

IMMERSE Virtual Training on Critical Raw Materials: Preparing Responsible Professionals for a Sustainable Future

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Keywords: Critical Raw Materials; Mining Education; Immersive Learning; Sustainable Engineering; Clean Energy Transition

Introduction**Materials and methods**

The accelerating demand for critical raw materials (CRMs) driven by the twin forces of climate change and digital innovation poses significant challenges for the mining sector. European industry is exposed to significant risk in terms of the supply of CRMs due to its high import dependence on other countries and the high level of concentration of these materials in specific countries. Therefore, the challenge of ensuring that key sectors have access to a sufficient supply of CRMs to facilitate the acceleration of the energy transition is considerable. Addressing these challenges requires a new generation of professionals equipped not only with advanced technical skills but also with a deep understanding of sustainability principles. The IMMERSE project, an Erasmus+ initiative, responds to this urgent need by embedding immersive Virtual Excursions (VEs) on the Life of Mine (LOM) cycle of CRMs into the university curricula of its project partners specializing in mining engineering and geosciences (Leilabadi et al. 2024).

IMMERSE simulates real-world mining environments by means of VEs utilizing high-resolution, field-captured 360° panoramas. These immersive virtual settings enable students to navigate realistic mine sites containing CRMs in a safe, controlled learning space (Machairas et al 2025). The VEs modules are integrated into academic courses focused on mining, geology, sustainable ore processing, geotechnical engineering, low-impact extraction technologies, cutting-edge exploitation methods and environmental management, ensuring alignment with both accreditation standards and essential industry skills.

Results and discussion

IMMERSE addresses critical challenges in mining education by bridging the gap between theoretical learning and practical skills development. Pilot implementations at partner institutions have shown that students who engage with VEs report higher motivation and a deeper understanding of complex mining processes compared to traditional classroom methods. The immersive environments effectively simulate operational mine sites and sustainable practices, enabling learners to safely explore real-world scenarios without geographical limitations. Furthermore, IMMERSE's modular design enables continuous feedback and adaptation to student needs, fostering an interactive learning experience. By providing a scalable, cost-effective alternative to conventional field trips, IMMERSE helps to offset declining enrolment trends and equips future professionals with the technical expertise and strong ethical framework necessary for sustainable resource management. This brings mining education into closer alignment with the evolving demands of the clean energy transition.

Acknowledgements: The realization of the IMMERSE project has been made possible by funding from the ERASMUS+ grant programme of the European Union (grant number: 2023-1-DE01-KA220-HED-000165332). We are deeply grateful for their invaluable support, which has enabled us to undertake this important endeavour. Their commitment to promoting educational initiatives and intercultural exchange has been

instrumental in shaping the trajectory of our project and empowering us to make meaningful contributions to our field.

References

- Leilabadi, Sh., Lottermoser, B. G., Roach, M., Varouchakis, E. A., Machairas, E., Barrionuevo, F. G., Macia, M. T., Nieto, J. M. 2024. The IMMERSE Project: Virtual Excursions on Critical Raw Materials for the Clean Energy Transition. Mining Report 160(6), 601-607. <https://mining-report.de/online-kiosk/mining-report-glueckauf-ausgabe-6-dezember-2024/>
- Machairas, E., Varouchakis, E., Lottermoser, B. G., Leilabadi, Sh., Roach, M., Barrionuevo, F. G., Macias, M. T., Nieto, J. M. 2025. Innovative Training in Critical Raw Materials: The IMMERSE Project's Role in Advancing Education for the Clean Energy Transition (No. EGU25-15577). Copernicus Meetings.