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Curriculum Development for Improving Mineral Exploration-Related Master Programs towards Innovation, Entrepreneurship and Social Responsibility †

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Abstract: Nordic and West Balkan countries are major investment regions in Europe for greenfield and brownfield mineral exploration; however, the availability of qualified technical, scientific and managerial personnel involved in the whole mineral cycle is limited, especially in West Balkan countries. The partners of the TIMREX EIT RawMaterials-labeled MSc program have developed a joint curriculum focused on innovative raw materials prospecting and exploration methods, with strong innovation and entrepreneurial components. The program incorporates new exploration techniques and methodologies, portable and more highly sensitive equipment, robotized exploration equipment and the processing and interpreting of large, multidimensional datasets. The TIMREX curriculum was built around the ideal mineral exploration program, as suggested by raw materials stakeholders and orientated to field geology, exploration techniques and data processing, and also includes elements of sustainability, transversal societal and regulatory aspects. The program also focuses on EIT Overarching Learning Outcomes (OLO-s), which are embedded as core elements of the curriculum (innovation, entrepreneurship, sustainability, creativity, leadership and intercultural competencies). Significant contributions to the OLOs also arise from cross-organizational program elements, including the Exploration Entrepreneurship course, summer field camp, the Internship and the Social and Civic internship.

Keywords: curriculum development; mineral exploration; innovation; entrepreneurship

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1. Introduction

A significant increase in the production of mineral resources of various types, including strategic and critical raw materials as well as construction and industrial minerals, is necessary to meet present and future societal challenges, such as the decarbonization of the transportation sector and the mitigation of climate change. The European Green Deal [1] and the 2021 United Nations Climate Change Conference (COP26) have both set ambitious goals, and in order to achieve these, a significant consumption of mineral resource will be required.

The wealth of Europe's mineral resources is not as negligible or unimportant as the general impression would have people believe. Nordic countries, the West Balkans,

the Iberian Peninsula and the British Isles [2] are four target regions with significant potential for strategic and critical metallic raw materials, and there has been targeted mineral exploration in recent decades. For the mineral prospecting and exploration sector, extending the use of mobile, field-based equipment; utilizing powerful, high-resolution analytical equipment; processing large, multivariable datasets; the use of robotized and automated solutions (such as drones, self-driving cars and remote-controlled operational systems); and continuing to integrate new and emerging technologies throughout the value chain are the major innovation trends [3]. Therefore, some of the key elements of future mineral exploration-related university curricula should be cutting-edge techniques, ideas, tools and data processing, especially with the support of extensive field work. However, the entrepreneurial mindset, especially for junior exploration companies where university graduates usually start their careers, sustainability and transversal societal and regulatory aspects should be additional critical soft skills.

The main objective of this publication is to describe the methodology of the curriculum development of the TIMREX EIT-labeled mineral exploration masters program, supported by the European Institute of Innovation and Technology (EIT) and its position within EU education strategies. This includes: (1) a background stakeholders questionnaire survey providing insight into the core and soft-skill program elements, and (2) the integration of the EIT Overarching Learning Outcomes (OLOs) into academic masters program and cross-organizational courses. The latter includes the development of innovation, entrepreneurship and social responsibility competencies for students.

2. Methodologies

2.1. EIT RawMaterials Questionnaire Campaign

At the beginning of 2020, a gap analysis of the existing portfolio of the EIT RawMaterials-labeled MSc programs revealed that mineral exploration geology and mineral economics programs are only partially represented (i.e., as secondary orientations of the existing labeled masters programs). The Educational Committee of EIT RawMaterials launched an online survey questionnaire (May–June 2020; 60+ answers equally representing industry, academy and students) exploring raw materials stakeholders' opinions on the main and secondary orientations, as well as necessary learning outcomes, of a future mineral exploration geology program. Stakeholders suggested that the ideal mineral exploration program should be positioned between a geology of ore deposits with a field-based learning approach, and integrated methods for innovative exploration in challenging environments. Core learning outcomes of a future mineral exploration geology program should focus on primary skills (applying and integrating data science to mineral exploration challenges, understanding the genesis of ore deposits, applying modern analytical techniques to mineral exploration, conducting detailed geological mapping of ore deposits, evaluating the resources and reserves of a deposit, etc.). The secondary orientation should include elements of sustainability (resource efficiency and circular economy), transversal skills (leadership, entrepreneurial and multidisciplinary skills), and societal and regulatory aspects (regulatory frameworks, stakeholder engagement and communication allowing social license to operate).

2.2. EIT Overarching Learning Outcomes

The EIT Label is an international quality certificate for masters or PhD training programs. The major objective of the EIT Label [4] is to develop a highly skilled workforce with an entrepreneurial mindset and knowledge triangle integration (KTI) skills. Labeled programs should apply a student-centered training methodology, based on the consistent improvement between intended and achieved learning outcomes in order to develop T-shaped professionals [5]. Students receive in-depth training in their own discipline accompanied by cross-thematic modules, allowing them to understand challenges to the raw materials value chain.

Entrepreneurship and KTI skills and competencies are embedded within the "Overarching Learning Outcomes" (OLOs) [4]. The EIT defines six OLOs in the Label's system of requirements: OLO 1—entrepreneurship skills and competencies; OLO 2—innovation skills and competencies; OLO 3—creativity skills and competencies; OLO 4—intercultural skills and competencies; OLO 5—making value judgments and sustainability competencies; and OLO 6—leadership skills and competencies.

The TIMREX joint masters program contributes to all six OLOs via core curricula courses provided by academic partners, and horizontally applied elements via cross-organizational mobility. The distribution of OLOs within the academic programs of individual academic partners are presented in Figure 1. Value judgment and sustainability competencies are highly represented in all participating universities, followed by creativity, innovation and entrepreneurship skills, whereas intercultural and leadership skills are weakly supported.

This is compensated via cross-organizational program elements, which include the Exploration Entrepreneurship course, summer field camp, the Internship and the Social and Civic (SOC) internship (Figure 2). Specifically, innovation skills, value judgment and sustainability and intercultural competencies are highly represented.

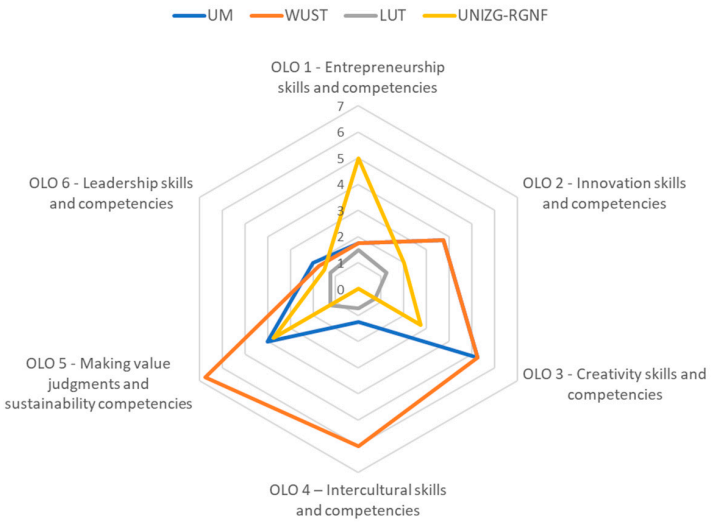

Figure 1. Distribution of OLOs within masters program courses of the academic partners.

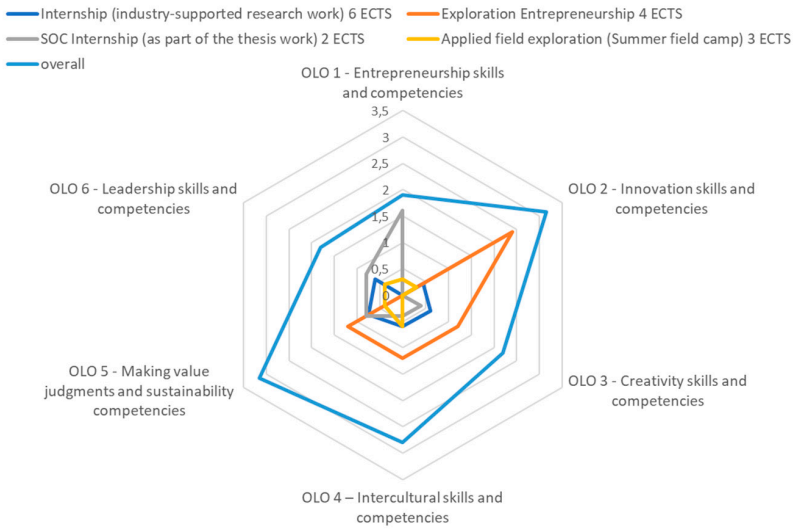

Figure 2. Integrated ECTS distribution of OLOs within cross-organizational courses.

Courses with multiOLOs present in all university programs, integrating knowledge of different disciplines and are relevant to innovation, creativity, value judgment and sustainability. When these courses apply project work as a teaching method, they also affect leadership skills (OLO6). Innovative pedagogies that rely intensively on the individual work of the students are applied by all academic partners, where the teacher mostly participates in the course as a mentor and supervisor. This requires students to meet complex mindset competencies such as critical thinking, creativity and value judgments, which are strongly relevant to OLOs 2, 3 and 5.

3. Results: TIMREX Mineral Exploration Program Curriculum Development

3.1. Embedding Innovation and Entrepreneurship into the Masters Program Curricula

Skills and competencies linked with innovation and entrepreneurship are diverse and range from technical (e.g., technology use, monitoring and control, and creating business plans) to soft skills (e.g., being innovative and creative). The TIMREX program embedded innovation and entrepreneurship within academic masters programs and cross-organizational courses (the Exploration Entrepreneurship course, summer field camps and internships) using the following methodology:

1. Direct add-ons to academic courses: solving specific industry problems (innovation and business challenges) via teamwork and interaction with external stakeholders;
2. Learning from knowledge triangle stakeholders: industry stakeholder presentations, training courses, seminars, conferences, networking and discussion groups;
3. Internships and scholarships: internships with research and industry partners, and participation in field missions;
4. Participation in national/international projects, competitions and challenges: entrepreneurial training and the integration of students into international innovation projects;
5. Online teaching/learning platforms: dedicated software or platforms for technical and collaborative work, such as Massive Open Online Courses MOOCs.

The major strengths of the TIMREX approach regarding innovation and entrepreneurship include the unique blend of education, research and industry partners that cover important technological and non-technological areas, the mentoring of students by industry professionals, knowledge on innovation and entrepreneurship teaching and ideation. Table 1 below shows how TIMREX incorporates innovation and entrepreneurial concepts.

Table 1. Comparison of the EIT-labeled handbook definitions vs. TIMREX's approach.

Definition (from the EIT Label Handbook [4])	TIMREX's Approach
Innovation: the ability to formulate knowledge, ideas and technology to create new or significantly improved products, services, processes, policies, new business models or jobs, and to mobilize system innovation to contribute to broader societal change, while evaluating the unintended consequences of innovation and technology.	Within TIMREX classes, innovation elements are included in the teaching methodology, including teaching innovative methodologies and the innovation process. This is complemented by the fieldwork aspect, where students should be able to see, learn and use innovative technologies developed by research and industry partners in a hands-on approach. The mentoring program focuses on supporting the development of knowledge and ideas for innovation creation.
Entrepreneurship: the capacity to identify and act upon opportunities and ideas to create social, cultural and financial value for others, including translating innovations into feasible business solutions, with sustainability at their core.	TIMREX makes strong use of fieldwork (in mining areas, supported by industry partners, and visits to research centres) with high levels of technological input from research and industry exploration companies, which show students how innovative prospects can be created to generate value. The business ideation and creation processes of partner companies are used to provide entrepreneurial skills. During the mentoring program, students shall be able to learn how to bring ideas into business creation and will be offered organizational support to kick-start their own ideas.

3.2. Curriculum Development towards Lighthouse Targets

Lighthouses, as defined by EIT RawMaterials, are large-scale and long-term innovation initiatives that address critical and specific raw materials challenges for Europe [6]. For the TIMREX curriculum, the Responsible Sourcing lighthouse is relevant, as it focuses on mineral deposit models for battery minerals and raw materials for photovoltaics and electronics, as well as on advanced methodologies and solutions to explore them. The learning outcomes of the TIMREX program, aligned with the EIT RawMaterials Responsible Sourcing lighthouse [6], include the awareness of the scarcity of critical raw materials on global and European scales, their availability in the Earth's crust, excavation methodologies, the availability of secondary resources and global demand. Students should have a broad understanding of the flow of raw materials and their current supply risks, especially with regard to the technologies used in the three strategic sectors: renewable energy, e-mobility, and defense and aerospace.

The TIMREX curricula encompass the three pillars of technological advances (Figure 3): mineral systems modeling, exploration methods and approaches, and data processing and data integration tools.

Figure 3. TIMREX three pillars of technological advances.

Mineral systems modeling is one of the main focuses of the TIMREX curricula. Different geological modeling software systems are taught and practiced in laboratory classes, combined with the introduction of the latest data processing and data integration tools. Moreover, methodologies used in geophysical exploration, remote sensing, global navigation satellite systems and other new exploration and data integration tools are also presented in detail.

3.3. Field Program Development

The aim of the intensive fieldwork for the students is to develop strong, practical skills in both state-of-the-art innovative exploration technologies and classic geological mapping techniques. The practical mapping is combined with lectures, providing a solid theoretical framework for field activities, such as ore genetic modeling, which help contextualize field observations and allow them to be used to vector in on mineral deposits.

The Swedish part of the field program builds on the course Applied Field Exploration, which was originally developed for the EXplORE EIT RawMaterials program [7]. This course takes place in the classic Skellefte mining district of Northern Sweden and simulates the discovery of a volcanogenic massive sulphide (VMS) deposit via an applied mapping campaign and the application of the VMS model [8,9]. Students are trained in the fundamentals of the VMS model and conduct mapping and surveying exercises in a part of the Skellefte district that has no historic mining record, but where a blind VMS deposit is known to be located from historic exploration by Boliden. Students examine a historic exploration drill core from the area, practice drill core logging and discuss the implications of the mapping campaign. The course's practical components are interlayered with presentations from industry professionals active in the exploration sector, addressing topics

such business models for exploration, social license to operate, research and development, exploration success stories and career development.

The course follows a flipped classroom approach, where abundant study materials, including theoretical background information, training videos and photogrammetric outcrop models, are provided in an online platform prior to the field mapping week in Sweden. Since mineral exploration is commonly conducted by teams that are both multi-disciplinary and of multiple backgrounds, this also help prepare the students for work life.

3.4. Mentoring Program and Social Responsibility Competencies Development

Mineral exploration and mining professionals (geologists, mining engineers, geotechnical engineers, economists, etc.) are competent in their own fields of study, but sometimes it is difficult to walk in someone else's shoes and communication between different professions might be not straightforward. This gap needs to be covered through the acquisition of key social and civic competencies and by introducing students to the following concepts: multidisciplinary skills, speaking the language of business and social networking and communicating technical concepts to a general, non-qualified audience.

The TIMREX curricula includes a mentoring module where the students will have the guidance of a senior professional for several weeks. The mentor will guide the student (mentee) in their professional development in a targeted way [10]. Mentoring contributes to the development of personal, social and professional skills.

This exclusive and international program is unique as it combines technical and soft knowledge to be applied in the professional lives of recent masters' graduates. Hence, they will increase their employability and entrepreneurship skills to meet current market demands. Additionally, the EFGeoMentoring scheme [10] aims at improving international networking and supporting the life-long learning and continuing professional development (CPD) requirements of experienced geology professionals.

Some of the skills covered by the mentoring program—taught by TIMREXas the exploration Entrepreneurship course—include the following:

(1) General: broadening the professional network, improving technical knowledge in a particular field, improving leadership/management skills, acquiring practical tools and strategies for the transition from a junior role into roles with higher responsibilities, benefiting from insider knowledge about work perspectives in another geoscience sector or other countries and obtaining practical advice and contacts, and support for the application to the European geologist title;
(2) Entrepreneurship skills: research and development, risk awareness, business awareness and attitude, market understanding, identifying investment opportunities and knowledge on intellectual property rights.

The TIMREX program considers social license to operate to be a key issue for the raw materials industry, especially for mining and for mineral exploration. Permit procedures for mineral resource exploration projects in the EU are highly complex, which should be understood and managed carefully by the new generation of mineral explorers. The improvement of the social and civic (SOC) competencies of students, contributing to OLO4 and OLO5, will be realized by completing a "SOC internship" in their final, diploma semester. The IN4SOC project developed a toolkit [11] in order to implement the SOC internship at technical universities. The IN4SOC methodology and toolkit will be used to realize the SOC internship, which is a mandatory part of the thesis preparation component. The topic of the SOC internship will depend on the specialty of the thesis topic, although it will be associated with sustainability and social responsibility goals.

4. Discussion and Conclusions

For more than a decade, one of the European Commission's outspoken aims has been to embed innovation and entrepreneurship into Higher Education Institutions (HEIs) within the EU, utilizing a number of important programss, initiatives and projects. The Directorate-General for Education, Youth, Sport and Culture (DG EAC) published several

reports and case studies on university–business cooperation in Europe between 2009 and 2011 [12,13]. The scanning of HEIs continued during 2017 in EU and non-EU countries and resulted in 32 reports on university and business perspectives [14]. The University-Business Forum (2008–2019) was established as a first platform for networking and the exchange of ideas and good practices between HEI stakeholders (business associations, public authorities, policymakers, etc.), exploring pathways for efficient collaboration [14]. The forum evolved into the Education and Innovation Summit in 2022. HEInnovate was launched in 2013 in partnership with the Organisation for Economic Co-operation and Development (OECD), supporting the self-evaluation of HEIs in order to explore their own innovation potentials [15]. The Higher Education for Smart Specialisation (2016–2022) project analyzed how HEIs can be better integrated into S3 policies and how European Structural and Investment Funds can be directed towards achieving S3 objectives. In 2022, the European Network of Innovative HEI was established, consisting of 38 HEI members from 27 members states that are collaborating to exchange knowledge, develop ideas, promote an innovation culture, and enable creativity, entrepreneurship and talent [16].

The Education Agenda of the EIT [17] includes:

(1) The design and launch of a pilot program HEI initiative, Innovation Capacity Building for Higher Education, supporting the innovation and entrepreneurial capacities of HEI. The activities include the exchange and implementation of best practices in knowledge triangle integration, the development of action plans regarding innovation management, start-up creation and development, and technology transfer and its implementation;
(2) The design and launch of EIT-labeled MSc and PhD programs, integrating innovation and entrepreneurship as a direct response to specific societal challenge [18,19].

The TIMREX EIT RawMaterials-labeled MSc program in mineral exploration is aligned with the EIT Education Strategy. It directly responds to the societal challenges caused by a forecasted significant increase in the consumption of critical and strategic mineral resources as the result of the decarbonization of the transportation sector and the mitigation of climate change [1]. The TIMREX program integrates EIT OLOs [4] into both academic masters programs and cross-organizational courses (see Figures 1 and 2). In particular, the cross-organizational courses, such as the summer field camp, internships and student research work, significantly contribute to the development of entrepreneurship and innovation skills and competencies, whereas the Exploration Entrepreneurship and Social and Civic internship courses significantly contribute to the intercultural skills, value judgments, sustainability and leadership skills of future young mineral exploration professionals.

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