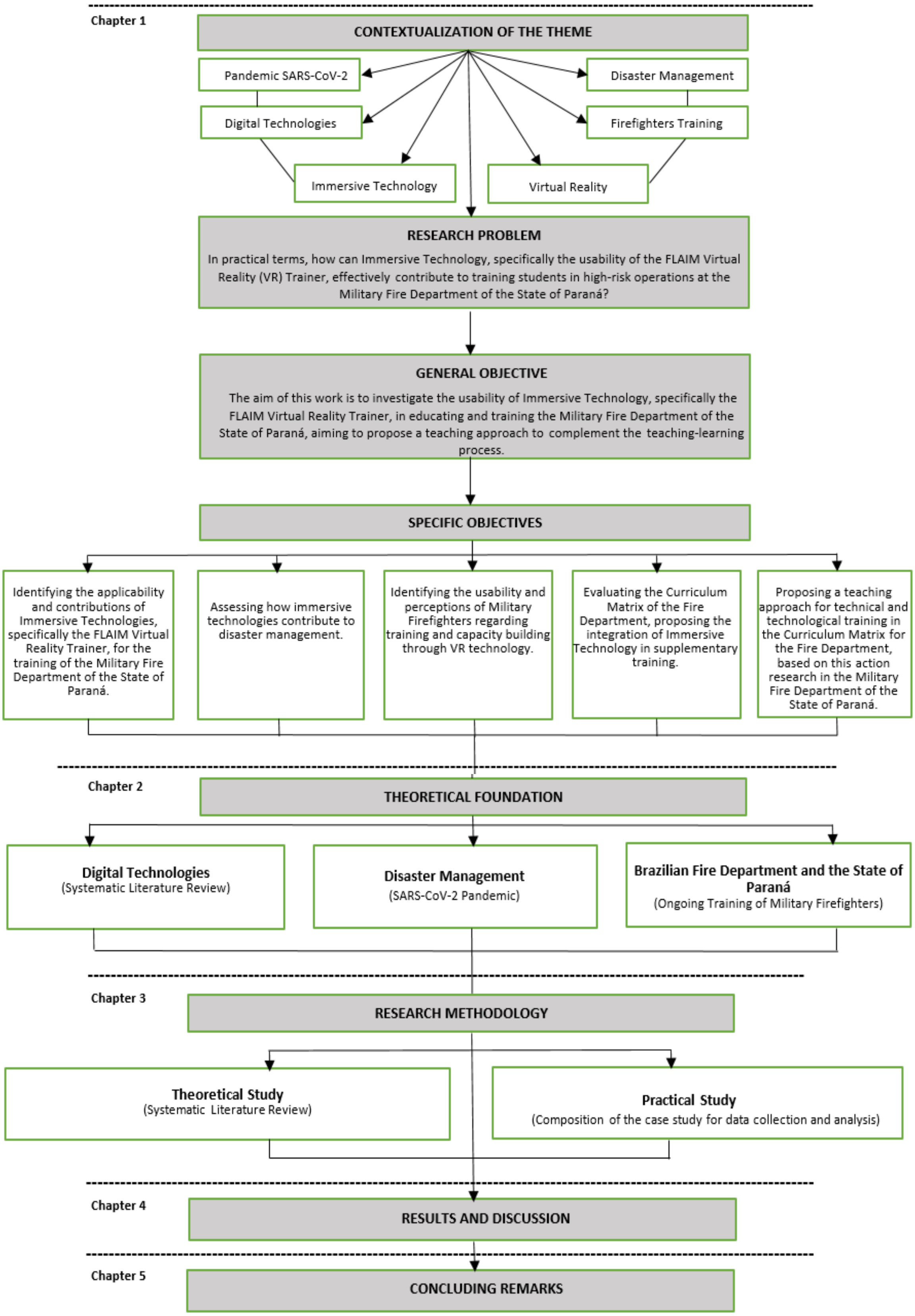
In Figure 2, keyword combinations are represented, indicating the quantity of articles found in the main databases and their intersections. Although few works were found involving the target keywords (Pandemic SARS-CoV-2, Disaster Management, Digital Technologies, Firefighters, Virtual Reality, and Immersive Technology), it is evident that this research remains unprecedented (as it has not been identified in any of the previously published articles), original in its peculiarities, and robust.

This work is relevant to contribute to proposing a teaching approach that complements the curriculum training of firefighters, encompassing the academic, military, and pedagogical community. It may involve aspects of metacognition that integrate contemporary teaching with innovative Immersive Technology, using resources such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). In this way, it offers firefighters a more comprehensive theoretical-practical education, with the potential for expansion to other organizations in the future.

1.5 Structure of the Work

The structure of this work is organized into five chapters, as illustrated in Figure 3.

Figure 3 - Flowchart of the work structure



Source: Own authorship (2023).

Chapter 1 presents the contextualization of the topic, introducing the research problem, objectives, and study justification.

Chapter 2 brings the Theoretical Framework, defining: - Characteristics associated with Digital and Immersive Technologies (IoT, AI, Big Data Analytics, 5G, VR, AR, and MR); - Disaster Management, with a special focus on the SARS-CoV-2 Pandemic; and - The Brazilian Fire Department and the Fire Department of the State of Paraná (Continued Military Training), encompassing its history, roles, trainings, and other specificities.

Chapter 3 introduces the Research Methodology, structured into two subsections: the theoretical study (systematic literature review) and the practical study (action research and instruments for data collection and analysis).

In Chapters 4 and 5, present the Results and Discussion sections, which contends the necessity of a theoretical-practical study on Immersive Technologies used by the Fire Department and the need to propose a teaching approach that encompasses Immersive Technology in the Curriculum Matrix of CBMPR.

Finally, Chapter 6 includes the Final Remarks, and the Bibliographic References.

2 THEORETICAL BACKGROUND

There is a highlighted need for ongoing training based on emerging virtual technologies, aiming to provide specialized and quality education. The goal is to empower professionals to handle complex and challenging situations, emphasizing the importance of an effective teaching, and learning approach.

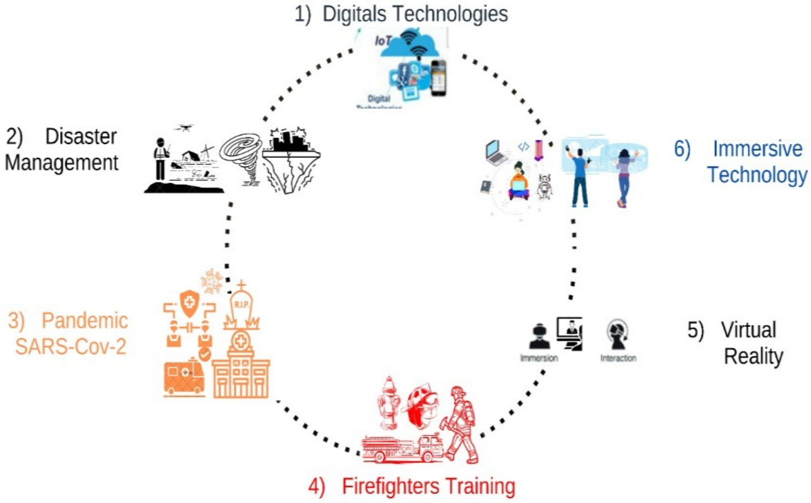
The proposed technological and technical training, based on technological and immersive education, incorporates relevant theories such as cognitive learning in virtual environments, automatic feedback of actions, and meaningful learning derived from practical experiences in virtual environments.

The priority lies in continuous, impactful, and engaging education that leads to meaningful learning, enabling them to act swiftly, decisively, and safely, as evidenced throughout this work.

2.1 Digital and Immersive Technologies

Known as Digital Technological Systems, technological clusters, or digital technologies (Alsunaidi *et al.*, 2021), artificial intelligence, IoT, Big Data Analytics, cloud computing, and 5G operate within integrated systems and communication networks. They allow data science to be analyzed and processed with the purpose of obtaining information that benefits organizations (Figure 4).

Figure 4 - Digital technologies and some of their applications



Source: Own authorship (2023).

Figure 4 exemplifies one of the applications of digital technologies, namely, the use of IoT, Big Data Analytics, cloud computing, 5G, and Immersive Technologies (mainly represented by VR and AR) in the healthcare sector (first aid, SAR-CoV-2 Pandemic, and Disaster Management).

Table 1, in turn, highlights the main authors describing how digital technologies can assist citizens in their lives.

Frame 1 - Main authors of studies on digital technologies

Terms	Authors
Internet of Things	Mubdir (2022); Nguyen *et al*. (2022); Paganelli *et al*. (2022); Park (2022); Bibi *et al*. (2020); Vaishya *et al*. (2020); Chamola *et al*. (2020a); Singh *et al*. (2020a); Nasajpour *et al*. (2020); Singh *et al*. (2020b); Swayamsiddha (2020); Javaid; Khan (2021); Jain *et al*. (2021); Vedaei *et al*. (2020); Hoffman (2020); Bokolo (2021); Alsamhi, (2020); Kumar (2020); Zhu *et al*. 2020; Hassen; Ayari; Hamdi (2020); Jahmunah *et al*. (2021); Lanza (2020); Asadzadeh ; Samad-Soltani ; Rezaei-Hachesu (2020a); Barroca Filho *et al*. (2021); Abuelkhail *et al*. (2021); Parikh *et al*. (2020)
Artificial Intelligence	Ahmed (2022); El-Sherif, *et al*. (2022); Kollu, *et al*. (2022); Imran *et al*. (2020); Nguyen *et al*. (2021); Li *et al*. (2021); Gunasekeran, *et al*. (2021); Kumar (2020b); Khan, *et al*. (2021); Wang, *et al*. (2021b); Xu, *et al*. (2021c); Wang, *et al*. (2021d); Alhasan; Hasaneen (2021); Jabarulla; Lee (2021)
Big Data Analytics	Alsunaidi *et al*. (2021)
5G Technology	Alhayani, *et al*. (2022); Chamola *et al*. (2020); Siriwardhana, *et al*. (2020); Alsamhi, *et al*. (2021)
Immersive Technologies, defining VR, AR, and MR	Lorusso, *et al*. (2022); Bliss; Tidwell; Guest (1997); Cha at al. (2012); Xu, *et al*. (2014b); Menin, Torchelsen and Nedel (2018); Engelbrecht, Lindeman, Hoermann (2019); Shi, *et al*. (2021)

Source: Own authorship (2023).

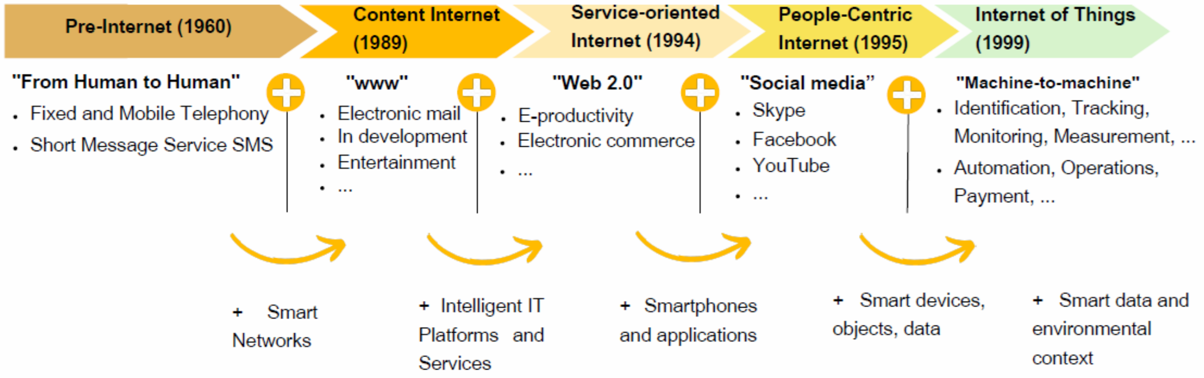
Through digital technologies, there has been the possibility of fluidity of data, connections, and decision support, which expanded the format of healthcare treatment and various other sectors.

2.1.1 IoT - Internet of Things

The Internet of Things (IoT) can be defined as the technological and virtual enablement of physical objects, such as smartphones, clothing, accessories, and equipment (Ceballos, 2021). This is achieved through the interaction between devices, objects, communication networks, and data control systems, which capture information via sensors in a prompt and real-time manner (Singh, 2020b).

In other words, IoT can be defined as 'a network of connections through sensors and application programming interfaces (Cho; Kim, 2016; Arêas; Peixoto, 2020) linked to physical objects (software and sensors), collecting data and information directly connected to the internet.' It enables objects and equipment to be remotely connected and controlled within their existing structural networks, integrated into physical/real and virtual scenarios efficiently, swiftly, and economically. Figure 5 depicts an evolutionary historical context of IoT.

Figure 5 - The evolution of the Internet of Things



Source: Own authorship (2023).

Created initially to improve productivity, energy efficiency, sustainability, and enhance users' quality of life (Lee *et al*., 2017), IoT was designed to facilitate communication and data acquisition, transforming the paradigm of digital tools and embedded technology (Elagan *et al*., 2021). Another advantage of IoT is its ability to minimize decision-making time (Gubbi, 2013). To achieve this, the technology incorporates products with sensors or identifiers into internet networks with particular IP addresses, allowing thousands of objects to connect with other interfaces.

According to Figure 5, communication became a substantial element for humanity. Over time, in its evolutionary process, it brought comfort, security, and agility to information. The internet, a tool created for these purposes, had its precursor in the American security department in 1962, during the "Cold War" between the US and the Soviet Union (Russia). Its pioneer and developer were the political scientist Joseph Carl Robnett Licklider (Kita, 2003), as the military's concern was data protection and strategies. From then on, research was expanded, fostering new technological advancements in the internet.

Therefore, industrial systems (Shalabi, 2020), strategically immersed in certain digital technologies and tools (Bail *et al*., 2020a; Da Xu *et al*., 2014b; Lee *et al*., 2015; Han *et al*., 2019, Hu *et al*., 2014), could broaden their perspective on clean production and circular economy, promoting, from their early installations, ecologically friendly mechanisms, and disaster management prevention.

In 2019, with the emergence and spread of the SAR-CoV-2 (Roh *et al*., 2021; Chamola *et al*., 2020a), projects for the development of digital technologies were, for some time, put on hold due to the arrival of an unprecedented global pandemic (Mubdir, 2022; Nguyen *et al*., 2022; Paganelli *et al*., 2022; Bibi *et al*., 2020). Severe restriction measures were quickly adopted for the entire population, and various activities were halted by global health organizations (Javaid; Khan, 2021; Jain *et al*., 2021). Consequently, healthcare emergency services had to adapt to new protocols for attending to pandemic victims, as did other services provided to the entire community.

2.1.2 Artificial Intelligence

The artificial intelligence was created in the 1950s at Carnegie Mellon University by scientists Herbert Simon and Allen Newell with the aim of developing an academic laboratory that would support the storage of large amounts of data (Mendes, 2022). Thus, technological advancements have brought transformations in industries and the service sector, prominently demonstrated after the advent of Industry 4.0, in areas such as Healthcare (Alhasan; Hasaneen, 2021; Elavarasan *et al*., 2021), Biotechnology, Logistics, Engineering, and Information and Communication Technologies (ICTs).

The official health agencies, for instance, enabled, through Artificial Intelligence (AI), the integration of emergency healthcare services (Javaid; Khan, 2021; Aazam; Zeadally; Flushing, 2021; Bail *et al*., 2022), connecting billions of devices in the concept of Health 4.0, applications, data collection sensors, patient information databases, georeferencing (Leiras *et al*., 2017; Xu *et al*., 2014b; Menin, Torchelsen; Nedel, 2018), hospital bed centers, emergency transport, medical supplies, and logistics.

2.1.3 Immersive Technologies

Immersive technology was initially created for entertainment by Morton Heilig in 1950, who developed a prototype of multisensory immersive technology called the "Sensorama" (Jones; Dawkins, 2018). It was a cabin (machine) that produced moving 3D colour images (stereoscopy), including internal devices capable of emitting stereo sound, aromas, wind, and vibrations. This technology gave users the sensation of riding a motorcycle through Brooklyn (USA), as seen in Hollywood movies.

Over the years, stemming from technological innovations such as IoT, 5G, AI, among others, Immersive Technologies demonstrate applicability in various sectors and purposes, including commercial, service-based (health and education), and industrial. Immersive technology can be interpreted as the ability of a process or device to create the illusion of immersion, altering a person's mental state to replace aspects of real spatial perception (Cardia; Affini, 2019).

As part of immersive technology, there are Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR). Augmented Reality involves overlaying virtual objects or components onto a real environment, allowing users to see these objects either statically or dynamically (Mokmin; Ridzuan, 2022). Virtual Reality (VR) immerses users in a virtual setting replicating specific real-world features (Mokmin; Ridzuan, 2022). Finally, Mixed Reality is a blend of both augmented and virtual realities (Mallam; Nazir; Renganayagalu, 2019).

The use of immersive technology can be regarded as one of the safest and most cost-effective methods in conducting hazardous activities, such as firefighter training and other professions (Slater; Sanchez-Vives, 2016; Menin, Torchelsen; Nedel, 2018; Suh; Prophet, 2018). Additionally, immersive virtual reality maintains its pedagogical nature in the form of games and training, providing users with augmented realism experiences, increased engagement, and motivation for learning.

Individually, the outcome of this immersion is the ability to perceive, feel, and cognitively process information that otherwise wouldn't be available (Suh; Prophet, 2018). Consequently, these technologies enhance users' cognitive abilities, such as reasoning, memory, and supervision, promote engagement in collaborative activities, and improve learning experiences (Suh; Prophet, 2018). In training, for instance, immersive technologies enable the instructor to replicate a variety of real locations within the confines of a classroom (Mokmin; Ridzuan, 2022). In this context, students and professionals are exposed to more dynamic scenarios in a facilitated manner (Mokmin; Ridzuan, 2022).

In Table 2, the main studies with applications of immersive technologies in various areas and sectors, such as training, irrespective of the professional field, are cited.

Frame 2 - Key Studies on Immersive Technologies in Education

Author, year	Title	Contribution
Baroroh; Agarwal, 2022	Immersive Technologies in Indonesia Faces "New Normal" COVID-19	Study on the use of immersive technologies (VR, AR, and MR) in Indonesia during the post-SARS-CoV-2 pandemic period.
Fracaro, 2022	Immersive technologies for the training of operators in the process industry: A Systematic Literature Review	Immersive technologies used for training and safety in the chemical industry. Following the PRISMA method, a comparison was made between conventional and immersive teaching methods.
Sandoval-Henríquez; Badilla-Quintana, 2022	How elementary students experience the use of immersive technology	Report of results from the use of immersive technologies in primary education for Chilean students, highlighting interactivity, attendance, and student retention due to increased motivation and facilitated learning.
Kaur, 2022	The Role of Interactive and Immersive Technologies in Higher Education: A Survey	Studies related to immersive technologies (VR, AR, Gamification) in the education of undergraduate engineering students. The relevance of this article demonstrates the confirmed improvement in higher education performance.
Mokmin and Ridzuan 2022	Immersive Technologies in Physical Education in Malaysia for Students with Learning Disabilities	Development of an application using the Optimal Motor Learning Theory and the Cognitive Theory of Multimedia Learning to assist students with intellectual deficits in Physical Education.
Mosher, 2022	Immersive Technology to Teach Social Skills to Students with Autism Spectrum Disorder: A Literature Review	Report on the applicability of digital technologies and tools used in developing skills and relationships for students with autism spectrum disorder (ASD). The main technologies employed were AR, VR, MR, and Extended Reality (XR), featuring dynamic content in audio and videos.
Pears and Konstantinidis,2022	The Future of Immersive Technology in Global Surgery Education	Report on the use of Artificial Intelligence (AI) technologies in higher education in medicine.
Ryan, 2022	Learning Outcomes of Immersive Technologies in Health Care Student Education: Systematic Review of the Literature	The study presents a comparison between conventional in-person learning and remote learning processes for students in health-related fields. Additionally, it discusses limitations and gains achieved.
Soroko, Lytvynova, 2022	The Benefits of Using Immersive Technologies at General School	Benefits of immersive technologies in the field of Education, highlighting creativity, spatial geometry, neuropsychological stimuli, knowledge assimilation, among others.
Osypova, 2021	Implementation of Immersive Technologies in Professional Training of Teachers	The study seeks to theoretically justify the use of immersive technologies in semi-presential education processes. One of the purposes is to support the optimal utilization of technologies and digital tools in teaching.

Ovunc, 2021	Using Immersive Technologies to Develop Medical Education Materials	Focus directed at the use of immersive technologies in the theoretical and practical teaching of surgical doctors.
Proniewska2021	Immersive technologies as a solution for general data protection regulation in Europe and impact on the COVID-19 pandemic	The study aims to demonstrate how the HoloView app (Microsoft HoloLens) can be applicable in-patient care, in Europe, affected by SARS-CoV-2 (case report).
Silva-Díaz, 2021	Use of immersive technologies and their impact on the scientific-mathematical attitudes of Secondary Education students in a context of risk of social exclusion	Impacts of virtual reality (VR) technology usability in elementary and high school education.
Tscholl, Morphew, Lindgren, 2021	Inferences on enacted understanding: using immersive technologies to assess intuitive physical science knowledge	The study aims to evaluate the positive impacts of immersive technologies in the academic and scientific environment, among teachers and researchers.
Whewell, 2021	Digital Learning Across Boundaries (DLAB): Immersive technologies supporting changemaking in an international context	Perceptions of 11 and 12-year-old students regarding education using immersive technologies showed significant improvements in their learning process, including benefits such as empathy development, intercultural understanding, and enhanced knowledge absorption speed, among others.
Dinh; Furukawa; Caruso, 2020	The virtual visit: Using immersive technology to visit hospitals during social distancing and beyond	Accounts of the challenges faced by medical residency students during the periods of the SARS-CoV-2 pandemic, due to social distancing and other imposed health restrictions.
Newbutt, 2020	The possibility and importance of immersive technologies during COVID-19 for autistic people	Research based on the opinions of experts in autism spectrum disorder (ASD) regarding how Virtual Reality technology can assist in education.
Pears, 2020	Role of immersive technologies in healthcare education during the COVID-19 epidemic	Immersive technology enabled the creation of applications and new devices in the field of Education. This study presents these capabilities.
Mallam; Nazir Renganayagalu, 2019	Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies	In this study, simulation equipment created through Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) technologies is addressed, focusing on training in the maritime sector.
Blyth, 2018	Immersive technologies and language learning	The study aims to highlight the main trends in emerging technologies for education, including intelligent machines, media ecology, and other language-based educational devices.
Suh; Prophet, 2018	The state of immersive technology research: A literature analysis	The study addresses the applications of immersive technologies in various sectors, such as educational environments, marketing, business, and healthcare. It is a literature review.
Anscombe, 2015	A different view: In Europe, virtual and immersive technologies are starting to change the landscape of medical simulation	The proximity to reality provided by Virtual Reality (VR) allows cardiac surgeons, teachers, and students to simultaneously operate in

		different locations for diagnosis, treatment, and disease assessment.
Shelton; Uz, 2015	Immersive technology and the elderly: A mini review	The research is based on the use of immersive technologies by elderly individuals, assessing the performance of technologies in forms of games, simulators, and social technologies, as well as their implications on motor and sensory coordination (hearing, vision, skills) from a cognitive and social perspective.

Source: Own authorship (2023).

Immersive technologies have been the focus of studies in teaching students at elementary and high school levels (Osypova, 2021; Silva-Díaz; Carrillo-Rosúa; Fernández-Plaza, 2021; Whewell, 2021; Sandoval-Henríquez; Badilla-Quintana, 2022; Soroko; Lytvynova, 2022), training healthcare professionals (Anscombe, 2015; Pears, 2020; Dinh; Furukawa; Caruso, 2020; Ovunc, 2021; Baroroh; Agarwal, 2022; Pears; Konstantinidis, 2022) such as medical students, surgeons, nurses, and providing support in healthcare settings (Proniewska, 2021). Other studies are focused on autism spectrum disorder (Newbutt, 2020; Mosher, 2022), intellectual disability (Mokmin; Ridzuan, 2022), and the elderly (Shelton; Uz, 2015), mainly offering contributions that can enhance learning and/or the health of individuals with these special needs or characteristics (in the case of the elderly).

Another group of studies also showcases the use of immersive technologies in sectors such as service industries (Bail, 2022), chemistry (Tscholl; Morphew, Lindgren, 2021), academia, scientific (Fracaro, 2022), maritime (Mallam; Nazir; Renganayagalu, 2019), and various other sectors (Suh; Prophet, 2018), mainly focusing on professional training.

Over the years, stemming from technological innovations (E-Health, IoMT, 5G, IoT, AI, among others), immersive technologies have demonstrated applications in various sectors and purposes, including commercial, services (health, education), and industrial.

As part of immersive technology, we have Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR). Augmented Reality involves the overlay of virtual objects or components onto a real environment, allowing users to view them statically or dynamically (Mokmin; Ridzuan, 2022). The use of immersive technology can be considered one of the safest and most cost-effective methods for performing hazardous activities, such as training for firefighters and other professionals (Slater;

Sanchez-Vives, 2016; Menin; Torchelsen; Nedel, 2018; Suh; Prophet, 2018). Furthermore, immersive virtual reality maintains its pedagogical feature in the form of games and training sessions, providing users with increased realism, engagement, and learning motivation.

The result of this immersion is the ability to perceive, feel, and cognitively process information that would otherwise not be available (Suh; Prophet, 2018). Consequently, these technologies enhance users' cognitive abilities such as reasoning, memory, and supervision, promote participation in collaborative activities, and improve learning experiences (Suh; Prophet, 2018).

In training, for example, immersive technologies allow the instructor to replicate a variety of real locations within the confines of a classroom (Mokmin; Ridzuan, 2022). Learning using immersive technologies generates enhanced simulated or purely artificial environments. In this context, students and professionals experience more dynamic scenarios in a facilitated manner (Mokmin; Ridzuan 2022).

The usability of VR-based technologies proposes a taxonomy of different levels of learning. Thus, it establishes levels of knowledge that allow for efficient training, cross-cultural encounters, and faithful reproduction of established environments, times, and conditions (Ruscella; Obeid, 2021). For educational purposes, VR equipment was introduced through entertainment technology in the form of games, gradually transitioning to distance education and in-person teaching (post-pandemic).

On the other hand, the idea of using immersive education (Wang, 2003e; Heldal, 2004) in cognitive processes (metacognition) can significantly enhance learning aspects for those involved in the educational process. By utilizing immersive technology in training, for instance, it's possible to measure performance through self-reports and field observations.

2.2 Immersion Technologies in Firefighters' Training

The official health agencies, through Artificial Intelligence (AI) and other digital technologies, enabled the integration of emergency care services (Bail *et al.*, 2022; Javaid; Khan, 2021; Aazam; Zeadally; Flushing, 2021), leading to advantages such as patient monitoring, rescue services, material transportation, among others.

In Brazil, the inclusion of immersive education has thus aimed to stimulate the five senses in terms of breadth and depth, encompassing virtual and remote spaces along with tactile, olfactory, and auditory systems (Steuer, 1995; Waterworth; Waterworth, 2003). Overall, immersive technology, connected with gaming, wellness, education, industry, and science, is gradually transitioning to the corporate sphere, notably highlighting its benefits:

- Digital evolution of the product and brand.
- Engagement and innovation of intangible assets.
- Actions and preservation of continuous improvement.
- Savings on training (transportation, meals, accommodation, human capital, vehicles, and equipment).
- Minimization of errors through learning in repetitive action processes.
- Reduction of waste; and
- Decrease in risks and hazards for employees.

Therefore, immersive technology was introduced in an unprecedented way in Latin America in the military field by CBMPR in 2021. In Brazil, specifically, this work has also contributed to make it well known as a training tool in the Military environment. Through the General Command and the Laboratory of the Fire Department's Higher School, the (VR) simulator was acquired during the pandemic with the aim of facilitating and promoting regional training for over 3,200 professionals (Figure 6).

Figure 6 - The Arrival of the FLAIM Trainer VR Simulator in Brazil - State of Paraná

Source: Own authorship (2023).

These benefits not only positively impact CBM PR's training but also foster significant advancements in other sectors. The author meticulously researched and analyzed this data to provide a solid foundation for the conclusions and insights presented in the subsequent chapters up to Chapter 3.

2.2.1 Technology (VR): virtual reality simulator

After numerous studies, the Fire Department's General Command opted to acquire a Virtual Reality apparatus to provide supplementary firefighting training, aiming at the safety of Firefighters training. In this context, involving the Fire Department, education in the form of training may be supported by the use of technology. Immersive technologies can complement technical education, which may contribute to allow classes and training sessions to be more dynamic and productive.

In Jánošíková and Zábovská (2021) and Bail *et al*. (2022), Virtual Reality (VR) technology is elucidated. The FLAIM Trainer was developed by Deakin University - Australia, emerging from a startup's 10 years of research endeavouring to create an immersive technology apparatus aimed at facilitating firefighter training (Jánošíková; Zábovská, 2021; Bail *et al*., 2022; Napthali, 2022). It's a fire combat simulator based on VR technology, incorporating interconnected elements and devices (hardware, software, and sensors) linked to smartphones, tablets, glasses, and wearable technologies, as depicted in Figure 7.

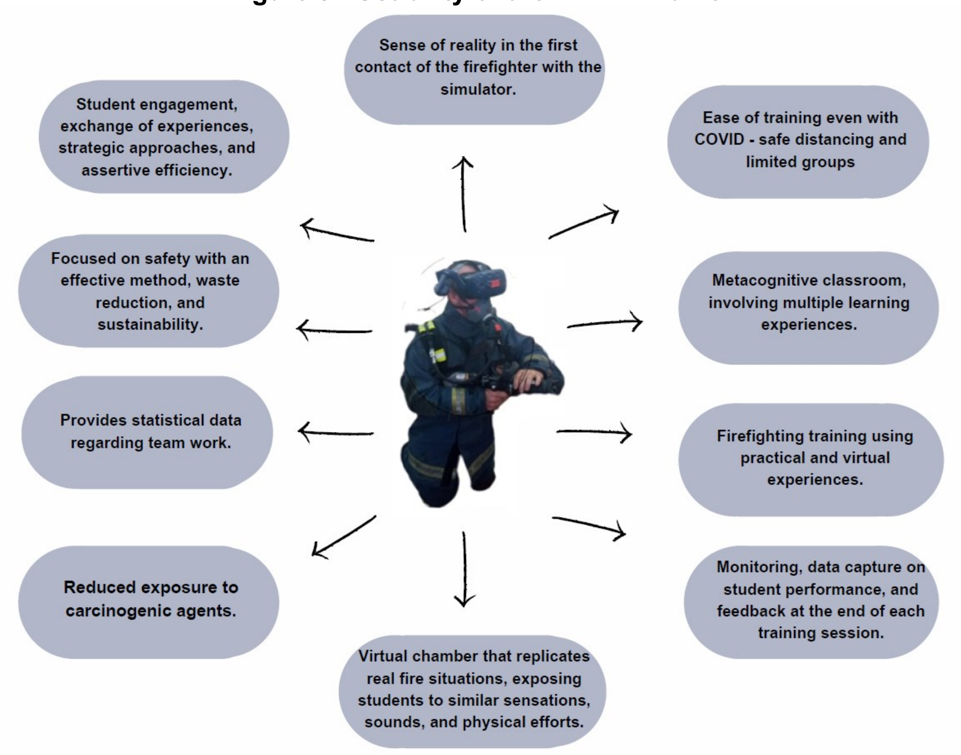
Figure 7 - Components of the (VR) simulator

Source: Adapted by the author (2023) from FLAIM (2023).

As mentioned previously, in Brazil, the inclusion of immersive education in firefighter training was introduced in an unprecedented way in Latin America by the Military Fire Department of the State of Paraná in 2021. This groundbreaking initiative is gaining recognition through this research, facilitated by the General Command and the Laboratory of the Higher School of Firefighters.

The simulator offers immersion in environments and challenges encountered during firefighters' work, aiming to familiarize them with the scenarios experienced in fire interventions. Immersive technologies encompass stimulating users through elements (sounds, temperature, vibrations, vision, movement, and displacement) to facilitate knowledge assimilation and learning, as depicted in Figure 8.

Figure 8 - Usability of the FLAIM Trainer



Source: Adapted by the author (2023) from FLAIM (2023).

The advantages outlined in Figure 8 highlight how immersive training, conducted through VR, can offer students innovative learning experiences. Other benefits can be detailed in Table 3.

Frame 3 - Advantages and Autonomy of Virtual Reality-based Immersive Technology

Aspect	Advantages
Safety and Health	- Reduces the risk of accidents during training. - Expands geospatial awareness of risk and fire scale. - Eliminates unnecessary exposure to carcinogenic agents.
Economic	- Increases training capacity for teams. - Versatility in transporting it to fire stations. - Minimizes logistical and specialized labour costs.
Environmental	- Reduces carbon emissions. - Prevents PFAS discharge. - Saves water consumption. - Eliminates runoff contamination.

Source: Own authorship (2023).

Within the aspects outlined in Table 3, it's evident that sustainability, user safety regarding risks, and the flexibility to engage in training sessions draw attention to the importance of the tool itself.

Finally, it's worth noting that other technologies already observed in this field include Effect XR, the LUDUS simulator, NAFFCO ARFF system, ADMS-Fire, RiVR programming, the First Responder Operation app by PIXO VR, and the ViRpa project (Grabowski; Jach, 2021).

2.3 Metacognition

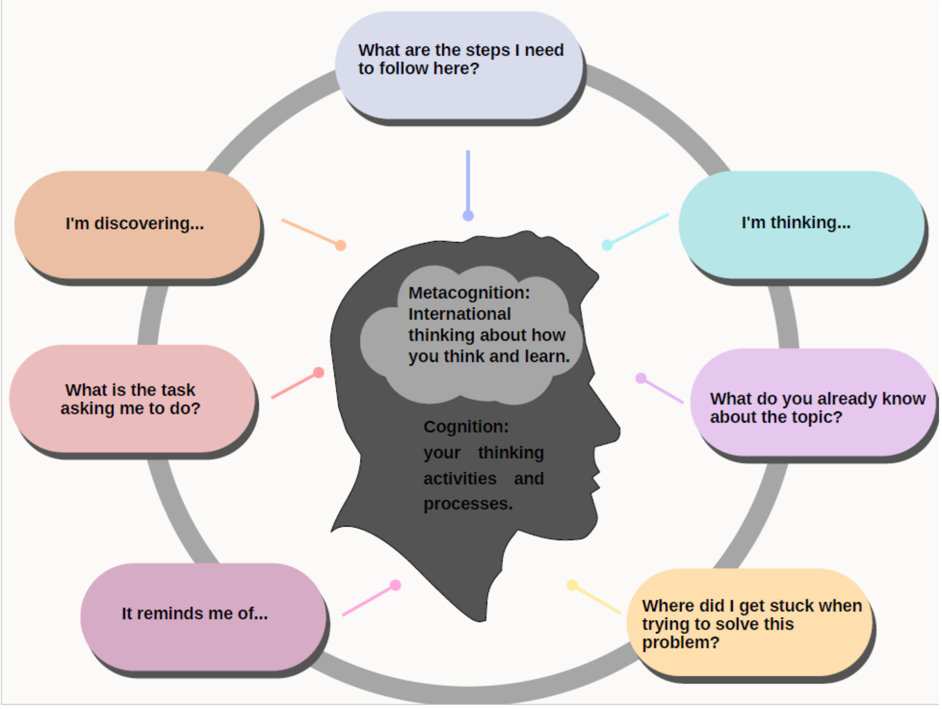
Metacognition can be understood as the ability to self-regulate and monitor cognitive processes (Ribeiro, 2003; Azevedo, 2020), stimulating intrinsic traits of reflective self-assessment associated with human learning, referencing past experiences, thereby enabling coordinated task performance. It's essentially the capacity to introspectively reprogram and regulate ideas and activities to be executed (Veenman *et al*., 2006; Peixoto; Brandão; Santos, 2007).

Neuropsychopedagogical plays a substantial role in the educational field, making it possible to elucidate cognitive processes (Figure 9, for example), by defining:

> […] education must update itself to the new precepts of neurology and neuropsychology in order to link these new neurobiological components to the sociocultural and psychosocial components already consistently embraced by education (Riechi, 1996, p. 1).

Thus, Figure 9 demonstrates how metacognition operates in brain areas to develop, stimulate, and connect the individual to learning mechanisms.

Figure 9 - Metacognition and cognition in the neurotransmission of learning



Source: Own authorship (2023).

According to Shea and Frith (2019), addressing the metacognitive aspects integrated into education and grasped by the human mind becomes necessary to assess elements of neuropsychopedagogical (Flavell; Wellman, 1975; Baddeley, 1992; Fleming *et al*., 2010; Donahue *et al*., 2018). Initially observed in medicine, specifically in brain anatomy or the prefrontal cortex region-being the most expanded area responsible for learning absorption-it's also seen as the gateway between sensory representations.

Through research on metacognition, it was possible to assess how the mind observes, captures information, and translates it into knowledge and skills, capable of organizing mental structures with various cognitive processes. The research is grounded in the neuropsychopedagogical region, seen as one of the "executive functions" (Schraw; Dennison, 1994; Corso *et al*., 2013; Drigas; Mitsea; Skianis, 2022). Table 4 presents the main terms and their meanings in the field of metacognition.

Frame 4 - Metacognition and the key terms used

Terms	Meanings	Authors
Cognitive actions	Language, memory, and attention.	Flavell, Wellman (1975)
Cognitive objective	Understanding the exact moment when learning occurs through readings, stimuli, and knowledge.	

Metacognitive experiences	Refers to the sensations emitted during the learning process. Often, one learns many things without even realizing the learning process.	Baddeley (1992) Schraw; Dennison (1994) Reich; Benbasat (1996) Kruszielski (1999) Ribeiro (2003) Peixoto; Brandão; Santos (2007) Veenman *et al*. (2006) Fleming *et al*. (2010) Corso *et al*. (2013) Fonseca (2016) Donahue *et al*. (2018) Shea; Frith (2019) Azevedo (2020) Drigas; Mitsea; Skianis (2022).
Metacognitive knowledge	Understanding clearly how metacognition is functioning (self-assessment of learning).	
Person variables - how one learns	- Universal characteristics: related to emotions, experiences, facilitating a faster absorption of content. - Interpersonal characteristics: the learning process differs between introverted and extroverted individuals. - Intrapersonal characteristics: establishes individual mechanisms, creating connections to learn-when listening, when seeing, or when creating a visual scheme-seeking to assimilate information more easily	
Metamemory	Ability to activate one's own memory and think about it.	
Metacognitive awareness	Ability to stay focused and think about thinking.	
Global workspace	Current available awareness focused on working memory, task execution, criticality, and values regarding previously acquired knowledge and skills.	
Global transmission	Domain-specific systems that enable contact between the workspace and metacognition, allowing for the connection of conscious and unconscious information, regardless of whether memories have been experienced or not.	

Source: Own authorship (2023).

As per Table 4, the terms were created to facilitate understanding about the mental capacities developed by metacognitive elements, aiming to enhance the way of learning: How to learn? Why learn? and Which facilitating pathways to follow?

Metacognition presents itself as a science of education, introducing cognitive elements in virtual formats that, in turn, establish mechanisms of self-assessment in knowledge absorption. It elaborates on the anatomy and physiological mental connections (in the cerebral cortex and prefrontal region) responsible for learning (Santos, 2017) and connected to neurolinguistics (speech and interpretation).

In the present time, following the post-pandemic era, significant advancements have occurred due to sanitary regulations, non-gathering protocols, and lockdowns.

The deepening of research on metacognition can be observed across various sectors: education, industry, research, and governance. The aim is to expedite studies that would typically take 5 to 7 years, adapting them for more immediate use. Notably highlighted are the cognitive approaches to learning (Gomes, 2023).

This is how remote, hybrid, and virtual EAD (Distance Learning) extended from primary education to universities, in remote classes composed of playful and innovative elements. Initially, they faced resistance and difficulties from both students and teachers, gradually adapting to the reality and needs experienced.

2.3.1 Immersion through virtual reality

At first, VR began in entertainment industries (games), but swiftly gained worldwide traction in concepts like "Smart Factory" (Industry 4.0), "Smart Cities," "E-commerce," and digital marketing, as well as in healthcare for high-quality knowledge generation and teaching-learning processes.

Considered an "advanced user connection," Virtual Reality (VR) provides access to computer devices, enabling the visualization and real-time three-dimensional movement of environments, creating interaction among programmable elements (Kirner; Kirner, 2011). It enriches and stimulates the five senses within the learning process, through accelerated cognition that enhances knowledge acquisition.

Virtual Reality (VR) can be defined as a communication medium that delivers synthetic sensory stimuli through physical immersion, enabling the user to mentally engage interactively within a virtual environment (Menin; Torchelsen; Nedel, 2018).

Is defined as software and hardware systems that comprehensively aim to perfect a sensory illusion of being present in another environment (Biocca, 1995; Ryan, 2015). It presents immersive aspects such as interactivity and technological connections by which the user can virtually modify simulated environments (Radianti, 2020).

Digital technologies, especially VR, benefit various sectors, notably the educational field, which has experienced a positive impact (Lorusso *et al.*, 2022; Cha *et al.*, 2012; Bliss; Tidwell; Guest, 1997). This occurs due to the ease and speed of acquiring information, interaction, and the efficiency of learning, which differs significantly from traditional approaches.

To assert that digital technology provides a unique teaching moment, one can mention the arrival of the SARS-CoV-2 pandemic in 2019. For instance, health authorities, in an effort to safeguard as many lives as possible, sought to innovate and invest in digital and immersive technology aligned with the real needs in combating the disease (Laplante; Voas; Laplante, 2016; Awais *et al*., 2020; Ahmed *et al*., 2020; Saadon *et al*., 2021; Shastri *et al*., 2021). In this context, among its applications, VR is directed toward the educational processes of healthcare professionals and other sectors.

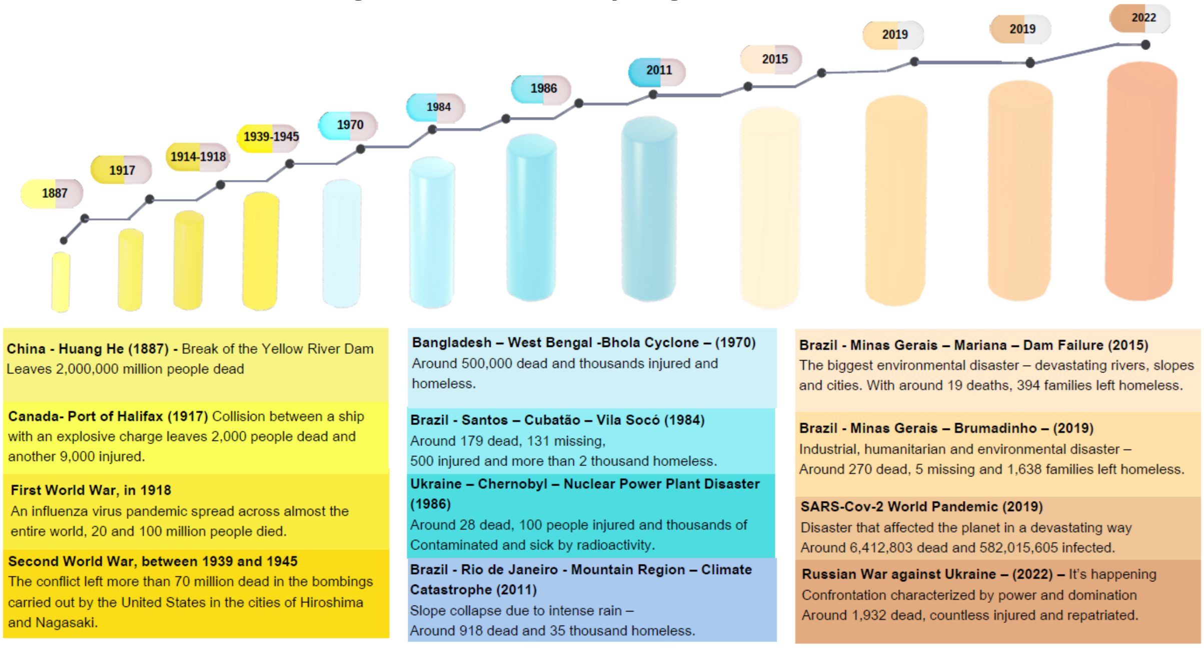
According to Ruscella and Obeid (2021), the usability of VR proposes a taxonomy of different levels of learning as it establishes tiers of knowledge that enable efficient training, intercultural encounters, and faithful reproduction of established environments, times, and conditions.

2.4 Disaster Management

Disaster refers to an extraordinary adverse event that leads to a state of public calamity, causing misfortunes, functional interruptions, and even loss of life (Bail *et al*., 2021a). It can be characterized according to the event - natural and human-induced. Natural disasters encompass climatic effects, while human-induced ones are those caused by human activities, respectively.

Natural or human-induced disasters can lead to incalculable effects on life and, in certain regions, due to their intensity and magnitude, they can manifest in various ways, such as earthquakes, hurricanes, tsunamis, floods, fires, collapses, terrorism, and pandemics (Huo *et al*., 2021; Dachyar; Yadrifil; Fahreza, 2019). Some of these disasters have been characterized by the magnitude of damages caused, as presented in Figure 10.

Figure 10 - Brief history of global disasters



Source: Own authorship (2023).

One of the earliest recorded disasters in world literature occurred in China (1887 at the Yellow River): the rupture of the Yellow River dam resulting in thousands of deaths (Yang *et al*., 2007), followed by the collision of two ships at the port of Halifax (1917) Nova Scotia - Canada (Drabek; McEntire, 2003; Hu *et al*., 2014; Han *et al*., 2019), causing numerous deaths, a tsunami, and destruction. Subsequently, the cyclone Bhola (1970) in West Bengal - Bangladesh resulted in over 50,000 deaths, followed by a series of other disasters.

Therefore, there was a need to establish disaster defence and mitigation agencies capable of providing immediate assistance to victims (UN, WHO, Fire Departments, Red Cross), contributing to impact mitigation actions and offering support, knowledge, training, investments, and technological innovations.

In Brazil, numerous adverse events have been experienced, many of them were caused primarily by human intervention. An example was the case of Vila Socó (1984) in Cubatão - SP, with an oil spill from a refinery, resulting in casualties, missing persons, and displaced individuals (Marples, 1988).

In Brazil, there was the rupture of the dam in Mariana, Minas Gerais (2015). It was considered the largest environmental disaster caused by humans, resulting in 262 fatalities, thousands displaced, and complete destruction of the region's ecosystem. Then, in 2019, in the Brumadinho region of Minas Gerais, a similar incident occurred with the rupture of the dam at Córrego do Feijão, causing an industrial, environmental, and humanitarian disaster, resulting in 270 deaths and 5 missing persons.

After 2019, with the onset of the SARS-CoV-2 pandemic, the high fatality rates, contagion, hospitalization, and deaths triggered emergency response protocols for firefighters, doctors, healthcare professionals, and security forces. The aim was to minimize the spread of the disease. The virus rapidly became an unprecedented illness (Sasangohar *et al*., 2020).

A viral pandemic that ravaged countries, challenging science, medicine, research, and healthcare organizations, revolutionized all of humanity, altering concepts of survival, work, economy, and service delivery.

Table 5 outlines the main authors who have conducted studies on Disaster Management and the SARS-CoV-2 pandemic, in particular.

Frame 5 - Key authors on Disaster Management

Terms	Authors
Disaster Management	Cvetković, *et al*. (2022a); Imran *et al*. (2020); Cvetković *et al*. (2020b); Chan *et al*. (2020); Elavarasan, *et al*. (2021); Daily (2010); Wang (2021a); Talisuna, *et al*. (2020); Sheek-Hussein; Abu-Zidan (2021); Chamola at al. (2020b); Sasangohar, *et al*. (2020); Fernandez-Luque. Imran (2018); Huo, *et al*. (2021); Al Harthi, *et al*. (2020); Xu, *et al*. (2021c);
SARS-CoV-2 Pandemic	Vaishya *et al*. (2020); Chamola *et al*. (2020); Singh *et al*. (2020a); Nasajpour, *et al*. (2020); Singh *et al*. (2020b); Swayamsiddha (2020); Kumar *et al*. (2020a); Tsikala Vafea, *et al*. (2020); Di Carlo, *et al*. (2021); Shastri, *et al*. (2021); Hooper, *et al*. (2021); Asadzadeh (2021b); Wang, *et al*. (2021c); Rathee, *et al*. (2021);

Source: Own authorship (2023).

Disaster and pandemic management have brought distinct characteristics to societies (Chamola *et al*., 2020b; Dutra, 2021), prompting a reassessment of concepts and priorities (prevention, preparedness, response, and recovery). One of the key examples was the necessity to adapt to survival by adhering to health protocols, leading to an inability to go to work, socialize, and live life normally.

Since then, there has been a highlighted need for more efficient digital technologies aimed at healthcare delivery and combating the pandemic, such as telemedicine. These advancements encompass emergency services (testing, guidance, transporting infected individuals, allocating medications and supplies, and providing virtual access to patient data), facilitating real-time mitigation of contagion and disease proliferation.

The immersive digital technology, previously focused on entertainment and individual well-being, swiftly had to change to aid during the pandemic. It adapted through internet-enabled object sensing in the form of smartphone applications, monitoring vital data, image applications (X-rays), remote surgeries, teleconsultations, laboratories, vaccine development, wearable measurement devices, data networks, electronic records, hospital bed availability, and the entire logistics chain of supply, provisioning, and transportation.

Non-governmental organizations (NGOs) and service sectors, including the Red Cross, engaged in humanitarian logistics and assistance (Ishiwatari *et al*., 2020; Bail 2019; Dachyar; Yadrifil; Fahreza, 2019), providing support for health and occupational safety (Adeel *et al*., 2019; Qin *et al*., 2018; Ray; Mukherjee; Shu., 20 17). Digital technologies massively contributed to this work (Cui, 2020; Deak *et al*., 2013; Zelenkauskaite *et al*., 2012), offering swift information dissemination, real-time connections with bases and stations established for receiving and transporting victims, equipment, materials, and vehicles.

According to Wang (2020a), Disaster Management underwent significant changes with the advent of SARS-CoV-2. It transitioned from the concept associated with climatic catastrophes, focused on initial care for the injured, to a broader perspective that encompasses multi-urban, health-related, architectural design, and logistical aspects.

Such concerns within disaster management became even more relevant when faced with the pandemic that began in 2019 and continued into 2022, resulting in over 6 million deaths worldwide. Even amid such devastation, Russia declared war on Ukraine (Choudhary, 2022), further affecting both the physical and mental health of society.

2.4.1 SARS-CoV-2 Pandemic

The SARS-CoV-2 virus was first detected in the city of Wuhan, China (Baker; Peckham; Seixas, 2020; Bail *et al*., 2021), and rapidly spread worldwide, challenging existing paradigms and highlighting the need for adaptation by responsible health agencies and their professionals (Singh, 2020a). Due to survival imperatives, these professionals had to accelerate research on modes of transmission, disease lethality, treatment mechanisms in hospitals, clinics, and emergency services (Polenta *et al*., 2020), as well as advance guidelines for quarantining infected patients, even if they displayed mild or moderate symptoms, reserving hospitalization only for severe cases.

The SARS-CoV-2, known as the coronavirus, was conceptualized as an infectious disease caused by severe acute respiratory syndrome (Shastri *et al*., 2021), namely, a mutated attenuated virus that affected over 609 million infected individuals and caused 6.5 million deaths worldwide (Antonelli *et al*., 2022).

Developed countries (Asia, USA, and Europe) were able to assess the pandemic as an event related to Disaster Management due to its magnitude and the extremely high number of deaths. These countries, accustomed to facing adverse events in their daily lives (such as hurricanes, tsunamis, earthquakes), assembled diverse emergency and risk management forces, such as Health-Related Emergency Disaster Risk Management (Health-EDRM) and Public Health Emergency of International Concern (PHEIC). They joined together in a task force for Public Health Emergencies of International Concern.

The rest of the world also adopted their protocols according to their economic and governmental realities. Consequently, numerous challenges arose, aiming to curb the spread and contamination of the disease (Ashraf *et al*., 2020; Ghimire *et al*., 2020), initially affecting the elderly but extending to everyone.

Due to needs, various social actors coordinated joint actions:

- Governments: health departments and agencies implementing information technologies, strategies for addressing and providing assistance to victims.

- Universities: scientists and researchers engaged in vaccine development, prevention protocols, and digital tools.

- Industries: production of PPEs, materials (masks, hand sanitizer, gloves, disposable gowns), equipment and respirators, and the adaptation to new forms of work.

- Society: collaborative efforts and restructuring of the economy and supply chain.

The combined efforts were made possible with the support of each sector. By combining acquired knowledge with digital technologies, new concepts regarding virus treatment and prevention emerged (Rehm *et al*., 2020; Mendonça, 2020; Chatterjee *et al*., 2020). This union enabled clinical assessments of patients via the internet, control of vital data, patient monitoring (wearable sensors), self-service kiosks, and general training.

2.5 Brazilian Military Fire Department and State of Paraná Fire Department

Global growth, the gradual increase in the world's population, and industrial expansion and development have contributed to raising risks and hazards in the workplace and other locations, whether individually or collectively (Bail, 2019). In this context, efforts emerge to mitigate prevention resources and risk management. According to Brewer (1986), the earliest accounts of emergency care refer to the surgeon Dominique Jean Larrey (1766-1842), who was concerned not only with rescuing victims on the battlefield but also believed that quick and precise care would be more effective.

In Brazil, on July 2, 1856, Emperor D. Pedro I signed a decree authorizing the creation of the first fire department post, which was intended to prioritize fire safety in the Court of Rio de Janeiro (Brasil, 2018). Subsequently, improvements were made through decrees and laws, authorizing the operation of this institution throughout the country.

With the aim of minimizing death rates during battles between peoples, Larrey created a two-horse-drawn vehicle known as 'flying ambulances', seeking to provide rapid assistance to injured soldiers (Silva, 2010; Ribeiro, 2011). In 1863, in Geneva, the International Red Cross was established for emergency care and assistance.

In Boston, the first fire service schools emerged in 1889, and in New York in 1914, to transform the professional ranks of higher and lower grades. During the 1st and 2nd World Wars, the fire departments were structured and operated in two-shift systems (Cote; Bugbee, 1988).

On July 10, 1924, in Chicago, the American Heart Association was founded by the College of Surgeons and Trauma, responsible for pioneering the initial studies related to pre-hospital emergency care worldwide. In 1933, a first aid manual (Travers *et al.*, 2010) was developed, targeting accidents occurring in various settings such as traffic incidents, industries, among others.

The firefighters, as public sector professionals, operate in various countries, carrying out fundamental roles in responding to fire victims and managing risks and disasters in first aid and rescue operations.

2.5.1 Continuous training for Military Firefighters

Throughout a firefighter's career, from their admission (learning and training process) and throughout their working life, ongoing training and continuous improvement are required as evaluative, necessary, and evidence-based elements. The aim is to assess the knowledge and skills required to respond promptly and accurately to emergency incidents. To achieve this, practical qualifications (simulations) are provided, using technological equipment such as devices, mannequins, machinery, among others. Consequently, annual training calendars are strategically planned for monthly team capacity-building, involving the entire logistical setup, accommodations, catering, instructors, vehicles, and other materials.

Military firefighters professionally engage in various activities aimed at addressing unusual situations with imminent and unpredictable risk of death. Therefore, the nature of each incident involves several aspects, such as traffic accidents with victims trapped in wreckage, underwater searches, confined spaces, hazardous materials, firefighting, search, and rescue operations, among others.

At CBMPR, the focus of this research, firefighter training typically revolves around two different scenarios, one involving live fire and smoke conditions. In this first scenario, a metal training container is utilized to gain specialized understanding of fire behaviour and firefighting techniques. The second training scenario involves the use of a concrete structure, mimicking real masonry residential conditions and concrete buildings to understand the boundary conditions of an accident scenario. Both formats require firefighters to be suitably attired in fire-resistant gear and equipped with respiratory apparatus, as depicted in Figure 11.

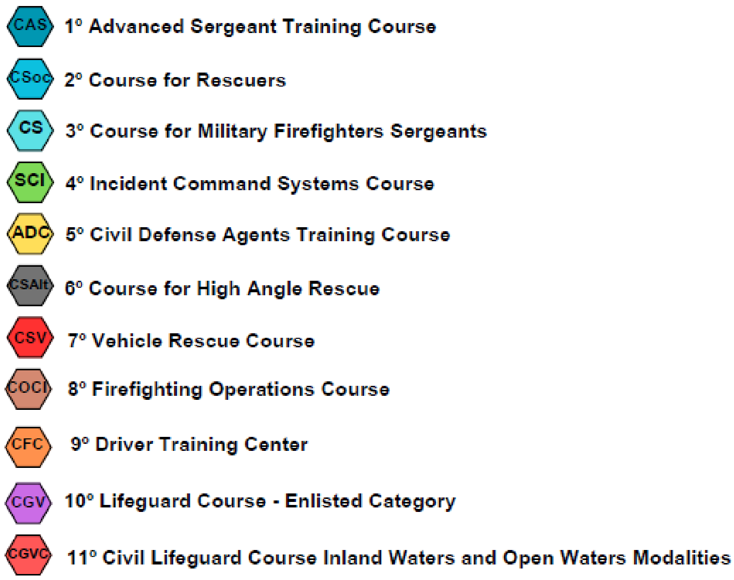
Figure 11 - Simulated Firefighting Training in Containers

Source: Own authorship (2023).

In many countries, it's quite common to have training buildings to simulate real firefights and similar emergencies. However, there are some usability limitations with this type of structure, as there are safety standards regarding the use of such buildings and environmental regulations that often restrict the use of concrete structures (Hakan *et al.,* 2018). These guidelines directly impact the development of firefighting training, limiting their actions.

In order to prioritizing effective training, emphasis is placed on quality courses, alongside constant investments in vehicles, advanced equipment, specialized pedagogical training, all aimed at ensuring the efficiency and safety of professionals on duty (Figure 12). In Figure 12, the infographic demonstrates the importance of ongoing education for these professionals.

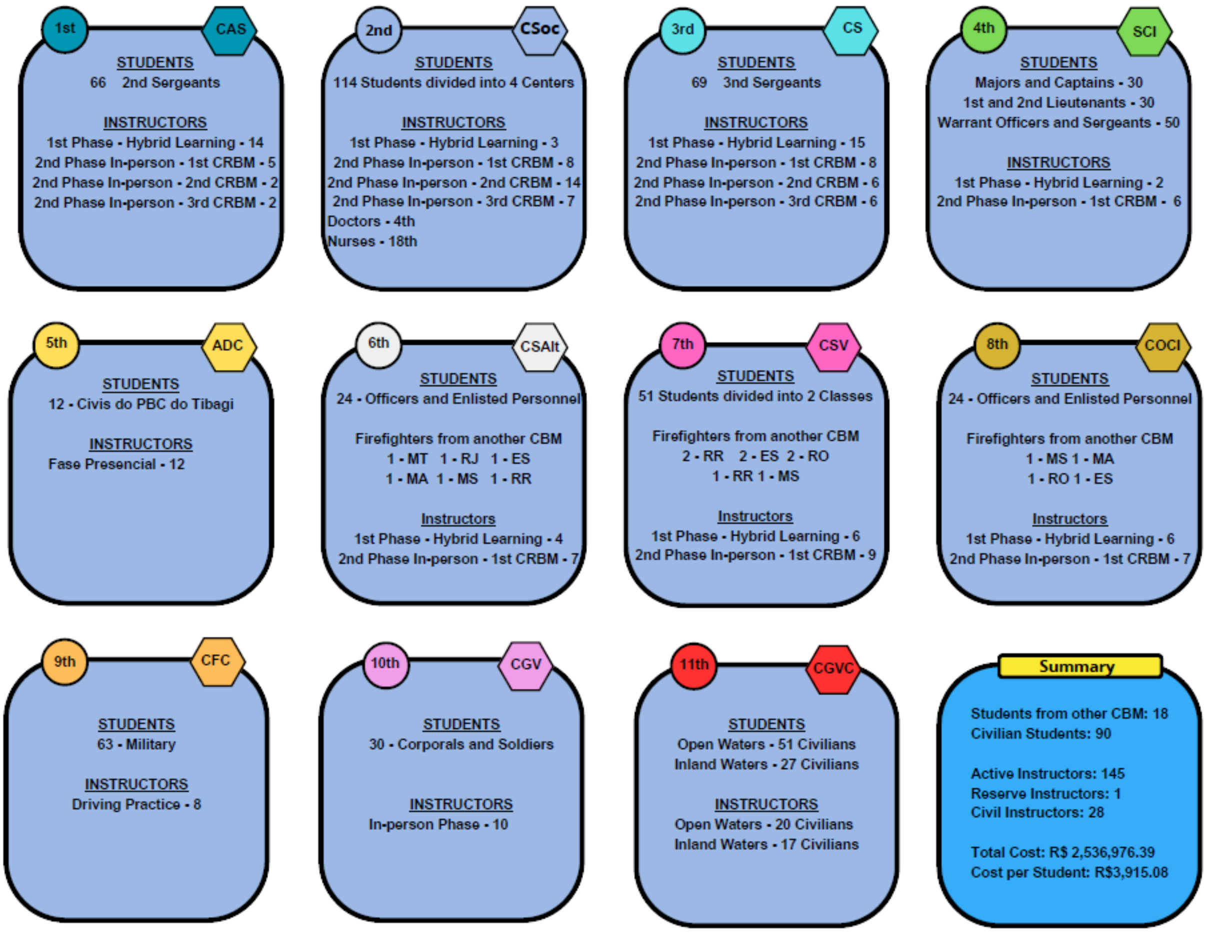
Figure 12 - Modules of courses conducted by Paraná firefighters in 2021



Source: Fire Department, PR (2022).

According to Figure 12, the course comprises 11 modules taught in 2021 that received didactic and pedagogical investments for service provision, including in the form of vehicles, equipment, ethics, and mastery of actions to ensure and mitigate impacts and safeguard lives. A breakdown of modules is described in Figure 13, featuring, for instance, the CBMPR.

Figure 13 - Distribution of Courses in 2021



Source: Fire Department of Paraná (2022).

Figure 13 describes the number of modules taught in 2021 and the respective quantities of students who underwent training (instructors, officers, and soldiers), and finally, it details the number of trained soldiers, financial investments, overall costs, and cost per student. This identifies the seriousness in shaping the skill set required for a Firefighter in Paraná.

Continuing the training process of the Fire Department in 2022, additional courses were conducted with the state troops, as shown in Figure 14.

Figure 14 - Courses conducted by Paraná firefighters in 2022

Source: Fire Department of Paraná (2023).

According to Figure 14, there were 8 continuing education courses conducted in 2022. As a distinguishing factor compared to 2021, the Officer Advancement Course (OAC) and the Troop Formation Course (TFC) were included, along with increased representation of female personnel in the training ranks (11.47%).

Every year, the General Command's concern is to ensure that its personnel can update and train comprehensively and continuously. Thus, six courses were repeated (CAS, CGV, CSoc; CS, CGVCV, CFC), emphasizing selectivity in the services provided to the population. There were also even greater financial investments (R$ 594,080.08 or $120,917.57 USD), providing qualifications for officers and hiring new teams through public tender.

The Teaching and Instruction Centre is responsible for the training, instruction, maintenance, and updating of the troops, as well as for the training of civilian personnel in fire prevention. The training and improvement of officers and enlisted personnel are conducted by the Military Police Academy of Guatupê and the Centre for Training and Improvement of Enlisted Personnel, with courses maintained by military organizations, military police, and, through agreements, by civilian entities. The Pedagogical Coordination (Head of CEI) is responsible for the training, instruction, maintenance, and updating of state military personnel, for the training of civilian personnel in preventive fire action, as well as, by delegation from the higher echelon, for the improvement and specialization of enlisted personnel (Corpo de Bombeiros 2023).

In this context, training and education need to be constantly enhanced with technologies. That said, choosing whether or not to include technology in the classroom is no longer an option, as it is part of students' lives in extracurricular contexts. Therefore, its application for the development of training and the addition of knowledge is seen as an excellent and necessary opportunity to enable classes and training sessions to be more dynamic and productive.

3 METHODOLOGY

The research classification can be characterized as applied, possessing an exploratory and descriptive nature, as its purpose was to discover and understand the topics addressed. In this context, the central focus of the research is to investigate the usability of immersive technology (VR), aiming to propose a teaching approach for technical technological training in the use of immersive technology in CBMPR training.

As for the research design, a mixed approach was adopted (data collection using both questionnaires and real practical training), combining qualitative and quantitative elements. Qualitative research was employed to explore the perceptions, experiences, and needs of military firefighters regarding training, as well as to gain insights into the effectiveness of immersive technology in the technical training process.

3.1 Adopted procedures

Within the samples, data were obtained through individual and group interviews. Considering the practical experiences lived by the author, this study reflects itself as an action research instrument, allowing the gathering of experienced, detailed, and in-depth information. Participants were strategically selected, encompassing active military firefighters and trained specialists/instructors (officers) involved with the recently available Virtual Reality (VR) simulators in the market.

The researcher obtained permission from Colonel Manoel Vasco de Figueiredo Junior, Commander of CBMPR, to actively participate in data collection. Remaining stationed for a week alongside the Firefighting Specialization Course (COCI), during which data and information were collected among the officer firefighters (students), involving both conventional training (theoretical/practical) and the initiation of tests with the firefighting simulator (VR). This immersion allowed for comprehensive sample collection, contributing as elements of action research, to be described in detail below.

According to Thiollent (2022), action research combines theory and practice, representing a participative approach where researchers collaborate with participants to identify problems, propose solutions, and implement changes. Described by Engel (2000), this methodology is integrated into VR training, being fundamental to enhance complementary training by relying on the direct experience of participants. This influences decisions and can lead to adaptations in the pedagogical training of those involved.

To assess the performance and learning of the military personnel, two new online questionnaires and standardized tests were employed. These methods aimed to gather statistical data that would highlight the relevance of immersive technologies in ongoing training. This approach allowed for a more accurate assessment of the impact of these technologies on the professional development of firefighters, complementing the qualitative analysis of action research.

For this study, authorization was obtained from the Brazilian Ethics Council, and approval for the researcher's participation was granted by the Fire Department's Central Command during the Firefighting Training Specialization Course (COCI).

The methodology adopted involved the following steps: i) Systematic literature review (keywords: emerging and immersive technologies; disaster management - pandemic; firefighter training and learning enhancement); ii) Collection of quantitative and qualitative data, data analysis, and interpretation; iii) Proposal of an immersive educational approach for technical technological training; and iv) Final considerations and recommendations based on the obtained results. Below, we'll detail the specifics of the methodological procedures used in this research.

3.1.1 Duration of the research

Regarding the research duration, from the initial planning phase to implementation and evaluation to investigate VR usability, it took 12 to 24 months. The initial planning spanned about 2 to 6 months, dedicated to literature review (keyword selection, defining the bibliographic portfolio, and article analysis). Subsequently, the research moved on to aligning objectives, defining the study's design (further exploration of knowledge regarding the VR simulator), and developing data collection instruments.

3.2 Theoretical Study

The construction of the bibliographic portfolio was based on a search through a Systematic Literature Review (SLR) (Conforto; Amaral; Silva, 2011), adopting formal protocols of Methodi Ordinatio and the Nvivo tool, respectively. Methodi Ordinatio is a Multicriteria method that allows ordering articles based on metrics such as Impact

Factor, year of publication, and number of citations. In this case, journal articles are ranked according to the highest values of InOrdinatio (Pagani *et al*., 2017). On the other hand, the Nvivo tool is primarily intended for content analysis, considering the generated bibliographic portfolio (Castleberry, 2014).

Considering the defined bibliographic portfolio (Appendix D), content analyses were conducted with the assistance of NVivo12. This analysis aimed to identify the key terms mentioned throughout the articles. Additionally, the bibliographic material underwent full readings to: 1) Assess how digital tools contributed to disaster management in the post-pandemic scenario; 2) Identify how Immersive Technologies, focusing on Virtual Reality (VR), can contribute to productive performance within the Military Fire Brigade; 3) Evaluate the importance of using Virtual Reality (VR) equipment for firefighter training, and; 4) Map the benefits of immersive technology (VR) in the Fire Brigade. The results are detailed in Appendix E.

3.3 Practical Study

Initially, an analysis was conducted within a theoretical-practical context on how digital technologies can contribute to disaster management in the post-pandemic period, particularly among healthcare professionals directly involved in combating COVID-19. The aim was to leverage this technology to enhance training methodologies.

In the pursuit of achieving the outlined objectives in this work, a methodological framework was developed (Table 6).

Frame 6 - Methodological procedures of the theoretical-practical study

Procedure	Description	Objectives
General objective: The aim of this work is to investigate the usability of Immersive Technology, specifically the FLAIM Trainer Virtual Reality, in the training for the qualification of the Military Fire Department of the State of Paraná with the purpose of proposing a teaching approach to complement the teaching-learning process.[1]		
Systematic literature review for theoretical studies and theoretical-practical studies, respectively	Initially, conduct research on Scopus, Web of Science, and Science Direct databases. Subsequently, support the acquisition of articles and systematic analysis, as per the previous Subchapter.	1. Identify applications and contributions of Immersive Technologies, specifically the FLAIM Trainer Virtual Reality, for the training of the Military Fire Brigade of the State of Paraná.

[1] Following the procedures described in Appendix A, the obtained results (numbers of articles, raw and after filtration) are presented in Appendices B and C, respectively.

Exploratory and evaluative research of data and publications (Brazil X Norway).	Analyse and compare data presented by participants in the research. Norway has experience with VR simulators among local civilian firefighters, conducting research among professionals and manufacturers.	2. Assessing how immersive technologies contribute to disaster management.
Field Research in Paraná	- Non-systematic participant observation of the Firefighting Operations Course (COCI) at the Guatupê Military Academy. - Comparative analysis between practical training instructions and virtual reality (VR) firefighting. - Assisted observation in Fire Stations and training environments throughout the state. - Documentary analysis through protocols, manuals, equipment, official documents, training, and pedagogical materials from the Fire Department of Paraná. - Data collection through the application of Forms 1 and 2 (Appendices I and J), involving troops, work teams of all ranks. - Case Study: Immersive technology integrated into the curriculum of military firefighters.	3. Identifying the usability and perceptions of Military Firefighters regarding teaching and training in VR technology.
Tabulation, analysis, and presentation of results	Participation in the training, collecting data, and administering Forms 1 and 2 to the participants.	
Documentary Research	Evaluate the current curriculum matrix of the firefighters	4. Evaluating the Curriculum Matrix of the Fire Department, proposing the integration of Immersive Technology in supplementary training.
Validate the proposed technological technical approach	After reformulating the Fire Department's Curriculum Matrix, validate it and propose a new teaching-learning approach.	5. Suggesting a teaching approach for technical and technological training in the Curriculum Matrix for the Fire Department, based on this action research in the Military Fire Brigade of the State of Paraná.

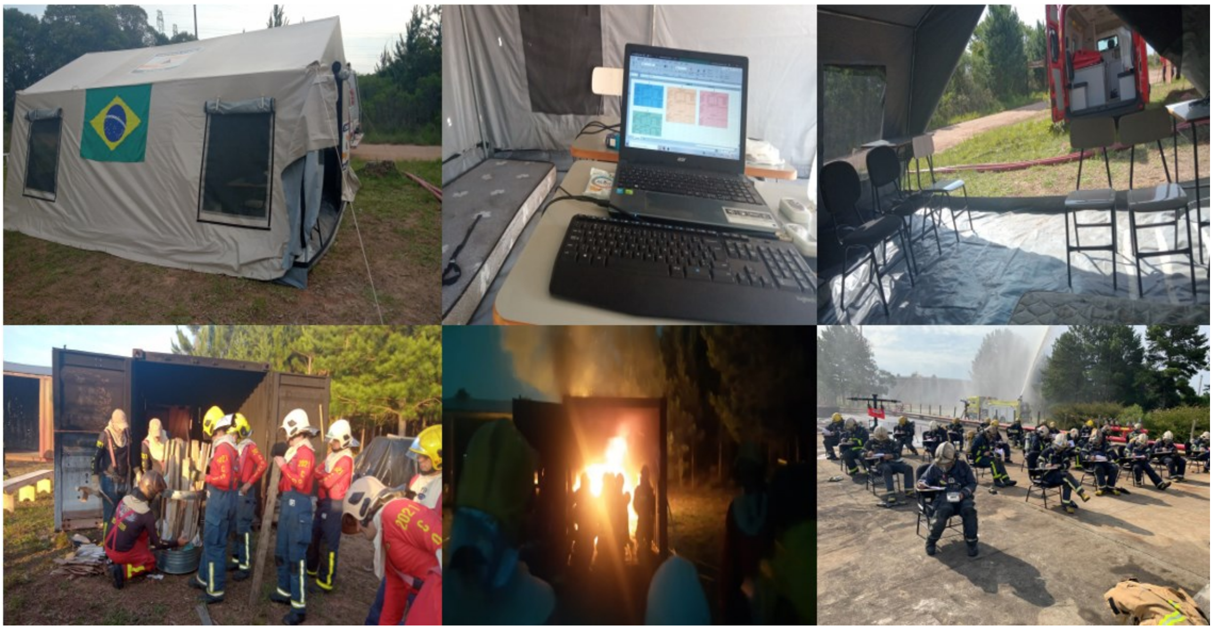
Source: Own Authorship (2023).

3.3.1 Assisted Participation and Action Research

3.3.1.1 Conventional simulated training

During the period of residence and assisted observation, the researcher had access to a large campaign tent set up by the officers. This structure enabled the author to collect data after practical training sessions, which involved day-and-night simulations of fire containment and combat conducted in containers. Additionally, she had the opportunity to participate in numerous training sessions and exercises held at the Guatupê Military Police Academy - Superior School of Public Security. These training sessions encompassed lectures and simulations in various scenarios and conditions, closely resembling the real situations experienced daily by the professionals (Figure 15).

Figure 15 - Simulated exercises and assisted participation



Source: Adapted by the author (2023).

3.3.1.2 Immersive VR Technology Training

3.3.1.2.1 Practical Virtual Reality Simulation

During the VR simulations, the researcher was able to observe them in a classroom setting, collecting data regarding the equipment's usability, operational aspects, maintenance, and other information provided by the Official Instructors. Among the activities, there was an introduction to the equipment and its fundamental handling principles, as well as instruction on manoeuvring through obstacles, variations in floor levels, hose usage, spraying techniques in firefighting, teleportation, and victim rescue. At the end of the simulated exercises, online questionnaires were administered to gauge information on the tool's importance as a supplementary qualification for military firefighters (Figure 16).

Figure 16 - Usability of VR tool in the classroom

Source: Adapted by the author (2023).

During the simulated exercises with the VR tool, the instructor could guide and monitor the training of each firefighter, teaching:

- What each component of the simulator does and how to manage it;
- The handling of each connection, instructing on its purpose and how to use it;
- Instructions on gearing up and how to interact cognitively with the virtual environments.

In each scenario experienced by the student, there were differentiated instructions for usability and skill, suggesting the most agile and effective way to rescue victims and combat the flames. Additionally, guidance was provided on whether or not to call in other teams to the location, offering supportive backup.

3.3.2 Participant selection

The selection of participants (research samples) was authorized by General Commander Colonel Manoel Vasco de Figueiredo Junior, so that the researcher could take part in the Specialization Course for Firefighting Operations (COCI), which involved theoretical and practical training.

A total of 5 qualified military officers, who were both trained in conventional methods and proficient in simulator (VR) operations, were chosen. The additional participants in this research comprised 87 individuals, including students from the Specialization Course designated by the command, encompassing both officers and enlisted personnel with practical experience relevant to the profession, located in the state of Paraná. Additionally, 61 students and professionals from Ponta Grossa, Paraná, belonging to the Fire Department Battalion (2nd BG), were involved.

There were inclusion and exclusion criteria for selecting participants in the conventional training, evaluated according to the instructors' determination. As the military personnel would be evaluated in both the conventional training (COCI) and the VR simulator training, certain requirements were established:

i) The exclusion of female personnel, primarily during exposure to high temperatures in confined spaces (burning in confined spaces), due to the menstrual cycle. Their participation would lead to severe dehydration.

ii) All male personnel were active participants in the container burning training, and;

iii) Regarding the VR simulator training, all individuals of both sexes were included.

3.3.3 Data collection instruments

As for the data collection instruments, given that this study is unprecedented in Latin America, more specifically in Brazil, information was provided by the Officer responsible for acquiring the FLAIM Trainer RV simulator (from Australia). In this context, the initial studies on VR aimed at the Fire Brigade were conducted through collaboration between the following institutions: Western Norway University of Applied Science (Norway), the Federal University Technology of Paraná (UTFPR - Ponta Grossa - PR), and the General Command of the Military Fire Brigade of the State of Paraná, as described in the Cooperation Agreement (Appendix F).

Major Eduardo José Slomp, the Pedagogical Coordinator of the Paraná Fire Brigade, was appointed to travel to Europe and establish the initial contacts and training sessions with the RV simulator. Later, he provided the contact details of the researchers, Professor Dra Ilona Heldal, and doctoral student Cecília Hammar Wijkmark. They commenced studies on RV alongside Norwegian and Swedish Civil Firefighters. Consequently, there were meetings, exchange of experiences, data, information, and joint scientific publications, as detailed in Appendix G.

This collaborative bond facilitated access to the usability of the simulator among European professionals, fostering the exchange of knowledge. In Brazil, the data collection stages and samples were obtained through interviews, filming, questionnaires, photos, assisted research, and participant feedback.

Regarding the instruments used for data collection, two questionnaires were developed, describing the variables related to the reality experienced by military firefighters in Brazil during their daily work routine. The first questionnaire was intended for Official Instructors, and the second for students of the Specialization Course (COCI), comprising experienced professionals (Officers and Enlisted Personnel).

Prior to the training sessions, instructions were provided to the brigade to clarify the purpose of information collection and the importance of cognitive differentiation between real and virtual experiences. These guidelines ensured that firefighters understood the study's relevance and adopted a reflective approach throughout the process. Consequently, this facilitated obtaining meaningful data and contributed to an accurate analysis of the results.

In the practical part of the firefighting training, professionals already possessed prior knowledge acquired since their initial training. Therefore, more intense and challenging adverse events were promoted to elevate the level of difficulty in their work experience.

Regarding the VR simulator training, information was provided on the interactivity of actions, instructing on how to operate the equipment to perform various activities such as cognitive teleportation between scenarios, firefighting, victim rescue, and other specific work-related tasks.

The instructors also demonstrated how to operate the simulator beforehand. At the end of the training sessions, questionnaires, interviews, and observations were conducted to assess the effectiveness of the training experience with the VR simulator. This approach allowed for a more comprehensive and well-founded analysis of the effectiveness of immersive technology in skill enhancement and firefighters' response to real-life situations.

3.3.4 Procedures for developing and evaluating VR usability.

After studying the need to technologically innovate their workforce, the General Command of the Military Fire Brigade of the State of Paraná (CGCBMPR), carefully assessing Virtual Reality (VR) immersive technology, decided to assign a group of specialized officers to travel to Norway to obtain information about the FLAIM Trainer virtual reality simulator. This simulator is used as a complementary tool in firefighting training.

After familiarizing themselves with the simulator, acquiring training and materials from the developer company, the specialized team of firefighters from Paraná adapted the equipment to Brazilian scenarios, encompassing different types of fires:

environmental, in buildings, vehicles, industries, chemicals, among others. With the aim of introducing the RV simulator among the troops, an event was planned to combine conventional practical training with the technology, facilitating the collection of data on importance, usability, similarities, and participant opinions.

At the Military Police Academy of Guatupê - Higher School of Public Security - Curitiba (PR) an opportunity was strategically seized for data and information collection for the research. The author and researcher were invited by the Command to reside at the barracks during the Specialization Course in Firefighting (COCI), alongside instructors and students (officers and enlisted personnel). In this context, it was possible to theoretically and practically evaluate and measure conventional firefighting training compared to training using the FLAIM Trainer (Figure 17).

Figure 17 - Start of barracks activities for data collection

Source: Paraná Fire Department (COCI 2021).

Both parties (instructors, students, and the researcher) shared numerous safety-related information, conditions, activity schedules, samples, timeframes, duration, and other details. Therefore, a strategic point was established for capturing and collecting data and information - a location strategically designated as a meeting point with the students after practical training. Additionally, in the classroom, simulations were conducted using VR (Figure 18), enabling data collection to occur simultaneously with the experiences.

Figure 18 - Conventional firefighting training (theory/practice)

Source: Paraná Fire Department (COCI 2021).

The firefighters involved received guidance to participate in the research and simulations (Figure 19) with the aim of establishing a linear perception between real and virtual training. This approach allowed for understanding the relationships between the two techniques, guiding them sequentially through the evaluation processes, perceptions, and opportunities created by both forms of training. Consequently, concrete data (questionnaires, interviews, recordings, and photo captures) about the importance and usability of the tool were collected.

Figure 19 - Theoretical/practical class with the VR Simulator

Source: Paraná Fire Department (COCI 2021).

This study was conducted through the collaboration of 5 official instructors (Major and Captains) from CBMPR, whose purpose was to adjust and validate the data collection instruments. These professionals had the opportunity to receive training (either abroad - directly from the manufacturer or in Brazil - with the local representative), forming a specialized team in VR training, specifically with the FLAIM Trainer technology.

Highlighting that the experience lived by the researcher during the residence period at the Guatupê Academy, Curitiba (PR) proved to be of utmost importance in the conventional firefighting training offered in the Specialization Course (COCI). It allowed for the assessment and collection of samples related to the soldiers' initial exposure to engagement in immersive technology training. In this setting, the author could immerse herself alongside the professionals at every stage of the course execution, particularly concerning the unprecedented, playful, and virtual format, addressing intricacies throughout the work's progression.

In this regard, within the quantitative analysis, the specific and precise feedback from the participants could support performance indicators. Additionally, it demonstrated aspects related to sustainability, economy, versatility, and the extensive opportunities for expanding training for those involved, which will be presented in Chapters 4 and 5 below.

4 RESULTS AND DISCUSSION

4.1 FLAIM Trainer (VR): A Practical Approach in the Fire Brigade

4.1.1 Questionnaire Application - Preliminary Study (Study 1)

In this section, the results derived from the questionnaire application in the preliminary study (Study 1) are explored. The collection and analysis of the samples revealed substantial insights outlining the practical implementation of the FLAIM Trainer (VR) in the operational context of the Fire Brigade. These pertinent data provide a solid foundation for in-depth analysis and discussions, highlighting not only the initial perceptions but also the fundamental points guiding the usability of the tool in the operational field.

In Tables 1 and 2, the main information obtained regarding the interviewees and their firefighting experiences, respectively, is presented.

Table 1 - Interviewees' information*

Gender	Experience in the field	Current position/title	City of residence
Male (100% of total participants)	25 years, 23 years, 16 years, 15 years, and 2 years	Commander (40% of participants), Captain (20%), Sergeant (20%), and Major (20%)	Ponta Grossa, Pinhais, Ivaiporã, São José dos Pinhais

Source: Own Authorship (2023).

Table 2 - Main actions related to firefighting

Residences and buildings	Vehicle fires	Parks or fields	Warehouses and industries
6 to 20 times (20%), 21 to 50 times (20%), and more than 50 times (60%)	6 to 20 times (40%) and 21 to 50 times (60%)	1 to 5 times (40%), 6 to 20 times (20%), 21 to 50 times (20%), and more than 50 times (20%)	1 to 5 times (20%), 6 to 20 times (60%), 21 to 50 times (20%)

Source: Own Authorship (2023).

All interviewees are male and hold distinct positions, albeit always associated with firefighting. It's notable that, except for one case, each of them has significant firefighting experience within the fire brigade. Consequently, these results hold value in the context of knowledge and technical competencies.

In mutual agreement, all acknowledge the need for additional or new training, particularly those focused on emerging technologies. Concerning conventional training, the adopted methods are deemed efficient, although improvements are highlighted. One of these improvements includes the need for ongoing training, even during periods of pandemics, to obtain new physical and cognitive sensations and experiences facilitated by Immersive Technologies, as shown in Table 3.

Table 3 - Perceptions regarding the current, conventional training

Most recent training	**Need for further training**	**Close proximity of training approaches to practical scenarios**	**Proximity of training in terms of physical and cognitive sensations**
2021	**A little / much more**	**Likert Scale (1 to 5)**	**Likert Scale (1 to 5)**
2021 (87.4% male and 12.6% female)	A little more (60%) and much more training (40%)	On a scale of 1 to 5: Grade 3 (40%) and Grade 4 (60%)	On a scale of 1 to 5: 2 (20%), 3 (40%), 4 (20%), and 5 (20%)

Source: Own Authorship (2023).

In Tables 4, 5, and 6, the main results associated with the use of immersive technology in daily life and at work are presented.

Table 4 - Contact of the interviewees with VR resources

Frequency in virtual games and/or simulations	**Frequency of using Virtual Reality-based technologies in everyday life, in general**	**Use of Virtual Reality-based technologies for professional purposes**
On a scale of 1 to 5: 1 (60%), 2 (20%), and 4 (20%)	On a scale of 1 to 5: Grade 1 (80%) and Grade 2 (20%)	Never (80%), 1 or a few times (20%)
Scale 1 (very low degree: unfavourable perception) and 5 (high degree: favourable perception)		

Source: Own Authorship (2023)

Table 5 - Perspectives regarding the use of immersive technologies at work, based on VR (FLAIM)*

Is there usability of Immersive Technology in firefighter training	**Need for realistic scenarios in training**	**Immersive technology based on Virtual Reality is complex (in terms of assimilation)**	**There is no acceptance of Immersive Technology among firefighters**	**High cost in acquiring Virtual Reality technologies**
Yes (100% of participants)	Yes (80%) and No (20%)	Disagree (100%)	Disagree (100%)	Agree (60%) and Disagree (40%)

Source: Own Authorship (2023).

Table 6 - Main discomforts after using VR (FLAIM)

Nausea	**Dizziness**	**Visual fatigue**	**Headache**	**Stress**
No (100%)	Yes (20%) and No (80%)	Yes (20%) and No (80%)	No (100%)	No (100%)

Source: Own Authorship (2023).

In summary, it is noted that the professionals in this study have little familiarity with immersive technologies, especially in training. The main highlighted aspects include: the perception of military acceptance regarding the usability of VR tools, the exchange of experiences among firefighters during the use of the simulator in the classroom, and each military member's self-assessment of the technologies, and how they contribute to complementary training.

4.1.2 Questionnaire Application with Firefighters in the State of Paraná (Questionaries 2 and 3)

This study was divided into two groups: questionnaire 2 involved 87 individuals residing in cities across the State of Paraná, while questionnaire 3 included 61 individuals from the city of Ponta Grossa, Paraná. Another distinct aspect is the job positions, with questionnaire 3 comprising professionals in higher-ranking positions. If the hierarchy of positions is considered in ascending order, it would generally follow the sequence: questionaries 1 (Instructors and Officials), 2, and 3.

Hence, to avoid repetition in presenting results, certain findings were given priority.

According to Table 7, the most represented position among the interviewees is a soldier (45.98% for study 2) and sergeant (32.79% for study 3), with the longest tenure of experience among all, amounting to 34 years.

Table 7 - Information from the interviewees**

Study	Gender	Experience in the field	Current position	City of residence
2	Male (88.51%), and Female (11.49%)	Longest experience (34 years) and shortest (7 years)	- Predominant positions: Soldier (45.98%), Sergeant (12.64%), Corporal (11.49%), and Lieutenant (9.20%), among others.	Rio Negro, São José dos Pinhais, Pinhais, Curitiba, Cascavel, Araucária, Lapa e Piraquara.
3	Female (4.91%), and Male (95.09%)	Longest experience (33 years) and shortest (7 years)	- Predominant positions: Sergeant (32.79%), Corporal (16.09%), and Soldier and Lieutenant (11.48% each), among others.	Everyone from Ponta Grossa, Paraná

Source: Own authorship (2023).

In Tables 8 and 9, the main results associated with the use of immersive technology in firefighter training (perspectives and perceptions, respectively) are presented.

Table 8 - Perspectives regarding the use of immersive technologies at work, based on VR (FLAIM)**

Study	Is there usability of Immersive Technology in firefighter training?	Immersive technology based on Virtual Reality is complex (in terms of assimilation)	High cost in the acquisition of Virtual Reality technologies
2	- Yes (89.66% of participants) and No (10.34%)	No (91.95%) and Yes (8.05%)	Yes (54.08%) and No (45.98%)
3	- Yes (95.08% of participants) and No (4.92%)	No (93.44%) and Yes (6.56%)	Yes (52.46%) and No (47.54%)

Source: Own authorship (2023).

Table 9 - Perceptions regarding training using VR (FLAIM)

Study	Overall, to what extent do your sensations while using VR correspond to the feeling of being in a field firefighting training?	To what extent does the heat sensation in VR correspond to the heat sensation in a field firefighting training?	To what extent does the sensation of using the VR hose correspond to using a hose in a field firefighting training?	To what extent do the sounds in VR correspond to the sounds in a field firefighting training?	To what extent do you understand the task you need to perform in VR compared to a similar task in a conventional training?	To what extent does the sensation in VR correspond to the sensation of being in a real fire?	To what extent did the fire generated in VR behave realistically?
2	On a scale of 1 to 5: Grade 4 (33.34%), 3 (32.18%), 2 (17.24%), 5 (11.49%), and 1 (5.75%)	On a scale of 1 to 5: 3 (34.48%), 4 (26.44%), 2 (18.39%), 1 (16.09%), and 5 (4.60%)	On a scale of 1 to 5: 4 (37.89%), 3 (32.18%), 5 (20.69%), 2 (5.75%), and 1 (3.49%)	On a scale of 1 to 5: 3 (34.48%), 4 (33.33%), 2 (18.39%), and 1 and 5 (6.90% each)	On a scale of 1 to 5: 4 (40.23%), 3 (32.18%), 5 (18.39%), 2 (8.05%), and 1 (1.15%)	On a scale of 1 to 5: 3 (37.93%), 2 and 4 (22.99% each), 1 (10.34%), and 5 (5.75%)	On a scale of 1 to 5: 3 (40.23%), 2 (25.29%), 4 (21.83%), 1 (6.90%), and 5 (5.75%)
3	On a scale of 1 to 5: Grade 4 (47.54%), 3 (27.87%), 2 (13.11%), 5 (9.84%), and 1 (1.64%)	On a scale of 1 to 5: 3 (32.74%), 1 (24.59%), 2 (22.95%), 4 (18.03%), and 5 (1.64%)	On a scale of 1 to 5: 4 (37.70%), 5 (27.87%), 3 (22.95%), 2 (11.48%)	On a scale of 1 to 5: 4 (39.34%), 3 (36.07%), 5 (18.03%), 2 (4.91%), and 1 (1.64%)	On a scale of 1 to 5: 3 (37.70%), 4 (27.87%), 2 (19.67%), 1 (8.20%), and 5 (6.56%)	On a scale of 1 to 5: 3 (37.70%), 4 (27.87%), 2 (19.67%), 1 (8.20%), and 5 (6.56%)	On a scale of 1 to 5: 3 (37.70%), 4 (36.07%), 2 (18.03%), 5 (6.56%), and 1 (1.64%)

Scale 1 (very low degree: unfavourable perception) and 5 (high degree: favourable perception)

Source: Own authorship (2023).

4.1.3 Data Analysis

To facilitate the understanding of the main results, a brief comparison was made among the three studies, as shown in Tables 10, 11, and 12.

Table 10 - Summary of interviewee information

Study	Number of participants	Gender	Maximum experience in the field	Primary current position	City of residence
1	5	Male (100, 88.51, and 95.09%, respectively)	25, 34, and 33 years old, respectively	Commander (40%), soldier (45.98%), and sergeant (32.79%) (studies 1, 2, and 3, respectively)	Cities in the State of Paraná
2	87				
3	61				Ponta Grossa, Paraná
Total	153				

Source: Own Authorship (2023).

Table 11 - Summary of perspectives regarding the use of immersive technologies at work, based on VR (FLAIM)

Study	Is there usability of Immersive Technology in Firefighter training?	Immersive technology, based on Virtual Reality is complex (in terms of assimilation)	High cost in the acquisition of Virtual Reality technologies
1	Yes (100, 89.66 and 95.08% of participants, respectively)	Disagree/No (100, 91.95, and 93.44%, respectively)	Agree/Yes (60, 54.08 and 52.46%, respectively)
2			
3			

Source: Own authorship (2023).

High correlation was found among the three studies. Overall, the majority of participants are male and do not find Virtual Reality (VR) technology complex in terms of knowledge assimilation and usability.

Table 12 - Synthesis of perceptions regarding training using VR (FLAIM)

Study	In general, to what extent do your sensations in using VR correspond to the feeling of being in a firefighting training in the field?	To what extent does the sensation of heat from VR correspond to the sensation of heat in a firefighting training, in the field?	To what extent does the sensation of using the VR squirt correspond to the sensation of using the squirt in a firefighting training, in the field?	To what extent do the sounds of VR correspond to the sounds in a firefighting training in the field?	To what extent do you understand the task you need to perform through VR, as well as a similar task in conventional training?	To what extent does the feel of VR match the feeling of being in a real fire?	How realistically did the fire generated in VR behave?
1	-	-	-	-	-	-	-
2	Grade 4 (33.34%) and 3 (32.18%) scales	Grade 3 (34.48%) and 4 (26.44%) scales	Grade 4 (37.89%) and 3 (32.18%)	Grade 3 (34.48%) and 4 (33.33%) scales	Grade 4 (40.23%) and 3 (32.18%)	Grade 3 (37.93%), 2 and 4 (22.99% each) scale	Grade 3 (40.23%) and 2 (25.29%) scales
3	Grade 4 (47.54%) and 3 (27.87%) scales	Grade 3 (32.74%) and 1 (24.59%)	Grade 4 scale (37.70%), 5 (27.87%)	Grade 4 (39.34%) and 3 (36.07%) scales	Grade 4 (39.34%) and 3 (36.07%) scales	Grade 3 (37.70%) and 4 (27.87%) scales	Grade 3 (37.70%), 4 (36.07%) and 2 (18.03%)

Scale 1 (very low grade: unfavourable perception) and 5 (high grade: favourable perception)

Source: Own authorship (2023).

According to Table 12, the technology used in VR-based training generated sensations of proximity to conventional training, including elements of real fire (heat, use of the hose, sounds, and fire), with ratings ranging from level 4 to 3 in most addressed aspects, primarily. In this case, only questionaries 2 and 3 feature these aspects, considering that questionnaire 1 was an initial and preliminary study.

In this context, the data was also analysed by calculating Cronbach's α to verify the internal consistency of the scale (reliability) of the applied instrument.

According to Kline (2009), there isn't a standard value for Cronbach's α to be considered good. Morales *et al*. (2003) argue that Cronbach's α values below 0.6 are questionable. Meanwhile, Hair Jr., Tatham and Black (2007) considers values below 0.6 as low and between 0.6 and 0.7 as moderate.

However, Kline *et al*. (2009) argue that if alpha is less than 0.5, it might indicate that 50% of the observed variance is due to random error. Based on these considerations, the chosen value falls between 0.6 and 0.7, or higher: $\alpha \geq 0.65$.

The data processing using the licensed Minitab 15 software from the Federal University Technology of Paraná - Ponta Grossa - UTFPR/PG showed that the total Cronbach's α and each construct reached a 'very good' level based on the researcher's chosen α option, as per the classification by Hair Jr., Tatham and Black (2007), which can be seen in Table 13.

Table 13 - Adhesion between results by Cronbach's α

Omission of variables	
Variable	**Alpha value**
Q1	0,9551
Q2	0,9541
Q3	0,9551
Q4	0,9555
Q5	0,9598
Q6	0,9544
Q7	0,9551
Q8	0,9547
Q9	0,9545
Q10	0,9549
Q11	0,9543
Q12	0,9539
Q13	0,9543
Q14	0,9538
Q15	0,9545
Q16	0,9544
Q17	0,9538
Q18	0,9549
Q19	0,9547

Q20	0,9547
Q21	0,9544
Q22	0,9550
Q23	0,9545
Q24	0,9542
Q25	0,9543
Q26	0,9537
Q27	0,9541
Q28	0,9547
Q29	0,9566
Q30	0,9569
Q31	0,9581
Q32	0,9616
Q33	0,9616
Q34	0,9577
Cronbach's alpha coefficient: 0.9565	

Source: Own authorship (2023).

As seen in Table 13, the α value for the total scale reached a notable level of α mean = 0.9565, suggesting that the questionnaire respondents demonstrated remarkable consistency in their responses, evaluating the items of each construct very closely. The results for each construct are detailed in Table 13 and provide the descriptive statistics of the samples.

The immersive technology proved to be effective in the training of the Military Firefighters of Paraná, evidenced by positive results in terms of usability, acceptance by professionals, and their respective advantages. To enhance and adapt the new teaching format based on immersive technology in the ongoing training of the Paraná Military Firefighters, an approach was proposed to incorporate the Immersive Technology discipline into the corporation's curriculum matrix, aiming to provide an adjustment and training of the military brought by the tool (VR).

The current Curriculum Matrix of the Fire Department is divided into three knowledge areas: fundamental, professional, and complementary. These areas encompass both the initial training of individuals in the military career and specific technical disciplines for each type of service provided by the military, as shown in Table 7.

Frame 7 - Knowledge Areas of the Military Firefighters Curriculum Matrix

Area	Number of disciplines	Workload	Description
Fundamental	17 subjects	555 hours	The stages of formation in this phase range from the historical context to the subjects of initial formation.
Professional	19 subjects	764 hours	At this stage, students receive all the technical training (theoretical/practical) of the activities pertinent to the training of the military firefighter.
Complementary knowledge	6 subjects	184 hours	At this stage, students have technical training (theoretical/practical) and internship activities in different departments and environments.
Total course load			1503 hours

Source: Adapted by the Author, CBMPR (2023).

In the context of complementary subjects, there isn't currently a specific discipline that imparts knowledge on equipment or simulators involving VR, AR, MR, and other technological aspects for future training and skill development. Therefore, the Immersive Technology discipline will be added to the complementary training, allowing students to learn elements related to both theoretical and practical contexts, such as:

- Understanding technologies
- Software and hardware
- Immersive technologies (VR, AR, MR)
- Components and devices associated with these technologies
- Use of digital technologies in professional training and development.

Immersive technology becomes indispensable for ongoing and technological education, as it can be applied in training, providing the opportunity to visualize environments or occurrences of practical attendances previously experienced. This, combined with the expertise evidenced by virtual reality in simulated fire occurrence environments, allows the simulator to recreate sensations of fire, high temperatures, imminent risks, and possible victims on-site, as well as the use of necessary equipment for firefighting and other attendances. These situations demand quick and assertive decision-making, assessing and deciding which actions to take without impacting the lives of the team and victims. These elements can be verified in Chapter 5.

5 A PROPOSAL FOR AN APPROACH TO THE CURRICULAR MATRIX OF THE PARANÁ FIRE DEPARTMENT

Within this chapter, we describe the development of a technical and technological training approach for the Fire Department, grounded in immersive technology, following a structured process ensuring effectiveness and alignment with the specific needs of the Military Firefighters. This approach comprises the identification of learning objectives, analysis of training needs, suitable selection of immersive technology, creation of realistic virtual scenarios, utilization of instructional design tools, conducting pilot tests for evaluation, and implementing continuous improvements based on the results obtained. Table 8 summarizes these stages, providing an overview of the process in constructing the immersive technology-based training approach.

Frame 8 - Process of Building the Teaching Approach in Immersive Technology

Stages of Knowledge	Effective Learning
1. Identify and know the Learning Objectives	Define clear, measurable, and relevant learning objectives to train professionals in firefighting situations, considering factors such as climate, equipment, decision-making, and effectiveness of actions.
2. Analyse Training Needs (VR)	Thoroughly assess the training demands of teams, identifying knowledge and skills gaps to direct the development of competencies, including the integration of immersive technology.
3. Discover Immersive Technology	Choose the most appropriate immersive technology, such as the FLAIM Trainer virtual reality simulator, to create interactive virtual environments that reproduce everyday situations, facilitating practice and decision-making.
4. Explore Virtual Reality Scenarios	Develop authentic scenarios that are close to the real experiences of firefighters, providing practice in crucial skills and decisions in a controlled and authentic environment.
5. Learn about Tool Instructional Design	Utilize instructional design to structure teaching-learning, focusing on immersive technology, such as the VR simulator, to optimize the educational experience.
6. Testing cognitive learning in Assessment processes	Implement and evaluate the teaching-learning approach based on immersive technology, measuring metacognitive learning indices, and preparing professionals to face challenges with confidence.
7. Propose a Continuous Improvement of Teaching and Learning	Based on results and feedback, continuously improve the approach, identifying strengths, areas to be reviewed and ensuring the relevance of activities to the real needs of students.

Source: Own authorship (2023).

The structure of the approach stages, as presented in Table 8, underscores the importance of meticulous planning aligned with the specific needs of the Military Firefighters. The developed technical proposal highlights a significant change by introducing immersive technology into the Pedagogical Training Curriculum of

CBMPR. Analysis of pedagogical documents and interviews with the Education Coordinator revealed that the inclusion of immersive technology as a new discipline offers several advantages, including cost savings on training, actions promoting continuous improvement and preservation, risk reduction, and sustainability.

The technological innovation used in this approach provides more engaging and creative cognitive experiences, enabling firefighters to train in a more realistic virtual environment. This significantly contributes to enhancing their skills and readiness to handle complex situations more efficiently and effectively. Therefore, the integration of immersive technology into the CBMPR Curriculum Matrix (Appendix H) fulfils the commitment of the General Command Officers to provide quality technological education aligned with current demands. This curricular complement for firefighters' professional development, as described in Table 14, includes the discipline of Immersive Technology.

Table 14 - Immersive Technology - Complementary discipline of the Curricular Matrix

SUBJECT: Immersive Technology for Fire Fighting Training			
Objectives: - Empower students to tackle firefighting situations through immersive technology. - Develop metacognitive and cognitive skills that integrate practical and virtual knowledge. - Promote assertive decision-making, agility, and precision in actions in emergency scenarios.			
TEACHING AREA	**Nº 43**	**MODULES**	**Workload**
COMPLEMENTARY	1º	**Introduction to Immersive Technology:** - Fundamental concepts of immersive technology and virtual reality. - Exploring the possibilities and benefits of technology in firefighter training.	4 hs.
	2º	**Metacognition and Cognition in Immersive Learning:** - Study of the interactions between the brain and immersive technology in the learning process. - Understanding of the cognitive and metacognitive strategies activated during immersive training.	6 hs.
	3º	**Instructional Design for Virtual Environments:** - Instructional design principles applied to the creation of virtual training environments. - Realistic scenario planning that simulates real firefighting challenges.	8 hs.
	4º	**Development of Immersive Scenarios:** - Use of tools and software to create immersive scenarios. - Integration of visual, sound and interactive elements simulating emergencies.	10 hs.
	5º	**Decision Making and Rapid Response:** - Training for real-time decision-making based on virtual scenarios. - Practice of rapid response and coordination of actions in critical situations.	8 hs.
	6º	**Assessment and Adaptive Feedback:** - Strategies for assessing student performance in virtual environments.	6 hs.

		- Use of adaptive feedback to improve skills and competencies.	
	7º	**Practical Application and Field Simulations:** - Application of acquired knowledge in real firefighting scenarios. - Integration of virtual experiences with practical training in the field (conventional/virtual, self-assessment).	8 hs.
EVALUATIONS	8º	**Subdivided into practical and virtual:** - Participation in the classroom. - Evaluative instrument (scenarios, use of the tool, virtual test). - Individual and group assignments that apply the concepts learned. - Firefighting simulation projects that demonstrate the integration from virtual learning to real practice.	6 hs.
TOTAL COURSE LOAD			**56 hours**

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Source: Own authorship (2023).

The discipline of immersive technology aims fundamentally to incorporate metacognitive elements into troop learning, providing military personnel with more effective and efficient performance in combat operations within challenging scenarios. The objective is to enable acquired knowledge to be reviewed through repeated simulations, without risks for those involved in real incidents, including the professionals themselves and the victims. The primary benefits of including this discipline in the curriculum matrix are:

- Advanced development of cognitive and metacognitive skills.
- Enhancement in decision-making during emergency situations.
-Effective integration between theoretical knowledge and practical experiences.
- Preparation of firefighters to act promptly, efficiently, and effectively in challenging scenarios.
- Encouragement of self-assessment of actions taken in simulated training exercises using immersive technology - VR.

5.1 Metacognition Approach to Immersive Technological Learning

The structure presented in Table 8 shows the importance of meticulous planning that meets the specific demands of Military Firefighters. The developed technical-technological approach proposes the integration of immersive technology into the Pedagogical Training Curriculum of CBMPR. Upon analysing pedagogical documents and conducting interviews with the institution's Education Coordinator, it was observed that the inclusion of immersive technology as a new discipline offers significant advantages. This innovation may provide more engaging and creative cognitive experiences, allowing firefighters to train in a more realistic virtual environment, thus contributing to the enhancement of their skills and better preparation for complex and challenging situations with increased effectiveness.

Furthermore, the implementation of immersive technology in Fire Department training doesn't aim to replace conventional practical training associated with professional practice. Instead, it creates opportunities for metacognitive training in shorter, more accessible timeframes within the daily work routine. The equipment is designed to be utilized in a mobile format, reaching all the state's barracks. This strategy aims to significantly increase military training time, providing advantages without entirely replacing conventional practical training.

Regarding sustainability, the integration of immersive technology, especially through VR simulations, stands out for generating a considerable saving of resources. In real-life scenarios, such as fighting residential fires, the use of large volumes of water, ranging between 6 and 10 thousand litters, is common, considering various circumstances. In practical training, despite efforts towards optimization and waste reduction, resources like water are still consumed. However, by adopting VR simulation, this consumption is eliminated. This approach not only contributes to reducing the carbon footprint by avoiding the burning of products and other elements present in traditional methods, but also significantly promotes environmental preservation.

Next topics to be addressed:

- Gradual implementation into curricula in other security areas.
- Impact of risk reduction on standard operating procedures.
- Integration of VR-based training protocols at a national level.
- Studies on operational cost reduction through VR usage.
- Evaluation of the positive psychological impact on firefighters using immersive technology in their training.
- Sustainability (environmental, economic, and social).

5.1.1 Objectives of Immersive Technological Learning

The primary objective of immersive technological learning is to provide a unique opportunity for individuals to delve into the understanding and exploration of their own learning process. By allowing a detailed analysis of how knowledge is assimilated and adapted, both in real and virtual contexts, this approach actively stimulates cognitive processes. Immersive technology acts as a catalyst, activating prior memory of acquired knowledge and integrating it into new learning.

The Metacognition Approach of Immersive Technological Learning enables a thorough analysis of cognitive skills activated during the learning process, establishing connections with experiences in the work environment. Through this metacognitive reflection, students can enhance their learning strategies, increasing the effectiveness of applying knowledge in practical situations. Therefore, immersive technology not only enriches the educational experience but also deepens the understanding of the learning process and its real-world applications, empowering individuals to reach a higher level of competence and excellence.

Such an approach, used to update the Curriculum Matrix of CBMPR with the integration of immersive technology, reflects the pursuit of alignment with contemporary technological advancements. The introduction of metacognitive learning empowers students to adopt new approaches to their own learning. Through the virtual simulator, there's a convergence between practical experiences and the cognitive sphere, fostering a synergy that connects experiential knowledge to the virtual realm.

The integration of immersive technology into the Fire Department's Curriculum Matrix goes beyond mere updating, paving the way for a more comprehensive learning experience. This metacognitive approach allows students to explore new perspectives. The technology employed, in this case, the virtual simulator, blends real experiences with the cognitive environment, strengthening practical understanding with an innovative reflective dimension. Immersive technology is strategically adopted due to its capacity to simulate realistic scenarios, promote active and adaptive participation, as well as provide education aligned with the current technological context and practical needs of the professional environment.

5.1.2 Requirements Analysis for Metacognitive Learning

The requirements analysis for metacognitive learning is an essential process in creating educational environments that foster self-reflection, informed decision-making, and the ability for self-regulation in learning. It involves identifying specific student needs, evaluating cognitive strategies, recognizing obstacles, and creating a learning context that enables them to develop refined teaching skills. This process is crucial to empower students, making them autonomous learners capable of maximizing their learning capacity and decision-making within the educational context.

The analysis process conducted by the researcher, along with the collected samples, allowed for a detailed mapping of the areas benefiting from immersive technology. This resulted in the enhancement of student training, aligning it with the complexities of the field. The analysis of encountered situations and feedback from involved parties served as the basis for creating a comprehensive instructional plan. The result is this teaching approach that balances practical, cognitive, and metacognitive demands, culminating in a more tailored and comprehensive training for firefighters, significantly and effectively connecting conventional and virtual learning.

5.1.3 Development of Virtual Scenarios

The development process of virtual scenarios, simulating training situations, involves an acquired VR simulator utilized by Brazilian firefighters. This simulator comprises gear, accessories, and VR goggles, offering a highly immersive experience. It mentally transports the user into a virtual environment that faithfully replicates the real conditions faced in their daily work routine. The virtual scenarios are designed to engage firefighters in situations requiring quick and effective logical reasoning, combining their intrinsic knowledge with the opportunity to analyse and enhance their skills and actions to be applied in each disaster occurrence.

3D modelling played a fundamental role in the creation of these virtual scenarios. In this sense, utilizing technologies such as VR, AR, and MR, precise modelling was carried out for structures, buildings, floors, vehicles, aircraft, and forest areas, among other elements, ensuring that each scenario faithfully reflected reality. For example, scenarios were created to represent accidents involving vehicles with fires, fires in residences with internally difficult access floors, interior fires in airplanes, ships, and open forest areas, proportionally increasing the risks and challenges (Figure 20).

Figure 20 - Simulated scenarios adapted to the Brazilian reality

Source: Antonino (2021).

Animation played a significant role in creating dynamic interactions within the virtual scenarios. Virtual animations were designed to simulate realistic fire behavior, victim movements in rescue situations, and other dynamic elements present in firefighting scenarios. For instance, in forest fire scenarios, animations realistically portrayed the spread of flames and the challenge of controlling them. This provided users with an immersive and engaging experience, enabling them to authentically interact and respond realistically and effectively to the challenges presented (Figure 21).

Figure 21 - Multiple Casualty Accident Simulation (AMUVI) - VR

Source: Wijkmark, Heldal and Metallinou (2019).

The unique ability to evoke real firefighting experiences encountered by the military during virtual training is noteworthy. This enables trainee firefighters to relive or enhance their responses to situations they have previously faced, opening doors to new approaches and learning opportunities, as described and differentiated in Appendix J.

5.1.4 Comparing Training Methods: Conventional and Virtual Reality (VR)

Throughout the action research stages, the author was able to observe and perceive specific elements regarding the usability of the FLAIM Trainer VR. Among these, the distinction between the vivid necessity of conventional training, as well as the importance of the complementary use of immersive technology in the professionals' daily routine.

5.1.4.1 Conventional Training

Brazilian military firefighters are considered 'Heroes' by the population as they work incessantly aiming to 'protect life, the environment, and property, promoting responsible and safe social development' - CBMPR. Therefore, besides their initial training period, they undergo monthly continuous training and capacity building.

Conventional training becomes necessary and cannot be replaced so that they can be prepared to respond to various types of emergencies. To achieve this, an entire system of strategic logistics is activated, ensuring that the troops fully participate in the stages.

5.1.4.1.1 Conventional Training - Logistic Demands, Costs, and Risks

Adequate time and physical space are required to accommodate all the operational planning, along with the high logistical costs involving:

- Professionals (Officers and enlisted personnel - student instructors)
- Personnel reassignment and availability (time in work schedules)
- Accommodation and meals for everyone during the course
- Transportation of vehicles, equipment, and materials, etc.
- Physical risks for participants (dehydration, burns, hyperthermia, accidents)
- Environmental impact (waste disposal, increased water consumption, emission of harmful gases).

5.1.4.2 VR-Based Training - Economic Emphasis, Sustainable Aspects, and Resource Efficiency

Supplementary training with the VR simulator does not replace the learning activities related to the conventional training required by the profession. However, it can be utilized with greater itinerary and transport flexibility. It can be used to complement curriculum-based training, making it available for on-duty teams at the barracks during flexible days and hours, in addition to numerous sustainable aspects, such as:

- Reduction and savings in water usage for simulations.

- Decrease in carbon footprint and greenhouse gas preservation.

- Lesser environmental impact (absence of physical and chemical residues).

- Simplified Logistics: (lower logistical needs, fewer personnel, materials, equipment).

5.1.4.2.1 Associated Risks

- Physical and Environmental Risks of Conventional Training:
- Exposure to physical health risks (burns, falls, injuries, etc.).
- Negative environmental impacts due to material burning and natural resource use.

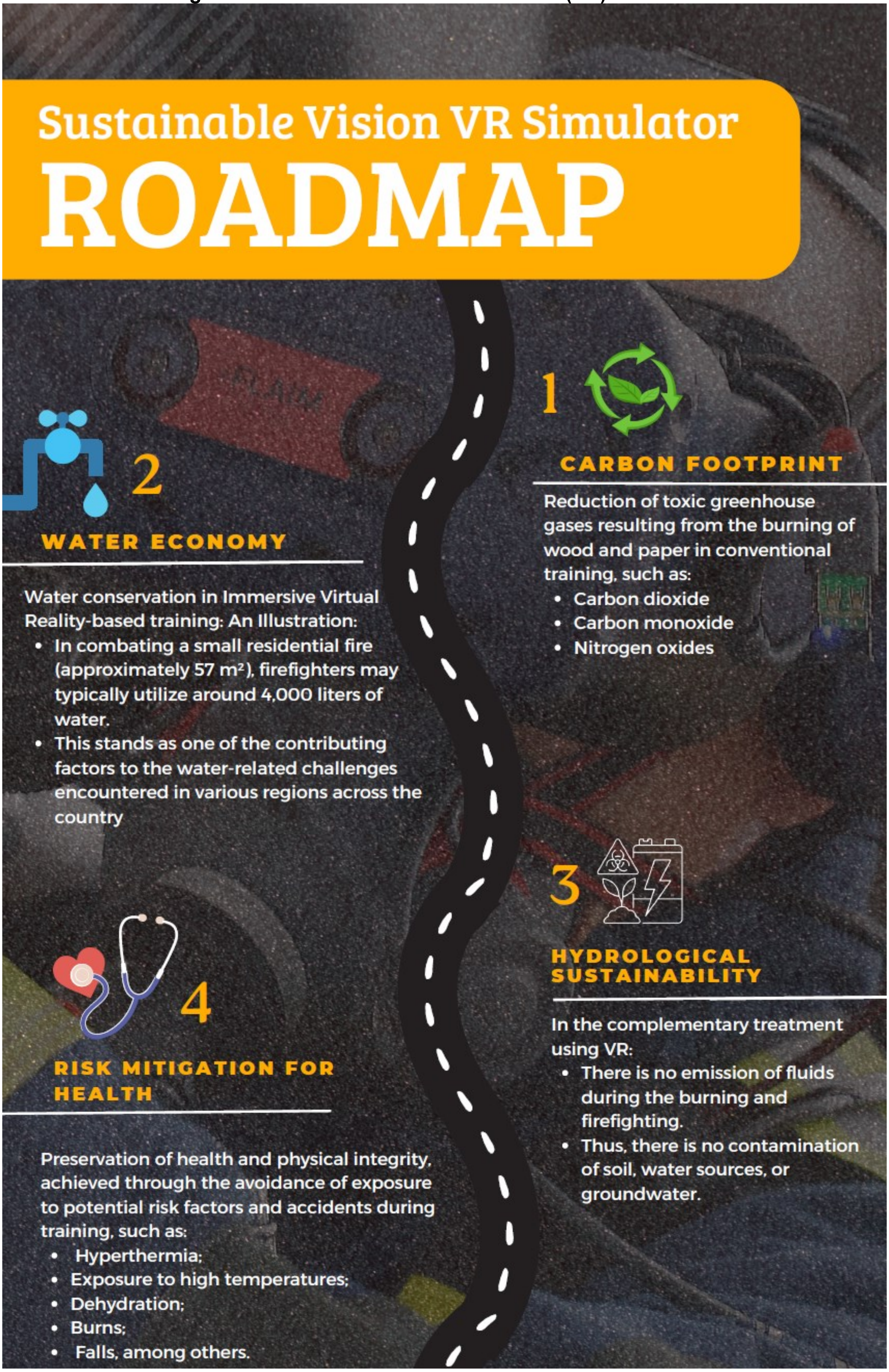
5.1.4.3 Usability and Expertise Developed in Immersive Technology

Some important aspects include:

- Improved Usability
- Development of specialized skills in a secure virtual environment
- Greater accessibility to training for different contexts and scenarios.

This approach highlights the key comparative aspects between the two types of training, prioritizing economy, sustainability, risks, and usability through immersive technology. Each section can be programmed and detailed as needed, including specific data, statistics, or examples to strengthen the comparison (Figure 22).

Figure 22 - Sustainable Vision Simulator (VR) ROADMAP



Source: Own authorship (2023).

The ROADMAP Infographic highlights the positive impacts of immersive technology, especially VR, in the training context of firefighters. It emphasizes the equity and sustainability that this technology provides, not only in terms of innovation and quality in professional training, but also in environmental and resource aspects. It details aspects such as reducing carbon footprint, water conservation, preserving water resources, mitigating health risks, and resource optimization. Additionally, it underscores the flexibility and mobility of the tool, enabling swift and efficient integration with troops in different operational scenarios.

6 FINAL REMARKS

The teaching approach for technical-technological training based on immersive technology represents a significant advancement in the training of the Military Fire Departments of the State of Paraná. By identifying the applicability and contributions of immersive technologies for educational purposes, this work has demonstrated the feasibility and benefits of integrating these technologies into firefighter training.

The study identified various applications of the FLAIM Trainer Virtual Reality for the training of the Military Fire Department of Paraná. This included simulating realistic scenarios of firefighting and rescues, providing a safe and effective training environment for firefighters to enhance their skills.

The research highlighted that immersive technologies play a crucial role in disaster management. By enabling detailed and practical simulations of emergency situations, this technology contributes to the preparedness and swift response to disasters, enhancing the efficiency and effectiveness of rescue operations.

The analysis of usability and perceptions among Military Firefighters revealed a positive reception towards Virtual Reality (VR) training. They showcased effective adaptation and a genuine appreciation for the immersion provided by VR in training, acknowledging improvements in understanding and practical application of the acquired knowledge.

In assessing the Curriculum Framework of the Fire Department, the inclusion of Immersive Technology was proposed as a valuable addition to training. Integrating this resource into the teaching for student training enriches the offered content, enabling practical application and skill enhancement through realistic virtual simulations.

Based on the action research conducted within the Paraná Fire Department, an educational approach proposal was developed to complement the Curriculum Framework. This proposal aims to strategically integrate Immersive Technology, providing guidelines and structures to enhance firefighters' training, focusing on practical scenarios, and efficiently preparing them for real-life situations.

The proposed objective of this study was fully achieved by investigating the usability of Immersive Technology FLAIM Trainer Virtual Reality to train the Military Fire Department of the State of Paraná. This research allowed proposing an efficient and effective approach to complement the teaching-learning process, highlighting the relevance and benefits of these technologies for firefighters' training. This approach complements the Curriculum Framework of the Paraná Fire Department (CBMPR), expanding the experiences of the military concerning spatial vision, logic, motor and sensory coordination, internalizing processes through repetition, memory, and learning.

Every experience gained during the research contributed to providing the author with a deeper intellectual foundation to conduct in-depth studies on how meaningful learning occurs through cognitive elements, aligning knowledge with the intrinsic experiences derived from firefighters' professional practice. This can contribute to a complementary and high-quality education and training.

Hence, the significance of this research extends to the training and capacity-building within the Fire Department, highlighting the importance of utilizing Immersive Technologies like the FLAIM Trainer Virtual Reality. Furthermore, it contributes to future endeavours in this field and other knowledge domains.

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APPENDIX A - Systematic Literature Review Procedures

SISTEMATIC LITERATURE REVIEW PROCEDURES

According to Pagani *et al*. (2017), the following steps constitute an RSL:

Stages 1 and 2: Establish Research Intent and Preliminary Searches: The first two stages aim to define the research objective. Consequently, potential keywords representing this objective are selected, and preliminary searches using these keywords are conducted across various databases.

Stages 3 and 4: Keyword Definition and Database Selection, and Final Search. Based on preliminary searches, keyword combinations and databases are selected, with the databases determined by the highest number of articles returns per search. Following this, the final search is conducted across chosen databases. To do this, specific configurations were set within the databases for the final search, including:

- Temporal Delimitation: No temporal cutoff filter was applied.
- Search in Fields: Title, Abstract, and Keywords.
- Filtering by Knowledge Area, resulting in articles more aligned with the study's theme. The results of stages 3 and 4 are presented in Appendix B of the study.

Stage 5: Feltrin Procedures. In this step, the entire bibliographic material underwent the following procedures: i) Removal of duplicates; ii) Elimination of studies outside the scope through preliminary readings of abstracts; and iii) Elimination of conference papers and books (only journal articles proceeded to subsequent steps due to their Impact Factor, which is measurable). Ultimately, the researcher may include conference papers or other materials in their portfolio if the topic/scope is relevant. The results of this stage are presented in Appendix C.

Stage 6: Identify Impact Factor metrics (most recent from Clarivate Analytics® - Web of Science), number of citations as per Google Scholar®, and the year of publication of the article, respectively.

Stage 7: InOrdinatio Analysis. In electronic spreadsheets, the InOrdinatio value for each article was determined using Equation 1.

$$\text{InOrdinatio} = \left(\frac{\text{IF}}{1000}\right) + \Big(\alpha \times \big(10 - (\text{ResearchYear} - \text{PublishYear})\big)\Big) + (\text{Ci}) \qquad (1)$$

In the Method, IF stands for Impact Factor, α represents the weight ranging from 1 to 10 assigned by the researcher; ResearchYear is the year the research was conducted; PublishYear is the year of the article's publication, and Ci is the number of citations for this article (Pagani; Kovaleski; Resende, 2015). With α (alpha) representing the importance of the timeliness of the topic, ranging from 1 to 10, as stated by the authors, in this study, the topic is current, thus assigning α a value of 10, and the ResearchYear is the year the search in the databases was conducted, which is 2022.

From the article sorting, a cutoff score was defined, allowing the selection of the most scientifically relevant articles. It was established that only articles with an InOrdinatio score above 100 would be included in the final portfolio. Appendix C presents the results of stage 7.

Stages 8 and 9: After compiling a bibliographic portfolio, the full-text articles were obtained, and a systematic analysis of the articles was conducted.

APPENDIX B - Definitive research in databases

DEFINITIVE RESEARCH IN DATABASES

Table 15 - Quantity of papers per theme combination

N	Keywords	Scopus	Web of Sciences	Science Direct
1	"Disaster Management" AND ("Pandemic*" OR "healthcar*" OR "SARS-Cov-2" OR "COVID-19")	369	173	40
2	("internet of things" OR "IoT" OR "Artificial intelligence" OR "5G") AND "healthcare" AND "Disaster Management"	11	10	3
3	("internet of things" OR "IoT" OR "Artificial intelligence" OR "5G") AND "healthcare" AND ("SARS- Cov-2" OR "COVID 19" OR "COVID-19" OR "pandemic")	443	165	72
4	("training" OR "capacity building") AND "firefighter" AND ("virtual reality" OR "immersive technolog*")	28	7	7
	Total		**1328**	

Source: Own authorship (2023).

APPENDIX C - Filtering Procedures

FILTERING PROCEDURES

Table 16 - Quantities of articles, after filtering

Procedures	Excluded articles	%
Deletion by duplicates	380	28,6%
Exclusion by document type (Books, Book Chapters, and Conferences)	6	0,5%
Exclusion by content (reading, title, abstract and/or full article)	706	53,2%
Total Excluded Articles	1092	82,2%
Number of articles in the portfolio	**236**	**18%**

Source: Own authorship (2023).

APPENDIX D - Bibliographic Portfolio

BIBLIOGRAPHIC PORTFOLIO

Table 17 - Bibliographic material obtained from Methodi Ordinatio

Article Title	Journal	InOrdinatio
Artificial Intelligence (IA) applications for COVID-19 pandemic	Diabetes & Metabolic Syndrome: Clinical Research & Reviews	907
A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact	IEEE Access	755
Internet of things (IoT) applications to fight against COVID-19 pandemic	Diabetes & Metabolic Syndrome: Clinical Research & Reviews	501
AI4COVID-19: AI enabled preliminary diagnosis for COVID-19 from cough samples via an app	Informatics in Medicine Unlocked	427
The effectiveness of virtual reality for administering spatial navigation training to firefighters	Presence: Teleoperators and Virtual Environments	253
Internet of Things for Current COVID-19 and Future Pandemics: an Exploratory Study	Journal of Healthcare Informatics Research	242
A virtual reality-based fire training simulator integrated with fire dynamics data	Fire Safety Journal	236
Internet of Medical Things (IoMT) for orthopaedic in COVID-19 pandemic: Roles, challenges, and applications	Journal of Clinical Orthopaedics and Trauma	209
Application of cognitive Internet of Medical Things for COVID-19 pandemic	Diabetes & Metabolic Syndrome: Clinical Research & Reviews	206
Preparedness and preventive behaviors for a pandemic disaster caused by COVID-19 in Serbia	International Journal of Environmental Research and Public Health	203
Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 Pandemic	Journal of Oral Biology and Craniofacial Research	200
Blockchain and AI-Based Solutions to Combat Coronavirus (COVID-19)-Like Epidemics: A Survey	IEEE Access	196
Digital technology, tele-medicine and artificial intelligence in ophthalmology: A global perspective	Progress in Retinal and Eye Research	195
Sociodemographic predictors of health risk perception, attitude and behavior practices associated with health-emergency disaster risk management for biological hazards: The case of COVID-19 pandemic in Hong Kong, SAR China	International Journal of Environmental Research and Public Health	192
Applications of industry 4.0 to overcome the COVID-19 operational challenges	Diabetes & Metabolic Syndrome: Clinical Research & Reviews	183
Emerging Technologies for Use in the Study, Diagnosis, and Treatment of Patients with COVID-19	CELLULAR AND MOLECULAR BIOENGINEERING	179
Internet of medical things (IoMT)-integrated biosensors for point-of-care testing of infectious diseases	Biosensors and Bioelectronics	169
The Fight against the COVID-19 Pandemic with 5G Technologies	IEEE Engineering Management Review	167
Telepsychiatry and other cutting-edge technologies in COVID-19 pandemic: Bridging the distance in mental health assistance	International Journal of Clinical Practice	162
COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life	IEEE Access	157
Applications of digital health for public health responses to COVID-19: a systematic scoping	npj Digital Medicine	149

review of artificial intelligence, telehealth and related technologies		
Increasing access to care: telehealth during COVID-19	JOURNAL OF LAW AND THE BIOSCIENCES	147
Managing disasters amid COVID-19 pandemic: Approaches of response to flood disasters	PROGRESS IN DISASTER SCIENCE	146
Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic	Health and Technology	145
A virtual reality-based fire training simulator with smoke hazard assessment capacity	Advances in Engineering Software	139
Green internet of things using UAVs in B5G networks: A review of applications and strategies	AD HOC NETWORKS	133
A hover view over effectual approaches on pandemic management for sustainable cities - The endowment of prospective technologies with revitalization strategies	Sustainable Cities and Society	132
Blockchain-Empowered Multi-Robot Collaboration to Fight COVID-19 and Future Pandemics	IEEE Access	131
An Analysis of VR Technology Used in Immersive Simulations with a Serious Game Perspective	IEEE Computer Graphics and Applications	129
A proposed collaborative framework by using artificial intelligence-internet of things (AI-IoT) in COVID-19 pandemic situation for healthcare workers	International Journal of Healthcare Management	127
A Review of Competencies Developed for Disaster Healthcare Providers: Limitations of Current Processes and Applicability	PREHOSPITAL AND DISASTER MEDICINE	127
Vision of China's future urban construction reform: In the perspective of comprehensive prevention and control for multi disasters	Sustainable Cities and Society	125
IoT PCR for pandemic disease detection and its spread monitoring	Sensors and Actuators B-Chemical	125
Spatial and temporal distribution of infectious disease epidemics, disasters and other potential public health emergencies in the World Health Organization Africa region, 2016-2018	Globalization and Health	125
A home hospitalization system based on the Internet of things, Fog computing and cloud computing	Informatics in Medicine Unlocked	124
Applications of artificial intelligence in COVID-19 pandemic: A comprehensive review	Expert Systems with Applications	123
Applications of big data analytics to control covid-19 pandemic	Sensors	122
Integrating Digital Technologies and Public Health to Fight Covid-19 Pandemic: Key Technologies, Applications, Challenges and Outlook of Digital Healthcare	International Journal of Environmental Research and Public Health	121
COVID-19: Challenges and its Technological Solutions using IoT	CURRENT MEDICAL IMAGING	120
A conceptual IoT-based early-warning architecture for remote monitoring of COVID-19 patients in wards and at home	Internet of Things	117
Disaster management of the psychological impact of the COVID-19 pandemic	INTERNATIONAL JOURNAL OF EMERGENCY MEDICINE	117
Disaster and Pandemic Management Using Machine Learning: A Survey	IEEE INTERNET OF THINGS JOURNAL	115
Future IoT tools for COVID-19 contact tracing and prediction: A review of the state-of-the-science	INTERNATIONAL JOURNAL OF IMAGING SYSTEMS AND TECHNOLOGY	115

Agents and robots for collaborating and supporting physicians in healthcare scenarios	Journal of Biomedical Informatics	114
Deep-LSTM ensemble framework to forecast Covid-19: an insight to the global pandemic	International Journal of Information Technology (Singapore)	114
Information technology in emergency management of COVID-19 outbreak	Informatics in Medicine Unlocked	113
A SWOT Analysis of the Field of Virtual Reality for Firefighter Training	FRONTIERS IN ROBOTICS AND AI	111
An IoT-Based Healthcare Platform for Patients in ICU Beds during the COVID-19 Outbreak	IEEE Access	111
Disaster Ergonomics: Human Factors in COVID-19 Pandemic Emergency Management	HUMAN FACTORS	110
Addressing the psychological impact of COVID-19 on healthcare workers: Learning from a systematic review of early interventions for frontline responders	BMJ Open	110
Humanitarian health computing using artificial intelligence and social media: A narrative literature review	International Journal of Medical Informatics	109
Internet of things for healthcare monitoring applications based on RFID clustering scheme	Wireless Networks	108
Scientific risk performance analysis and development of disaster management framework: A case study of developing Asian countries	Journal of King Saud University - Science	107
Applications of virtual and augmented reality in infectious disease epidemics with a focus on the COVID-19 outbreak	Informatics in Medicine Unlocked	107
An internet of things-based point-of-care device for direct reverse-transcription-loop mediated isothermal amplification to identify SARS-CoV-2	Biosensors and Bioelectronics	106
IOMT-based automated detection and classification of leukemia using deep learning	Journal of Healthcare Engineering	106
Applications of drone in disaster management: A scoping review	SCIENCE & JUSTICE	106
Application of artificial intelligence to the electrocardiogram	European Heart Journal	105
Virtual reality in training: an experimental study with firefighters	Multimedia Tools and Applications	105
Telehealth and Artificial Intelligence Insights into Healthcare during the COVID-19 Pandemic	HEALTHCARE	105
Artificial intelligence for COVID-19: battling the pandemic with computational intelligence	Intelligent Medicine	105
Spatial knowledge and firefighters' wayfinding performance: A virtual reality search and rescue experiment	Safety Science	104
All around suboptimal health - a joint position paper of the Suboptimal Health Study Consortium and European Association for Predictive, Preventive and Personalised Medicine	EPMA JOURNAL	103
5G standards for the Industry 4.0 enabled communication systems using artificial intelligence: perspective of smart healthcare system	Applied Nanoscience (Switzerland)	103
Challenges for Nurses in Disaster Management: A Scoping Review	Risk Management and Healthcare Policy	103
ANN Assisted-IoT Enabled COVID-19 Patient Monitoring	IEEE Access	102

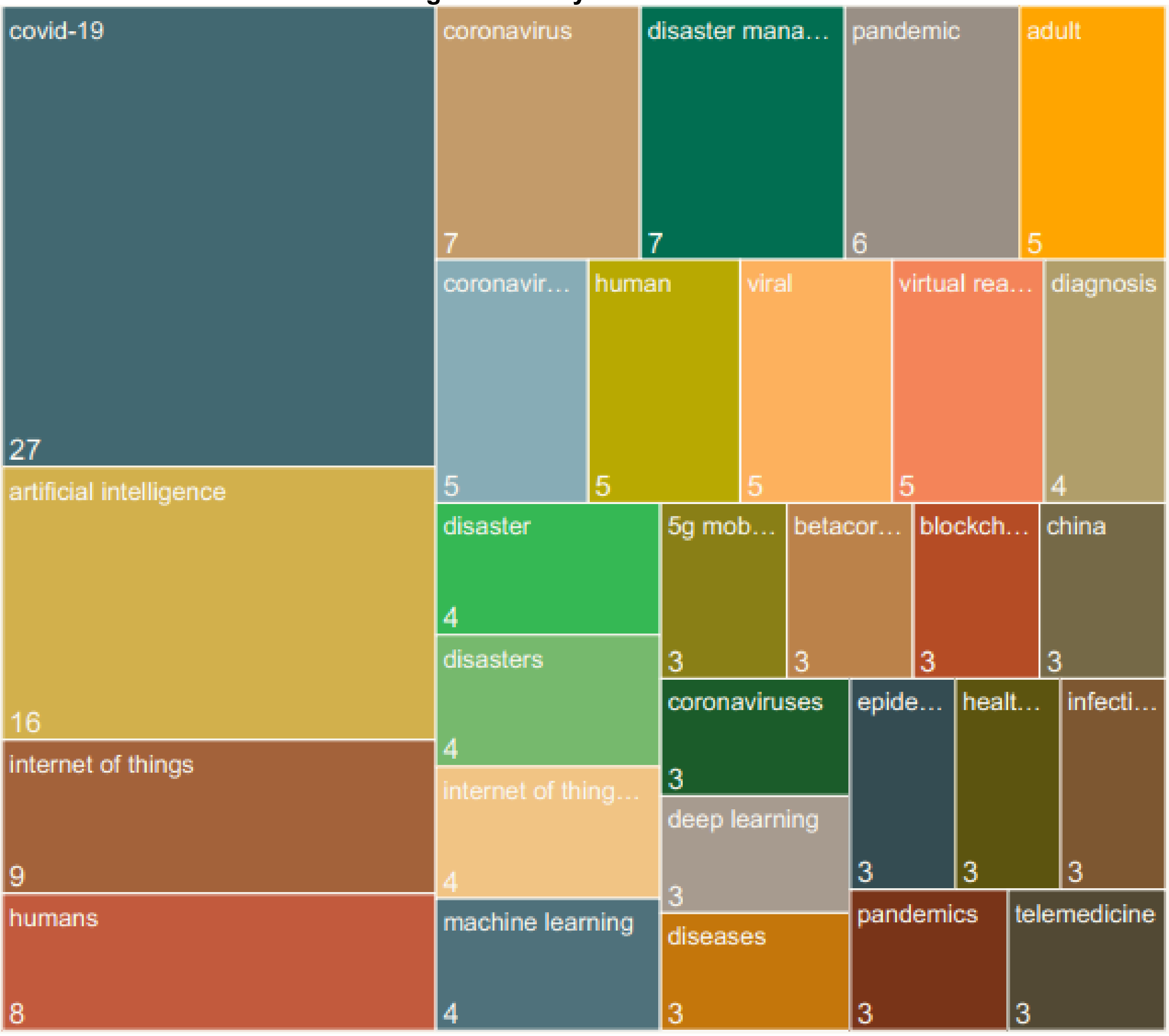
Development of Advanced Artificial Intelligence and IoT Automation in the Crisis of COVID-19 Detection	Journal of Healthcare Engineering	102
Fire Emergency Evacuation from a School Building Using an Evolutionary Virtual Reality Platform	Buildings	102
Advances in Telemedicine in Ophthalmology	Seminars in Ophthalmology	102
Artificial Intelligence for COVID-19: A Systematic Review	FRONTIERS IN MEDICINE	101
Digital imaging, technologies and artificial intelligence applications during COVID-19 pandemic	Computerized Medical Imaging and Graphics	101
The influence of COVID-19 on community disaster resilience	International Journal of Environmental Research and Public Health	101
A Predictive Model of Pandemic Disaster Fear Caused by Coronavirus (COVID-19): Implications for Decision-Makers	International Journal of Environmental Research and Public Health	101
Digital Healthcare for Airway Diseases from Personal Environmental Exposure	YONSEI MEDICAL JOURNAL	101
Adopting MQTT for a multi protocols IoMT system	International Journal of Electrical and Computer Engineering	101
A Blockchain and Artificial Intelligence-Based, Patient-Centric Healthcare System for Combating the COVID-19 Pandemic: Opportunities and Applications	HEALTHCARE	101
Knowledge, attitude, and practice of artificial intelligence among doctors and medical students in Pakistan: A cross-sectional online survey	Annals of Medicine and Surgery	101
A Cross-sectional Study About Nurses' and Physicians' Experience of Disaster Management Preparedness Throughout COVID-19	DISASTER MEDICINE AND PUBLIC HEALTH PREPAREDNESS	101

Source: Own authorship (2023).

APPENDIX E - Results of Content Analysis

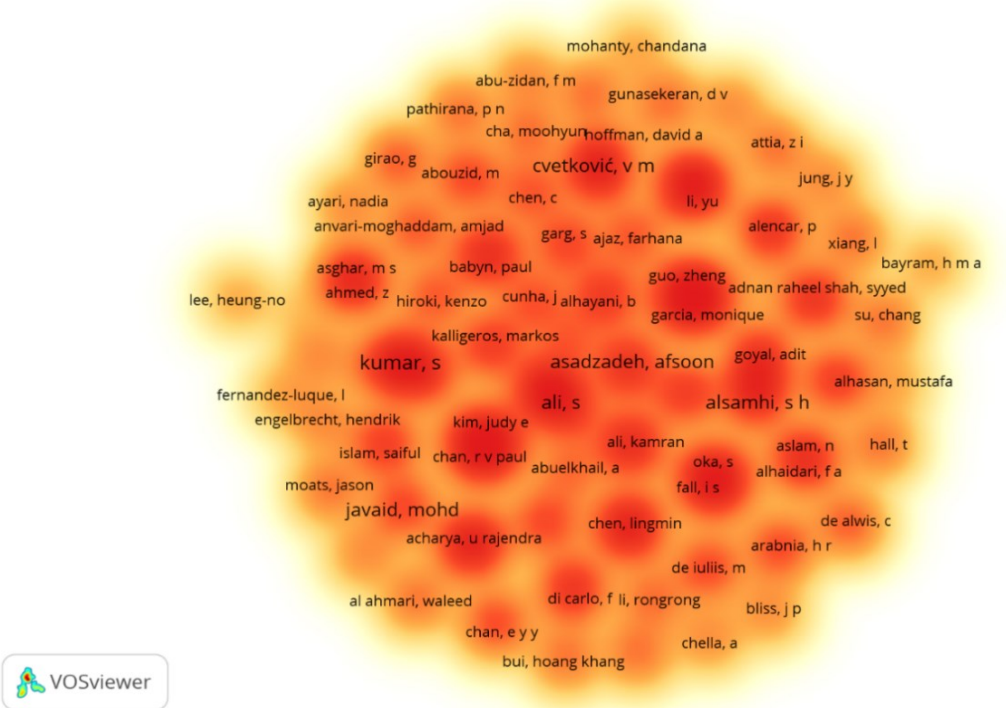
RESULTS OF CONTENT ANALYSIS

Figure 23 - Keyword Portfolio



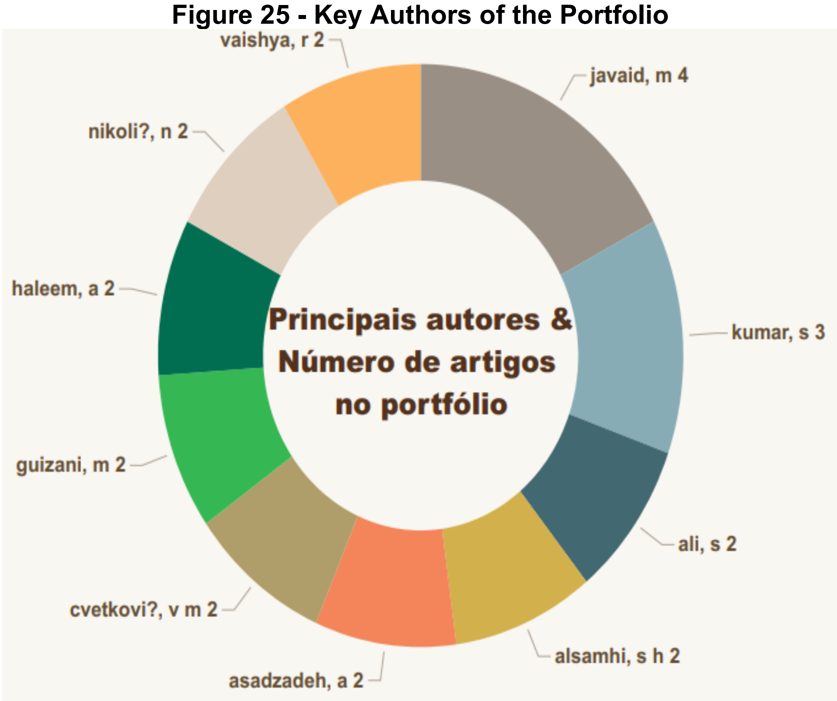
Source: Tree Map, software Power BI (2022).

Figure 24 - Portfolio Authors Density Map



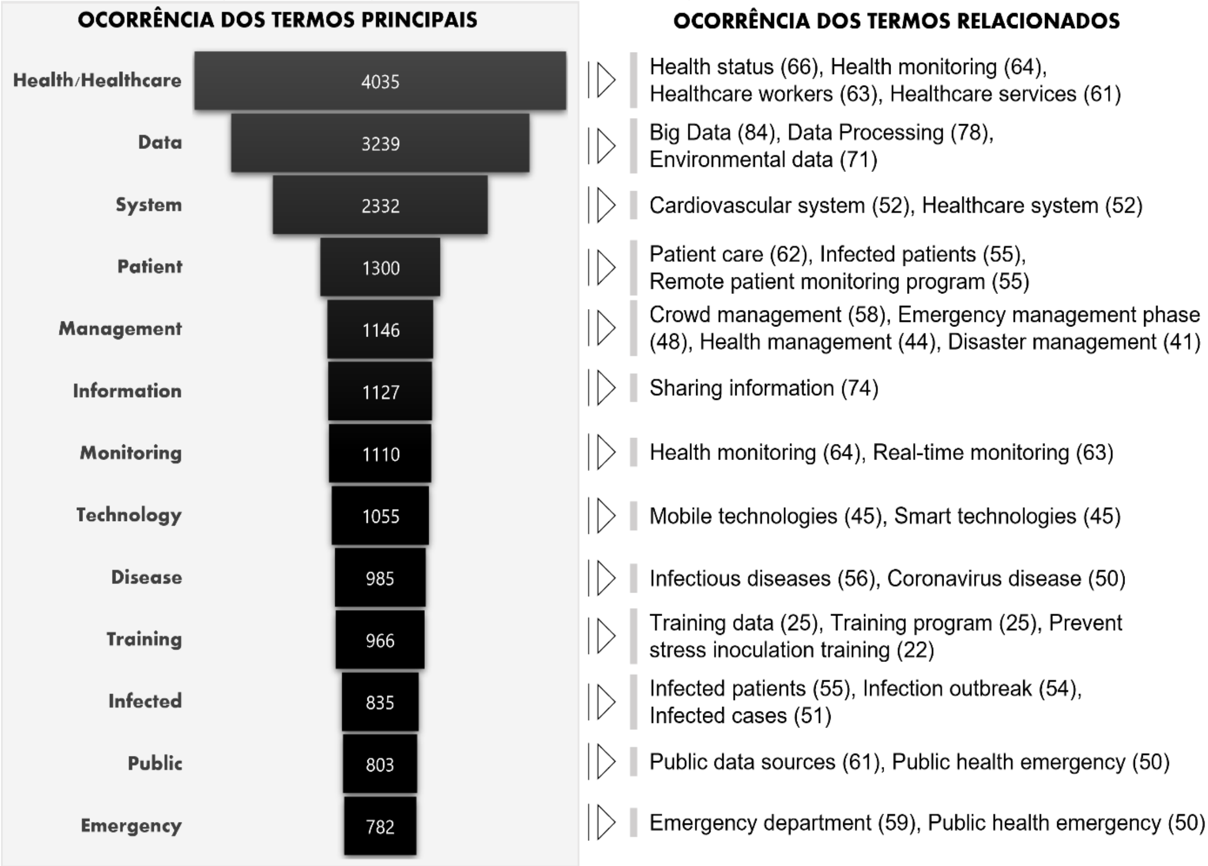
Source: Software VOSviewer (2022).

Figure 25 - Key Authors of the Portfolio



Source: Software VOSviewer (2022).

Figure 26 - Key terms mentioned throughout the portfolio articles



Source: Software Nvivo 12 (2022).

APPENDIX F - Cooperation Agreement - Norway and Brazil

WORK PLAN (Aug 2021 – Dec 2022)

VIRTUAL REALITY (VR) FOR FIREFIGHTER SKILL TRAINING

Collaboration project between:
WESTERN NORWAY UNIVERSITY OF APPLIED SCIENCES (HVL), NORWAY
FEDERAL UNIVERSITY OF TECHNOLOGY OF PARANÁ (UTFPR), BRAZIL
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APPENDIX G: Publication between Universities and Fire Department

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Journal of Applied
Technical and Educational Sciences
jATES

ISSN 2560-5429

http://jates.org

jATES
Journal of Applied
Technical and
Educational Sciences

Introducing Virtual Reality for Firefighter Skills Training

Opinions from Sweden and Brazil

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Abstract: The emergence of immersive virtual reality (IVR) technologies has raised interest in the use of fire and rescue services (FRS) as a supplement to the established practice-based hot fire-live simulation (HF-LS) training. This is due to features such as time efficiency, portable technologies, and training in scenarios not possible in HF-LS. However, whether IVR provides realistic firefighter training situations has been called into question. Previous studies have revealed differences regarding perceived presence in, and attitudes toward IVR training between novice firefighters (who can only relate to HF-LS training) and experienced firefighters (who can relate to both HF-LS and real fires). In the present study, two groups of experienced full-time employed firefighters, 53 from Brazil and 18 from Sweden tested the same IVR technology. The hypothesis was that differences in national education and training programs and real fire experiences might influence experiences in IVR technology. This study examines the differences and similarities in experienced presence, opinions on whether the graphical representations and tasks performed convey realism, and attitudes toward the IVR-supported training format. Data were collected via systematic post-training presence questionnaires and observations. The results revealed a highly experienced presence and perceived realism of the representations by the participants from both countries. However, attitudes toward using IVR technologies differed. The motivation to utilize currently available IVR training tools was higher in Brazil than in Sweden. This may be partly explained by less frequent HF-LS training opportunities in Brazil. Nevertheless, further research is needed to investigate the training transfer of IVR technologies and how these can better support skills training.

APPENDIX H - Curriculum Matrix of the Fire Department of the State of Paraná

ESTADO DO PARANÁ
POLÍCIA MILITAR
COMANDO DO CORPO DE BOMBEIROS
CENTRO DE ENSINO E INSTRUÇÃO
"Presidente Carlos Cavalcanti"

MATRIZ CURRICULAR DO CFP – BM – TURMA 2022

CURSO DE FORMAÇÃO DE PRAÇAS BOMBEIROS MILITARES			
ÁREA DE ENSINO	**Nº**	**DISCIPLINA**	**CARGA HORÁRIA**
FUNDAMENTAL	01	História das Polícias e Corpos de Bombeiros	20
	02	Deontologia Profissional	20
	03	Saúde e Segurança Aplicada ao Trabalho	15
	04	Sistema de Comando de Incidentes	30
	05	Direitos Humanos e Constitucional	30
	06	Legislação Institucional	20
	07	Direito Administrativo	30
	08	Direito Disciplinar	30
	09	Noções de Direito Penal, Penal Militar e Processual Penal Militar	30
	10	Fundamentos da Gestão Pública	15
	11	Comunicação Social	30
	12	Armamento e Tiro Policial	30
	13	Tecnologia da Informação	20
	14	Língua e Documentação Técnica	10
	15	Ordem Unida	30
	16	Natação	75
	17	Educação Física Militar	120
TOTAL FUNDAMENTAL			**555**
ÁREA DE ENSINO		**DISCIPLINA**	**CARGA HORÁRIA**
PROFISSIONAL	18	Telecomunicações	20
	19	Segurança Contra Incêndio e Pânico	60
	20	Combate a Incêndios	108

	21	**Combate a Incêndios Florestais**	**36**
	22	**Salvamento Terrestre**	**20**
	23	**Busca Terrestre**	**20**
	24	**Salvamento Veicular**	**40**
	25	**Busca e Resgate em Estruturas Colapsadas**	**20**
	26	**Salvamento em Altura**	**60**
	27	**Salvamento Aquático**	**40**
	28	**Busca Aquática**	**40**
	29	**Sistema de Defesa Civil**	**30**
	30	**Intervenção em Emergências com Produtos Perigosos**	**40**
	31	**Atendimento Pré-Hospitalar**	**130**
	32	**Psicologia das Emergências**	**30**
	33	**Fundamentos da Perícia de Incêndio**	**10**
	34	**Espaço Confinado**	**20**
	35	**Primeira Intervenção em Crises**	**20**
	36	**Salvamento em Águas Rápidas**	**20**
TOTAL PROFISSIONAL/OPERACIONAL			**764**
ÁREA DE ENSINO	**Nº**	**DISCIPLINA**	**CARGA HORÁRIA**
COMPLEMENTAR	**37**	Estágio no COBOM	**12**
	38	Estágio no ABTR	**96**
	39	Estágio no AA	**48**
	40	Estágio na Vistoria	**08**
	41	Atividade Social Comunitária	**08**
	42	Estágios em Ambientes Hospitalares	**12**
TOTAL COMPLEMENTAR			**184**
TOTAL FUNDAMENTAL, OPERACIONAL/COMPLEMENTAR			**1503**

APPENDIX I - Form for Official Fire Instructors (Form 1)

FORM 1

You are free to take part in this study and contribute to our research to enhance firefighter training with your participation. Your responses will be treated confidentially. If you agree to participate, please answer the following questions below and then proceed to the second questionnaire about the use of Virtual Reality (VR) Equipment. If you do not agree to participate, please close the survey now.

Your participation as an Instructor Officer is crucial and contributes to the research on (VR) in Brazil. If you agree to participate, please answer the following questions below and then proceed to the second questionnaire about the use of Virtual Reality (VR) Equipment.

Section 1:

1. If you agree or disagree to participate, please select the option below. If your answer is yes, please complete the questionnaire until the end.

( ) I agree
( ) I disagree

2. Please enter your full name and Corporation ID.

3. Enter your email address.

4. Date of birth

5. Gender

( ) Male
( ) Female

6. For how many years have you been working as a firefighter?

7. What is your position or role?

8. In which Fire Department do you currently serve (city and neighbourhood)?

Section 2:

Respond based on your professional experiences.

In the following questions, we would like to inquire about your previous experiences as a firefighter in 'actual fire incidents.' During your years as a firefighter, estimate how many times, in total, you have fought fires using a water or foam hose:

9. How many times have you fought fires *In:* houses/apartments/inside buildings?

o 0

o 1 - 5

o 6 - 20

o 21 - 50

o More than 50

10. How many times have you fought vehicle fires?

o 0

o 1 - 5

o 6 - 20

o 21 - 50

o More than 50

11. How many times have you fought large fires *In:* forests/parks/fields?

o 0

o 1 to 5 times

o 6 to 20 times

o 21 to 50 times

o More than 50 times

12. How many times have you fought fires *In:* large buildings/warehouses/industries?

o 0

o 1 to 5 times

o 6 to 20 times

o 21 to 50 times

o More than 50 times

13. Are you currently a Fire Instructor?

o Yes

o No

14. For how many years have you been a Fire Instructor?

- o for 1 year
- o for 2 to 3 years
- o for 4 to 5 years
- o for 6 to 7 years
- o More than 7 years

Section 3:

The following questions are related to your EXPERIENCES as an Instructor in firefighting training.

15. Think about it, when was the last time you conducted a firefighting training?

- o Before 2015
- o in 2016
- o in 2017
- o in 2018
- o in 2019
- o in 2020
- o in 2021

16. What month was it?

- o January
- o February
- o March
- o April
- o May
- o June
- o July
- o August
- o September
- o October
- o November
- o December

17. What is the approximate time you remain actively engaged in firefighting (excluding discussions, preparation, etc.) during an instruction?

- o Less than 10 minutes

- o from 10 to 20 minutes
- o from 20 to 30 minutes
- o More than 30 minutes

18. What is the estimated total time dedicated to training, from the beginning to the conclusion of activities, including preparation, execution, and equipment cleanup? Please provide an approximate answer in hours:

- o Less than 1 hour
- o from 1 to 2 hours
- o from 2 to 4 hours
- o from 4 to 6 hours
- o from 6 to 8 hours
- o More than 8 hours

19. To what extent are you satisfied with the amount of firefighting training you receive? Please complete the sentence: 'I would like to train...

- o Much more
- o A bit more
- o About the same
- o A little less
- o Much less

20. To what extent do the tasks you perform in firefighting training correspond to the activities you perform in real firefighting incidents? Please respond on a scale from 1 (not very relevant) to 5 (extremely relevant):

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

21. To what extent do the simulated fire scenarios in Virtual Reality training correspond to real fire incidents? On a scale from 1 to 5, where 1 represents very low correspondence and 5 corresponds to very high correspondence:

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

22. To what extent do the sensations from live firefighting training correspond to the sensations of being in a real-time fire incident? Please estimate on a scale from 1 to 5, where 1 = very low and 5 = very high:

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

Section 4:

The following questions will be about your experiences with games in your daily life.

23. How often do you use games on your cell phone in your daily life? Please estimate on a scale of 1 to 5, where 1 = never and 5 = many times per week:

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

24. How often do you play on your computer or cell phone weekly? Please estimate on a scale of 1 to 5, where 1 = never and 5 = many times per week:

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

25. How often do you use Virtual Reality in your daily life? Please estimate on a scale of 1 to 5, where 1 = never and 5 = many times per week:

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

26. Have you ever used any kind of Virtual Reality (VR) in games or simulations related to your occupation?

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

27. Have you ever used any type of Virtual Reality (VR) in games or simulations related to your occupation?

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

Section 5:

In the following questions, we will ask for your current opinion on the use of Virtual Reality (VR) equipment as a training tool for the Fire Department. Read the statement below and mark your opinion.

28. Can (VR) be used for training firefighters' skills?

o Yes
o No
o Not today, but in the future

29. More training for firefighters?

o Yes
o No

30. Environmentally friendly training?
- o Yes
- o No

31. Trainings without exposure to smoke particles?
- o Yes
- o No

32. Time-efficient training?
- o Yes
- o No

33. Realistic scenarios?
- o Yes
- o No

34. Dynamic scenarios that are impossible to train a firefighter?
- o Yes
- o No

35. Trainings involving unexpected events?
- o Yes
- o No

36. Training involving high-risk situations?
- o Yes
- o No

37. Is training cost-effective?
- o Yes
- o No

Section 6:

Based on your understanding of (VR) training today, mark your opinions on. Check whether you "agree" or "disagree" with the question:

38. Is there a risk of learning and getting used to a false sense of security provided by the equipment during the simulation (no real danger/heat)?

o I agree

o I disagree

39. Is it difficult to understand how the equipment (VR) works?

o I agree

o I disagree

40. Is it very easy to extinguish fires with (VR)?

o I agree

o I disagree

41. Is it very difficult to extinguish fires with (VR)?

o I agree

o I disagree

42. Is (VR) not accepted as a training method among firefighters?

o I agree

o I disagree

43. Is (VR) too complex to use in our training?

o I agree

o I disagree

44. Is (VR) too expensive to use for our training?

o I agree

o I disagree

45. After the training with (VR), how did you feel?

a)	Nauseated	( ) yes	( ) no
b)	Dizziness	( ) yes	( ) no
c)	Visually strained	( ) yes	( ) no
d)	With headaches	( ) yes	( ) no
e)	With stress	( ) yes	( ) no

46. If you would like to contribute further to this research, please leave below the questions you believe are necessary. Thank you very much!

APPENDIX J - Form for Official Firefighters and Students (Form 2) (Questionnaire 2 - applied at (COCI) Curitiba, PR), and (Questionnaire 3 applied at 2nd GB - Ponta Grossa, PR)

FORM 2

You are free to take part in this study and contribute to our research to enhance firefighter training with your participation. Your responses will be treated confidentially.

If you agree to participate, please answer the following questions below and then proceed to the second questionnaire about the use of Virtual Reality (VR) Equipment. If you do not agree to participate, please kindly close the survey now.

Q2 Brasil - O Questionário é composto por 3 Seções:

1, Section 1: We ask you to compare your experience in (VR) with your previous firefighting training experience.

Section 2: We ask you to compare your experience in (VR) with your previous real-life incident experiences.

Section 3: We inquire about the use of (VR) for firefighter training based on your overall (VR) experiences.

Section 1:

1. If you agree or disagree to participate, please select the option below. If your answer is yes, please complete the questionnaire until the end.

( ) I agree

( ) I disagree

2. Enter your full name and Corporation ID

3. Enter your email

4. Date of birth

5. Gender

( ) Male

( ) Female

6. For how many years have you been working as a firefighter?

7. What is your position or role?

8. In which Fire Department division do you currently serve (city and neighbourhood)?

Section 2:

Here, we will describe some basic terms that we use:

Presence: refers to your experience of non-mediation in all your senses. Very high presence when you are in a virtual reality kitchen is the feeling of being in the actual physical kitchen. Very low presence is feeling the limitations of the (VR) technology.

Realistic (representations): By realism, we mean the extent to which the representation in (VR) corresponds to objects, phenomena, and interactions with incidents in society.

9. Think about the sensation of being in a firefighting training situation in your training field. How intense was the sensation you experienced with (VR) today? Please estimate on a scale from 1 to 5, where 1 = very low intensity and 5 = very high intensity.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

10. To what extent do your sensations while using (VR) correspond to the sensation of being in a firefighting training? Please estimate on a scale from 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

11. To what extent does the sensation of using the hose in (VR) correspond to the sensation of using the hose in a firefighting training? Please estimate on a scale from 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

12. To what extent does the sensation of moving with (VR) correspond to the sensation of moving in a firefighting training? Please estimate on a scale from 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

13. Have you used teleportation to move with (VR)? Teleportation is when you use the blue circle and click on the button on the hose to move to more distant areas using (VR).

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5,

14. How difficult or easy was it to use teleportation? Please estimate on a scale from 1 to 5, where 1 = very difficult and 5 = very easy.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

15. To what extent do the tasks you perform with (VR) correspond to tasks that can be done in a firefighting training? Please estimate on a scale from 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

16. To what extent does the heat sensation in (VR) correspond to the heat sensation in firefighting training? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

17. To what extent do the sounds in (VR) correspond to the sounds in firefighting training? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

18. To what extent does the stress sensation in (VR) correspond to the stress sensation in firefighting training? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

19. To what extent could you understand the task you need to perform, similar to how you would understand a similar task in firefighting training? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

20. To what extent do the scenarios in (VR) that you encounter correspond to the scenarios encountered in firefighting training? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

Section 3:

Compare your experience with (VR) to your previous experience with real-life incidents.

21. To what extent does the sensation in (VR) correspond to the sensation of being in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

22. To what extent does the sensation of using the hose in (VR) correspond to the sensation of using the hose in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

23. To what extent does the sensation of moving with (VR) correspond to the sensation of movement in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

24. To what extent does the heat sensation in (VR) correspond to the heat sensation in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

25. To what extent do the sounds in (VR) correspond to the sounds of a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

26. To what extent does the stress sensation in (VR) correspond to the stress sensation in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

27. To what extent can you move in (VR), compared to how you can move in a real fire incident? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

In the following questions, we ask you to assess how you rate your performance in solving the task (extinguishing the fire) as intended.
28. To what extent can you understand the task in (VR), compared to understanding the task in a real fire incident? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.
( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

29. To what extent could you manage the task of extinguishing fires in (VR), as well as you would have managed the corresponding task in a real fire incident? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

30. Did anything prevent you from managing the task in (VR)?

- Sim
- Não

31. Did anything prevent you from managing the task in (VR)?

- Sim
- Não

Here, we will inquire about the use of (VR) for firefighter training based on your overall experiences with (VR).

32. To what extent is the visual appearance of FIRE in (VR) realistic? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

33. To what extent is the visual appearance of SMOKE in (VR) realistic? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

34. To what extent is the visual appearance of WATER in (VR) realistic? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

35. To what extent does the Water in (VR) really resemble the water you use in a real fire? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

36. To what extent did the FIRE in (VR) behave realistically? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

37. Think about a real firefighting incident you participated in before. To what extent did you feel like you were in a real fire scene this time? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5

38. To what extent did you find the visual appearance of the following representations in (VR) realistic for firefighter training purposes? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

a) Fire 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
b) Smoke 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
c) Water 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
d) Foam 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
e) Buildings 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
f) Surroundings 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )

39. To what extent did you find the interactions with the following representations in (VR) realistic for firefighter training purposes? Provide an estimate on a scale of 1 to 5, where 1 = very low degree and 5 = very high degree.

a) Nozzle use 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
b) The sensation of the heat as you approach the fire 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
c) The response of fire to your actions 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
d) The spread of fire 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
e) The spread of smoke 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )
f) The state of burnt buildings/vehicles 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( )

From your understanding of (VR) training today, mark whether you agree, agree to some extent, or disagree with the statements below.

40. Can (VR) be used for firefighter skills training?

o Yes, today.
o Yes, in the future
o No

41. Mark the values you believe VR training can offer:

a) Additional training for firefighters Yes ( ) No ( )
b) Environmentally friendly training Yes ( ) No ( )
c) Training without exposure to smoke particles Yes ( ) No ( )

d) Efficient time training Yes ( ) No ( )
e) Realistic scenarios Yes ( ) No ( )
f) Dynamic scenarios, impossible to train Yes ( ) No ( )
g) Training for adverse events Yes ( ) No ( )
h) Training for high-risk situations Yes ( ) No ( )
i) Cost-effective training Yes ( ) No ( )

42. Read the statements below. Based on your understanding of (VR) training today, mark your opinions on:

a) There is a risk of learning false security (without real danger/heat) in (VR)
Yes ( ) No ( )
b) It is difficult to understand the learning in (VR)
Yes ( ) No ( )
c) It is very easy to extinguish fires in (VR)
Yes ( ) No ( )
d) The use of the nozzle is not realistic enough in (VR)
Yes ( ) No ( )
e) (VR) is not accepted as a training method among firefighters
Yes ( ) No ( )
f) (VR) is too complex to use in our training
Yes ( ) No ( )
g) (VR) is too expensive to use in our training
Yes ( ) No ( )

43. If you would like to contribute further to this research, please leave below the questions you believe are necessary.