

IMMERSE Virtual Training on Critical Raw Materials for the Clean Energy Transition

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ABSTRACT

The transition to a circular economy and the goals of the European Green Deal have intensified the global demand for critical raw materials (CRMs), which are vital for clean energy technologies but remain vulnerable to supply disruptions. Securing a sustainable CRM supply requires professionals who are not only proficient in advanced extraction technologies but also well-versed in the circular economy principles governing CRM value chains, from exploration and production to reuse, recycling, and responsible closure.

This work presents *IMMERSE*, an ERASMUS+ project that embeds immersive Virtual Excursions (VEs) into university curricula in mining engineering and geosciences, with a focus on the full Life of Mine (LOM) cycle for CRMs. Through high-resolution 360° field panoramas and interactive digital environments, students can explore realistic CRM mining sites, analyze geological and geotechnical features, and engage with sustainable processing and environmental management practices. *IMMERSE* emphasizes circular approaches such as CRM recovery from mine waste and the reuse of materials.

Initial pilot results indicate improved student outcomes in spatial reasoning, safety awareness, and process planning compared to conventional instruction (Leilabadi et al., 2024; Machairas et al., 2025). A continuous feedback system supports content adaptation based on student performance and user experience.

Overall, *IMMERSE* demonstrates that virtual training can cost-effectively complement limited field access, reduce learning risks, and produce graduates who are better prepared to contribute to a sustainable and circular raw materials sector.

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