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ENHANCING OCCUPATIONAL SAFETY IN MINING: INSIGHTS FROM THE STRIM PROJECT

Abstract: *The project 'Safety Training with Real Immersivity for Mining' (STRIM) aims to enhance occupational health and safety training in the mining industry by integrating virtual reality (VR) and augmented reality (AR) tools. Given the high-risk nature of mining operations, effective training is essential to reduce workplace accidents and improve workers' preparedness. To identify key challenges and training needs, 26 semi-structured interviews were carried out with occupational health and safety professionals in Angola and Mozambique. These interviews explored their roles in occupational health and safety issues in their organisations and existing gaps in training. The findings revealed three priorities: 1) The need to create in-depth and well-founded training programmes across all levels of the industry, from mine workers to company managers and higher education institutions; 2) The need to strengthen the legislative framework on occupational health and safety regulations to be implemented in the extractive industry, and 3) The need to promote a more effective safety culture and to learn how to adequately perform risk analysis. The study concludes that adopting immersive technologies can significantly enhance learning experiences, strengthen regulatory compliance, and improve overall safety in the mining sector. Achieving these goals requires a collaborative effort involving industry professionals, policymakers, and educational institutions.*

Keywords: virtual reality, augmented reality, occupational health and safety, professional training.

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INTRODUCTION

The extractive industry is one of the sectors of activity with the most significant exposure to occupational risks, involving complex work environments, often underground, in which heavy machinery is used, explosives are handled, and geological conditions can be unstable. These aspects make health and safety issues in this context a priority for the sector.

In Angola and Mozambique, the mining sector plays a critical role in driving their respective national economies, contributing significantly to gross domestic product (GDP), job creation, and foreign exchange earnings (Caixao, 2021; Edwards et al., 2014). Both countries are rich in natural resources, including diamonds, gold, and other valuable minerals, making mining a cornerstone of their development strategies. However, despite its economic importance, the mining industry in these nations grapples with profound occupational safety and health (OSH) challenges that threaten worker welfare, operational efficiency, and sustainability (Moyo et al., 2017; Moyo et al., 2015). High rates of workplace accidents, limited access to specialized training, and inadequate implementation of safety regulations underscore the pressing need for systemic improvements in OSH practices (Moroe & Khoza-Shangase, 2022).

Gyekye and Salminen (2009) have developed a study on the impact of education on perceptions of workplace safety, concluding that "higher-educated workers recorded the best perceptions on safety, indicated the highest level of job satisfaction, were the most compliant with safety procedures and recorded the lowest accident involvement rate" (Gyekye & Salminen, 2009, p. 20). It is clear that education and training are fundamental in promoting occupational

safety and health. However, discussing what methodologies could promote better outcomes is still important. Traditional teaching methods — generally centered on expository lectures and printed materials — have proven insufficient to engage workers meaningfully, especially in high-risk environments, where practical experience and quick decision-making are essential (Burke et al., 2006). In this context, the STRIM project emerges as an innovative response, proposing the integration of virtual reality (VR) and augmented reality (AR) technologies into mining training programs. These technologies offer immersive experiences that simulate risk scenarios in a safe and controlled way, enabling active learning and the development of critical skills (Gonzalez-Franco & Lanier, 2017). Research indicates that virtual reality training can significantly increase knowledge retention and improve emergency response capacity (Lindgren et al., 2016). This article aims to discuss preliminary results on the challenges and main training needs of OSH in Angola and Mozambique.

METHODOLOGY

Considering that the STRIM project aims to improve occupational health and safety training in the mining industry by integrating virtual reality (VR) and augmented reality (AR) tools, it was relevant to identify specific training needs in Angola and Mozambique. To this end, four exploratory and 26 semi-structured interviews were carried out with a diverse group of agents involved in promoting occupational safety and health in the extractive industry in these two countries. The four exploratory interviews were carried out with the coordinators of African higher education institutions partnering with the project, with the following objectives: 1) understand the specific needs of these institutions concerning OSH in the mining sector; 2) identify existing training on the project's themes, at various levels of education; 3) collect existing data relating to current legislation for the area, accidents and incidents in the mining sector and risk assessment methodologies; 4) identify the topics on which there is a greater need for training.

The 26 semi-structured interviews were carried out with different professionals directly involved in occupational health and safety in the extractive industry, with 10 interviews relating to the Mozambican context and 16 to the Angolan context. This cohort includes mining engineers, health and safety managers, university educators, and government inspectors, providing a broad spectrum of perspectives on the industry's occupational safety and health (OSH) challenges. Most of these professionals were mining engineers and were responsible for the Health and Safety department in the workplace. These interviews aimed to 1) understand the training path of these professionals, particularly regarding OSH issues and the functions they currently perform, 2) understand the main problems associated with OSH in the organization in which they work, and 3) understand the primary training needs within the scope of OSH in the extractive industry. Through these interviews, valuable insights were gathered about the practical realities of OSH practices, the effectiveness of existing training programs, and the challenges posed by legislative frameworks.

A rigorous thematic analysis was employed, inspired by previous studies regarding the topic of the project, to process and interpret the data, allowing the identification of recurring patterns and key areas of concern (Safarpour et al., 2020; Tetzlaff et al., 2020; Tetzlaff et al., 2017). This approach revealed critical gaps in training, where the lack of standardized and specialized programs limits the preparedness of workers to handle industry-specific hazards such as explosives, heavy machinery, and mining-specific risks. Legislative deficiencies also emerged as a major concern, with regulatory enforcement and compliance gaps contributing to unsafe working conditions. Furthermore, accident patterns highlighted the prevalence of preventable incidents, often linked to inadequate training, poor risk management, and a lack of a safety-oriented culture within mining operations. The thematic analysis categorizes these challenges and underscores their interconnections, demonstrating how training deficiencies, weak legislative enforcement, and unsafe practices collectively perpetuate risk in the mining industry.

RESULTS AND DISCUSSION

The analysis of the interviews carried out within this project's scope revealed some gaps concerning the training of professionals in the area of occupational safety and health in the extractive industry in Angola and Mozambique. Three major axes stand out from these gaps and should be considered in framing the training to be developed in both countries. This section will present and discuss data from each of the identified axes.

1) The need to create in-depth and well-founded training programmes across all levels of the industry, from mine workers to company managers and higher education institutions

The data collected reveal some initial training in occupational safety and health offered by different types of institutions in Angola and Mozambique, with no concrete guidelines that respond to the complex needs of occupational safety and health in the extractive industry.

The analysis of the training path of interviewees working in occupational safety and health departments reveals three aspects:

a) Some professionals do not have occupational health and safety training or even mining engineering. In some cases, people playing the role of OSH manager combine it with other roles, such as organization manager or operations manager. In some cases, they feel it is unnecessary to undergo specific training in these areas. Some quotes substantiate these issues:

"I have a basic level of education, acquired in Zimbabwe. This is my first professional experience in a mining company, and I have been here for 12 years. Before that, I worked in a sugar company, in the area of occupational health and safety." (P18)

"Graduate in Environmental Management from the Higher Institute of Management, Commerce and Finance. Have 26 years of experience in managing safety, health, and environment in mines" (P15 - safety, health, and environment manager at the company).

"I have a master's degree in accounting, auditing, and management." (P16 – company manager and responsible for OSH)

"Q – Do you consider it necessary to have training in the area? A – Not really. I think this comes more in a way, from the basics that you learn at university and then with the combination of practice, seeing, and researching in a more autonomous way." (P8 – Mining Engineer, no formal training in OSH)

b) In cases where there are professionals with training, this was developed in other countries (with a special focus on training in Brazil and Portugal – due to linguistic approximation, but also in other African countries), as the next interviewee says:

"Also, remember that I completed some international certifications. I completed NEBOSH through the Safety Bridge Council in the U.K. I completed other training, some of which I had to travel to Portugal, I completed training at APQ, the Portuguese Quality Association, in terms of environmental legislation, in terms of quality, in terms of the European quality system, I also completed training in the implementation of integrated occupational health and safety systems by SGS, the Academy of Portugal. And I did other training through Bureau Veritas, also in Portugal." (P10)

c) In cases where training is provided, the organizations where the professionals work (mostly in multinational companies) offer it.

While international training offers access to advanced methodologies and standards, it is often inaccessible to most workers due to financial and logistical constraints, leaving a substantial portion of the workforce undertrained. Several interviewees reveal a lack of training:

"There is a lack of training, both for me and for all the members of the hygiene and safety team. And then the technicians, those who have higher education, advance a little further in terms of training, mainly in acquiring knowledge in terms of hygiene and safety management software, and also national and international standards in terms of this hygiene and safety matter. There is a lack of training. Training and improvement." (P8)

"So, if we have few occupational hygiene and safety engineers, it means that the level of knowledge in this chain of command is a little low compared to companies that don't have one. Just imagine, companies that only work with supervisors, people who have taken a basic course in occupational hygiene and safety. These people don't have enough experience to support the range of personnel that comes after them." (P9)

2) The need to strengthen the legislative framework on occupational health and safety regulations to be implemented in the extractive industry

Legislation is crucial in implementing and maintaining the extractive industry's occupational health and safety systems. In Angola and Mozambique, there are legal frameworks for regulating work and the mining industry, with references to guaranteeing the safety and health of workers. However, some gaps persist despite these efforts and some evolution and updating. According to some interviewees, these gaps are in the legal systems themselves; others are in applying the law. In some cases, as evidenced in the testimonies below, the interviewees, despite implementing safety and health systems at work, are unaware of the legislation.

"Honestly, I never had much time to study Angolan legislation in terms of safety and hygiene at work." (P9)

Another pattern that I noticed is that companies mostly use foreign legislation rather than Angolan legislation, because Angolan legislation in terms of health and safety at work is very limited, very small." (P10)

"Q – What OSH subjects/content would you like to see covered more?

R- Well... we'll get into that... the contents are generic, and I think that probably being more specific, the legislation itself should focus, since the aim is to... prevent accidents, it should be much more specific in terms of what aah... would be the exact measures to be dedicated to each job according to its specificity. We have to know in a general way, but specifically for that job, how it should be, or what the positioning of the section that looks after that job within the company should be. That's more or less it; the operating model or something like that, we need that." (P12)

"The technical safety and health regulations have a problem that should be improved as they oblige the employer to carry out medical examinations on workers before, during and after leaving work (retirement/resignation), however, it does not indicate the types of examinations specific and mandatory for each type of mining activity to be carried out, resulting in the presentation of identical medical certificates to companies for all areas of work." (P26)

The gaps identified point to the need to deepen legislation on safety and health at work in the specific sector of the extractive industry. However, they reveal the need for better training of professionals regarding understanding the legal framework in force and the conceptual issues that underlie the legislation.

3) The need to promote a more effective safety culture and to learn how to adequately perform risk analysis

Promoting an effective safety culture is essential to ensure compliance with occupational health and safety

protocols and promote proactive risk management. The interviews revealed important challenges to promoting a safety and health culture in the extractive industry. On the one hand, workers underestimate the importance of personal protective equipment and other safety measures, considering them optional and not essential. On the other hand, top management does not always get involved in safety initiatives or contribute to their prioritization compared to production prioritization.

Risk assessment in the extractive industry in Angola and Mozambique is generally characterized by reactive rather than proactive approaches. Companies that prioritize safety often implement measures such as daily safety briefings, bulletin boards to track accident statistics, and regular inspections of equipment and facilities. However, these practices are not uniformly adopted across the industry, leaving significant gaps in accident prevention. Large companies are more likely to have formalized risk management systems, while smaller operators rely on informal methods, increasing their vulnerability to security risks.

"We haven't carried out any risk assessments, as far as accident prevention is concerned, it's just day-to-day awareness-raising. Normally, when I'm here, I talk to the quarry manager to advise on what PPE to use and what CPEs to use. It's more of this kind of guidance. We have someone there who circulates throughout the quarry to make sure everything is going according to plan." (P8)

"There is no risk assessment as such, but all workers receive induction although there are always difficulties for workers to comply with the rules, for example, they can go down to the mine well dressed with personal protective equipment, but they can be surprised at the bottom of the mine without shirts, helmets, etc., claiming to feel hot due to the relatively high temperatures." (P19).

These results provide relevant insights for public policy in Angola and Mozambique. The identified gaps in training, the incipient enforcement of legislation, and the almost complete absence of a safety culture suggest the need for consistent interventions at the governmental level. It would be important for these countries to develop standardised OSH training programmes and review the legal framework to adapt it to mining risks. Investment in immersive technologies, such as VR and AR, to modernize safety education would also be an interesting avenue to explore (Gonzalez-Franco & Lanier, 2017; Lindgren et al., 2016). These measures can strengthen accident prevention capacity, improve compliance with legislation, and support the long-term sustainability of the mining sector (Moroe & Khoza-Shangase, 2022; Moyo et al., 2017).

CONCLUSIONS

The discussion developed in this article refers to the need to create a training strategy for occupational safety and health professionals in Mozambique and Angola that contributes to a rapid and overall improvement in safety and health conditions in the extractive industry. Therefore, it is considered necessary to:

- Standardized Curriculum: Develop a unified, nationally recognized curriculum for OSH training, with modules tailored to the specific risks of mining activities.
- Practical Learning Opportunities: Introduce hands-on training sessions, such as simulations and equipment demonstrations, to enhance workers' preparedness for real-world scenarios.
- Mobile Training Units: Deploy mobile training facilities to reach remote mining sites, ensuring that even small-scale operations can access high-quality OSH education.
- Capacity Building for Trainers: Invest in certifying and training a new generation of OSH instructors, focusing on mining-specific expertise.

All these improvement aspects can benefit from integrating virtual reality (VR) and augmented reality (AR) tools, which the STRIM project is creating and integrating into 2 courses to be implemented in both countries.

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