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JOINT TRAINING PROGRAMMES FOR THE RAW MATERIALS SECTOR

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Executive Summary

Raw materials industries face skill shortages in many countries. Increasing global competition for talent, cyclical fluctuations in commodity prices, ageing of the industry workforce, and technological advances in exploration, extraction, processing, and recycling of mineral raw materials complicates the situation. Concurrently, the digitalisation of the raw materials sector and a stronger focus on social and environmental performance is changing the traditional skills' mix of the workforce and contributing to a larger skills gap.

This report defines a pathway for enhanced cooperation between the industry, universities, and vocational training providers aiming to create joint education programmes to close the raw materials skills gap. Creating joint education programmes is a complex task that requires the alignment of curricula and learning outcomes, a solid programme structure and a robust administrative support system. But the resulting talent attraction and growing numbers of international students' enrolment has economic, knowledge-sharing, quality assurance and quality control advantages that provide a significant competitive edge to high education institutions (HEI) and vocational education and training (VET) providers. However, three challenges must be considered: 1) the recognition of the qualifications obtained; 2) the emergence of new reference systems and teaching methods; and 3) the expanding range of professional paths in the raw materials sector.

The recognition of the qualifications obtained in a foreign country can be made through academic or professional pathways and can be difficult and time-consuming. The development of joint training programmes encompassing HEI and VET providers from different regions contributes to homogenise and streamline reference points and quality assessment/quality control procedures, hence overcoming the hurdles of recognising qualifications.

Joint training programmes should grant micro-credentials (i.e. proof of the learning outcomes that a learner has acquired following a short, transparently-assessed learning experience) to address the increasing demand for recognition of learning and skills within the much shorter diploma or post-graduate qualifications instruments (a consequence of the fast pace of change in the industry and the ongoing upskilling and reskilling efforts). Micro-credentials can be awarded by HEI and VET providers (and employers) for soft and hard skills and can be credit-bearing, i.e. earn admission towards a formal qualification.

The COVID pandemic accelerated the global uptake of online courses hosted in learning management systems such as Coursera or edX. Massive open online courses (MOOCs; designed for unlimited participants, free of charge, openly licensed and open entry) have become common, and many renowned universities are already providing them, proving the concept works and deserves to be explored. In this context, joint education programmes adapted to different competency profiles and functions in the raw materials sector should use the high-impact, anytime/anyplace/anywhere interaction provided by learning management systems and MOOCs.

The priority themes for joint training programmes (reflecting the expanding range of professional paths in the raw materials sector) fall into two broad areas: 1) digital technologies (as a consequence of the adoption, by the industry, of increasing levels of automation, big data, the internet of things and artificial intelligence); and 2) environmental and social governance, including community's engagement, communication and outreach.

The objectives to materialise joint training programmes and cooperation strategies between HEI, VET providers industry stakeholders include: 1) the development of joint educational and training courses that are theme- and problem-oriented, in line with the sector needs; 2) the development of MOOCs that award micro-credentials; and 3) the promotion of peer-to-peer collaboration, best practice exchange and capacity-building linkages between HEI and VET providers. Attaining these objectives would contribute to expanding excellence in skills development and tackle skills mismatches, building inclusive and connected higher education and vocational systems to address the needs of the mineral raw materials area. A critical aspect of this endeavour is its governance, which should be allocated to the (about-to-be-created) International Network of Raw Materials Training Centres.

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1. INTRODUCTION

Access to and sustainable use of mineral resources materials, particularly critical raw materials such as rare earths, have been identified as key prerequisites to the delivery of the European Green Deal (European Commission, 2019). However, raw materials industries face skills shortages[1] in many countries, and increasing global competition for talent, cyclical fluctuations in commodity prices, ageing of the industry workforce and technological advances in exploration, extraction, processing and recycling of mineral raw materials complicates the situation. Promoting education and training and enhancing the current workforce's mobility are the complementary tools that INTERMIN is developing to tackle this problem. INTERMIN has six specific objectives:

1. Outline a comprehensive competency model for employment across the raw materials sector;
2. Introduce an international qualifications framework for the raw materials sector;
3. Develop standard metrics and reference points for quality assurance and recognition of training;
4. Create a conceptual framework for the development of joint educational training programmes based on present and future skills' needs;
5. Develop and launch an online educational platform that collates and points to various initiatives around the world to optimise international interaction and collaboration between stakeholders of the minerals value-chain;
6. Facilitate the creation of joint international training programmes for the raw materials sector.

This report is directly connected to the sixth objective, and it lays down the foundations for the creation of international joint education and training programmes for the raw materials sector, building on the reference points and best training practices described on INTERMIN's deliverable 3.2, and on the Action Plan to close skill gaps and enhance existing education and training programmes outlined in deliverable 3.4.

It is important to highlight that when the INTERMIN project was conceived, i.e. before the COVID pandemic reached every country in the world, it was assumed that cooperation strategies between vocational education and training (VET) centres and/or higher education institutions (HEI) aiming to deliver training programmes for the raw materials sector should be defined using a top-down strategic design perspective. In this approach, organisations engaged in partnerships would be the driving force, and training/education programmes and topics

[1] Acknowledged as the second most significant risk to mining (Ernst and Young, 2019).

would be defined and organised considering partner organisations' strengths and local needs and conditions.

But the COVID pandemic accelerated the global uptake of remote work and learning methods based on communication technologies, forcing people to work and learn from home, and overcoming the idea that education/training courses and certificates made online were not so respectable/trusted by employers as education/training courses and certificates obtained in conventional classrooms.

Consequently, many high-profile HEI and VET centres embraced eLearning platforms and developed courses to be provided online, hosted in learning management systems such as Coursera or edX. Simultaneously, massive open online courses (MOOCs) have become common, expanding distance learning offerings.

Moreover, many MOOCs are free and provide micro-credentials[2], and this points to a disruptive innovation affecting the existing business models of VET providers and HEI. This is not exactly news since claims are being made for several years that *low-cost, online universities may emerge to offer degrees built completely around massive open online courses offerings* (Michael Horn, cited in Smith, 2012).

The dynamic, anytime/anyplace/anywhere interaction provided by learning management systems and MOOCs is levelling the playfield for students and shifting the power balance from conventional education and training models to online learning platforms and learners. In this emerging reality, cooperation strategies between VET providers and HEI must consider a bottom-up perspective that reflects learners' interests, available resources and certification options (such as issued micro-credentials or college credits).

Hence, this report defines priorities, objectives and key performance indicators for cooperation between VET providers and/or HEI, aiming to foster the creation of joint international training programmes for the raw materials sector, having in consideration the capacity of existing learning management systems and MOOCs to provide global access to an extraordinary number of courses offered by world-renowned institutions and teachers.

[2] By the end of 2020, there were 1,180 micro-credentials offered by MOOCs to 180 million learners (Shah, 2020a).

2. INTERNATIONAL COOPERATION IN EDUCATION

International cooperation in education is expressed in policy dialogue between countries and regions (e.g. the European Higher Education Area -EHEA- that brings together 48 countries that agreed to and adopt reforms on higher education on the basis of common key values), in the exchange of best practice (e.g. Erasmus+ programme key action 2), on the promotion of the mobility and cooperation between universities (e.g. Eurydice, a network of 39 national units based in all 36 countries of the Erasmus+ programme, Australian and Canadian researcher mobility cooperation, EducationUSA) and on the compilation and exchange of information on education indicators and statistics (e.g. the European Commission's Mobility Scoreboard). This section explores existing cooperation frameworks and instruments that are relevant for the establishment of joint training programmes for the raw materials sector.

2.1 Background

The most impressive figures on international collaboration on education and training come from Europe, thanks to the creation of the European Higher Education Area (EHEA). The historical and political legacy of the European Union was the main driver for the creation of the EHEA, defined by the Bologna Process (Bologna Working Group, 2005). The Bologna Process was an intergovernmental higher education reform process launched in 1998-1999, that started in 30 European countries (expanding over the years to 48 countries). Despite the different political, cultural and academic traditions, these countries agreed to and adopted reforms on higher education on based on shared fundamental values– such as freedom of expression, autonomy for institutions, independent student unions, academic freedom, free movement of students and staff (European Higher Education Area and Bologna Process, 2021).

The main purpose of the Bologna Process was to enhance the quality and recognition of European higher education systems and to improve the conditions for exchange and collaboration within Europe, as well as internationally (Correia *et al.*, 2019). The Process established goals for reform in the participating countries, including a three-cycle degree structure (bachelor, master's, doctorate), and adopted shared instruments, such as the European Credits Transfer and Accumulation System and the European Standards and Guidelines for Quality Assurance in the EHEA.

Because qualifications frameworks are critical to developing degree systems and study programmes at higher education institutions, the EHEA adopted, in 2005, the European Qualifications Framework (EQF), a common reference framework that allows qualifications from different countries to be easily compared (Figure 1), using learning outcomes associated

with each qualification[3]. This established a basis for improving the quality, accessibility, linkages and employers' recognition of qualifications within a country and internationally (Correia *et al.*, 2019).

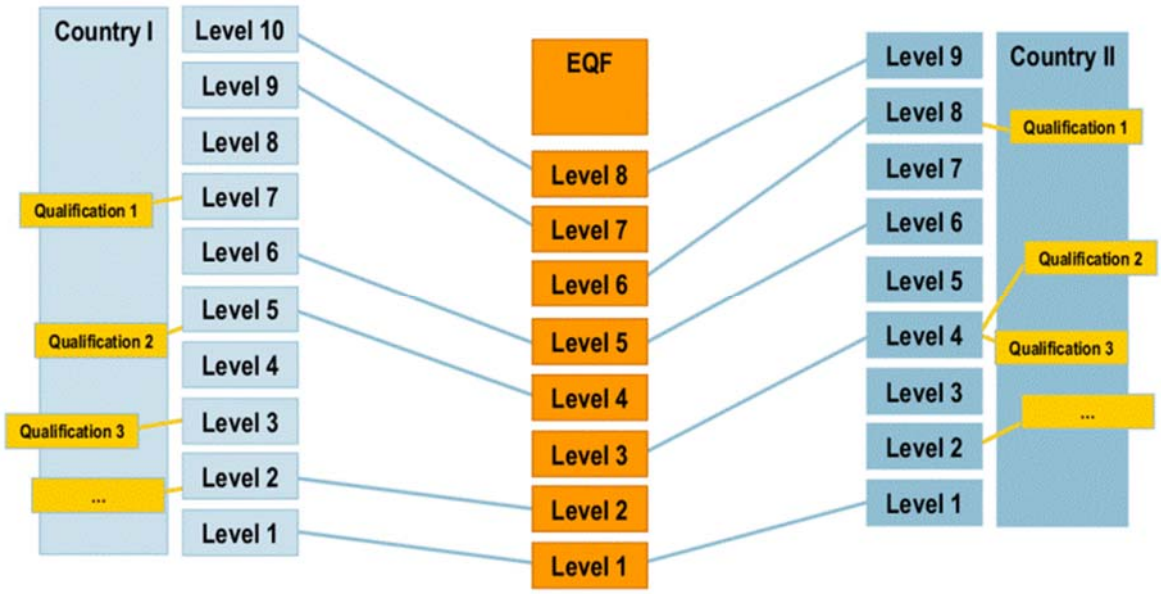

Figure 1 – The EQF as reference system that enables comparison of national qualifications systems based on learning outcomes (adapted from Fietz *et al.*, 2008).

The EQF considers three cycles of higher-education qualifications that are described using the European Credit Transfer and Accumulation System (ECTS[4]):

- First cycle: typically 180–240 ECTS credits (a minimum of 60 credits per academic year), usually granting a bachelor's degree;
- Second cycle: normally 90–120 ECTS credits (a minimum of 60 credits per academic year), generally granting a master's degree;
- Third cycle (doctoral degree): There is no specific credits' range since the disciplines vary in length and comprehensiveness.

[3] INTERMIN advanced an international qualifications framework for the raw materials sector, that is based on the EQF. For additional information see INTERMIN deliverable 3.1., available on https://interminproject.org/2020/01/08/international-qualification-framework-for-the-raw-materials-sector/.
[4] One academic year corresponds to 60 ECTS credits, typically equivalent to 1500–1800 hours of total workload, irrespective of standard or qualification type.

The EQF enabled the development of a European credit system for vocational education and training (ECVET) in 2009. In the ECVET, credits express a set of learning outcomes of an individual which have been assessed and which can be accumulated towards a qualification or transferred to other learning programmes or qualifications. The ECVET uses points, i.e. a numerical representation of the overall weight of learning outcomes in a qualification and the relative weight of units related to the qualification. Allocation of ECVET points to a qualification assumes that 60 points correspond to the learning outcomes expected to be achieved in a year of formal full-time VET (Lavigne, 2012). ECVET enables building a qualification at learners' own pace from learning outcomes acquired in formal, non-formal and informal contexts, in their own country and abroad (European credit system for vocational education and training, 2021). It stands out in the European lifelong learning strategy as the instrument for encouraging individual learning pathways across and within national VET systems. The ECVET offers a framework for making learners more mobile and qualifications more portable, laying down principles and technical specifications and making use of existing national legislation and regulations, and it applies to VET qualifications at all levels of the European qualifications framework (ibidem).

The EQF was adopted by many countries that are not part of the European Union to facilitate the movement for their citizens across Europe (e.g. Albania, Armenia, Azerbaijan, Kazakhstan, Turkey), and propelled the convergence of national higher education policies and the definition of comparable regulatory frameworks and benchmarks on quality assurance. Consequently, European universities benefited from increasing student mobility and enrolment, and those with a long internationalisation tradition reinforced their global market share (Frølich *et al.*, 2005).

The Erasmus Programme[5] ((**E**u**R**opean Community **A**ction **S**cheme for the Mobility of **U**niversity **S**tudents) was the instrument that boosted student mobility globally, building on the Bologna Process and the ECTS. Since its creation in 1987 and until 2014 (when it was replaced by Erasmus+ programme), Erasmus promoted the mobility of more than 3.3 million students within the EU, that had access to more than 4,000 university institutions from 31 countries (Brandenburg, 2014), and was (still is) probably the most effective mechanism to strengthening the European identity. In 2019, Erasmus+ supported more than 940,000 learning experiences abroad, financed close to 111,500 organisations and funded around 25,500 projects.

The ongoing Erasmus+ programme allocates 8.5 billion euros (30% of its budget for the period 2021-2027) to cooperation projects and policy development activities (Erasmus+ factsheet, 2021). Cooperation among organisations and institutions is framed by the Erasmus+ key action 2, and supports (Erasmus+ Programme Guide, n.d.):

[5] Erasmus is an EU student exchange programme established in 1987. It was replaced in 2014 by Erasmus+, which combines all the EU's current schemes for education, training, youth and sport.

- Partnerships for Cooperation, including Cooperation Partnerships and Small-scale Partnerships;
- Partnerships for Excellence, including Centres for Vocational Excellence, Teachers Academy and Erasmus Mundus Action;
- Partnerships for Innovation, including Alliances and Forward-looking projects;
- Capacity Building projects in the field of youth;
- Not-for-profit European sport events.

Hence, Erasmus+ has a dual effect, providing to individuals (students, trainees, apprentices, adult learners, and professionals involved in education, training and youth) improved competences, boosting their employability and career prospects, and to the participating organisations, further experience in international cooperation, strengthening their innovation capacities, good practices and network.

Australia and the USA are also leading initiatives that promote HEI students and staff exchanges, conducted by agencies responsible for implementing governmental higher education internationalisation policies. However, these initiatives are primarily motivated by economic factors, under a competition paradigm.

The most effective is EducationUSA, which uses its network of US embassies and consulates, Fulbright commissions, bi-national cultural centres, and US nongovernmental organisations to assist in recruiting fee-paying international students and help universities to secure international research and consultancy contracts. About 1 million international students were enrolled in US institutions in 2019-20, attracted by the high quality of US higher education, its value on the global labour market, and access to job opportunities in the United States after graduation (Israel and Batalova, 2021).

Australia is also particularly active, and in November 2017 had 621,192 international students studying on student visas and over 100,000 students studying trans-national education programs delivered offshore. International education supports more than 130,000 Australian jobs and is Australia's largest services export, adding almost $31 billion to the Australian economy in 2017 (Council for International Education, 2018). Under its 'National Strategy for International Education 2025', being implemented by the Council for International Education, Australia seeks to strengthen education and research cooperation with Commonwealth countries, the EU and Latin America, and to take the global lead in onshore enrolments of students from China, India, Vietnam, Thailand, Nepal, Malaysia, Brazil and South Korea (Deloitte, 2016).

The assessment of the automatic recognition of qualifications within the European Higher Education Area (EHEA) – vital for the success of the EQF – and of the equivalence of learning outcomes – essential for the success of Erasmus+ – is made by the EU Mobility Scoreboard. This scoreboard contains indicators in the areas of higher education and initial vocational education and training, and it is available on https://www.cedefop.europa.eu/en/events-and-projects/projects/mobility-scoreboard.

Another instrument for recognising qualifications that must be pointed, although it is a voluntary tool that does not impose automatic recognition of foreign qualifications, is the 'Global Convention on the Recognition of Qualifications concerning Higher Education 2019', adopted by UNESCO. The most significant aspect of this convention is that it simplifies recognition processes by turning the burden of proof from applicants to recognition authorities. Under this new approach, and in the countries that voluntarily joined, it is up to recognition authorities to prove why qualifications should not be recognised if recognition is not granted (United Nations, 2019).

2.2 International cooperation initiatives to deliver education and training programmes in the raw materials sector

The economic globalisation, the political push for the free movement of persons (and with it the mutual recognition of professional qualifications) and the Bologna Process made internationalisation part of the regular operations and structure of many education and training providers. The promoters of international education and training initiatives programmes in the raw materials sector are typically universities, companies and governments, and an overview of existing international education and training initiatives driven by these institutions was presented in INTERMIN deliverable 4.1 (Strategic plan of the international network of raw materials training centres). This section builds upon and updates that information.

2.2.1 Inter-university cooperation

As part of the Mining, Minerals and Sustainable Development (MMSD) project, a worldwide survey on mining engineering education covering 275 universities providing tertiary mining engineering training was conducted by the International Institute for Environment and Development in 2000 (McDivitt, 2002). The results indicated the decline of undergraduate programmes in North America and Western Europe and the shift to Eastern Europe and South Asia, South and Central America[6]. The MMSD report on the survey results describes the dismantling of programmes or absorption and rebranding, such as in Japan, where mining is now taught only in courses within a resource engineering or environmental engineering department. The report proposed an International Union of Mining Organisations linking geoscience bodies, mining ministries and industry associations (McDivitt, 2002). The creation

[6] In the US in 2002, only three of four departments had near 100 students enrolled, in contrast to Stanislav Stacszic University of Mining and Metallurgy in Poland, which had six departments within the Faculty of Mining with a total of 1,532 full-time students, 1,051 part-time students and 139 teaching staff. In Ukraine, there were six applicants for each acceptance.

of the International Council of Mining and Metals (ICMM) as the peak global Industry organisation in 2001 resulted from the fundamental challenges listed in the MMSD report[7].

A more recent analysis of higher education programmes in Europe (Sand and Rosenkranz, 2014) shows that European universities benefit from international students' enrolment for postgraduate studies. Many of these students chose universities considering historical, cultural and linguistic links (e.g. African and Asian students often chose universities in former colonial countries, while Eastern European students typically prefer German and Austrian universities). The existing data also shows that graduates from developing countries move on to institutions in developed countries for postgraduate studies. Consequently, universities from developing countries tend to concentrate on undergraduate training, with research-oriented students from countries like China and India going abroad to Europe, the U.S., Canada or Australia for advanced studies (Sand and Rosenkranz, 2014). This trend is leveraged by students exchange programmes (e.g. Erasmus+), inter-university collaboration (e.g. on dual and joint programmes), massive sponsoring of research by industry, and the existence of industry-education collaboration within continuing education.

One of the first examples of inter-university collaboration to create a geoscience-related programme in Europe was initiated by the Helsinki University of Technology (TTK), which joined RWTH Aachen, the Technical University Delft and the Imperial College in 1995 to establish a joint master's degree programme in resource engineering (Kastel, 2007). The master (named European Mining Course) was focused initially on Mining Engineering, and later expanded to a 2-year triple master's degree that also includes Mineral Engineering and Geotechnical and Environmental Engineering. Partner universities associated in a consortium named Erasmus Mundi Minerals and Environmental Programme (EMMEP)[8]. The number of participating institutions increased to nine in 1999, and relations between the participants were formalised when the Federation of European Mineral Programs (FEMP) was established (Kastel, 2007).

FEMP coordinates the EMMEP since 1999, benefiting from solid industry support[9]. Admissions for 2019-2021 included two options: 1) Mining Engineering; and 2) Mineral and Recycling Process Engineering. Participating students study together at two or three universities (Aalto, Delft, Miskolc, RWTH Aachen or Wroclaw) for one or three semesters. A one-semester thesis project is carried out at one of the universities. Recently, these options were reduced: admissions for 2021-2023 are only possible for the European Mining Course, a two-year Master organised between Delft, Aalto and RWTH Aachen universities. In the first three semesters, students attend classes at each participating university, and in the fourth

[7] However, although ICMM publishes dozens of reports on different extractive topics each year, education does not figure prominently.
[8] Initially European Mining Minerals and Environmental Programme.
[9] FEMP was established with a network of 35 companies and institutions in 12 countries on three continents. These companies have contributed over 2 million Euros since 2001, which was used for the support of 800 students of 40 nationalities (FEMP, 2021).

semester, they develop the thesis project. The course covers the entire mining value chain and awards a triple master's degree (European Mining Course, 2021). International students are eligible for scholarships provided by the European Commission.

Erasmus+ boosted collaboration among European universities offering master courses on geosciences. Among the most successful is the joint master's degree Programme on Advanced Mineral Resources Development developed by Montanuniversität Leoben (Austria) and TU Bergakademie Freiberg (Germany) and a third partner university (TU Bergakademie Freiberg, 2018). Students will study the first semester at Leoben, the second semester at Freiberg, and the third and fourth semester at one of the seven partner universities (also comprising universities from outside Europe)[10]. European students have lower tuition fees, and non-EU students are eligible for scholarships that cover 50% of tuition fees.

Another long-standing example of inter-university collaboration is the two-year EMerald master's programme in Resource Engineering, involving the Universities of Liège, Lorraine, Luleå and Freiberg, that delivers a triple diploma on resources engineering (one from each of the universities that students have attended) and a diploma supplement from the coordinating university (EMerald, 2020). Moreover, the EMerald has the EIT (European Institute of Innovation and Technology) RawMaterials label[11], providing opportunities to network with the EIT RawMaterials community, and it has the support (financial, internships) of leading companies from the raw materials value chain. Erasmus+ and the EIT RawMaterials support EMerald and offer scholarships to European and non-European students.

A singular example of inter-university collaboration encompassing African universities was ESDA, Education for Sustainable Development in Africa. The programme started in 2009 and ended in 2018, and involved the following eight universities: the University of Ghana, Kwame Nkrumah University of Science and Technology, and University for Development Studies in Ghana, Kenyatta University and the University of Nairobi in Kenya, the University of Cape Town in South Africa, the University of Ibadan in Nigeria and the University of Zambia in Zambia. The United Nations University (UNU) joined as a 9th Partner University through its Institute for the Advanced Study of Sustainability. In October 2011, UNU and the African Partner Universities signed MOUs to jointly implement the ESDA Programme (United Nations University, 2019b), aiming to advance graduate training and research for promoting sustainable development in Africa.

ESDA benefited from the support of Japanese and European universities and international organisations active in sustainable development, including UNESCO, UNEP, UN-HABITAT and the African Development Bank. After four and a half years of developmental work, ESDA

[10] The number of partner universities decreased from seven in 2000 to five in 2001. Current partner universities are: China University of Mining and Technology-Bejing, Amirkabir University of Technology Tehran (Iran), Instituto Superior Técnico of the Universidade de Lisboa (Portugal), Universidad Politécnica de Madrid (Spain) and St. Petersburg Mining University (Russia).

[11] For more information on the EIT RawMaterials see section 2.2.3.

generated problem-solving field-work oriented master's programmes in three areas – 'sustainable integrated rural development', 'sustainable urban development' and 'mineral and mining resources'. In the fall of 2013, the African partner universities started implementing these programs based on the MOUs made with UNU. ESDA started providing Master graduates – 14 – in 2016. Another major initiative of ESDA was the establishment of a Next Generation Researcher (NGR) team, comprising young researchers nominated by the partner universities, for promoting problem-solving research to generate learning materials to be used in ESDA classes as well as to create needed space for the students' fieldwork. The NGR team is presently engaged in collaborative research with Asian universities (United Nations University, 2019b).

Intercontinental examples of collaboration are scarce. Montanuniversität Leoben introduced two Dual Degree two-year master's programmes with the Colorado School of Mines. In these programmes, students could complete a joint master programme on Mining Engineering or Petroleum Engineering. In the end, they would earn a U.S. as well as an Austrian Master's Degree (Montanuniversität Leoben, 2019). However, in 2020 the master's programme on Mining Engineering was postponed. And the partnership to deliver the master's programme on Petroleum Engineering was shifted to the UFA State Petroleum Technological University, a technical university from Russia (Joint International Master Program in Petroleum Engineering, 2021).

Other examples of inter-university intercontinental collaboration that do not include European universities are scarce. For example, the curricular content of the Minerals, Materials and Society programme being launched in 2020 by the University of Delaware (U.S) was developed in collaboration with the Sustainable Minerals Institute of the University of Queensland (Australia). The partnership includes exchanging staff and organising field trips, as well as University of Delaware students enrolling in University of Queensland courses (University of Delaware, 2020).

2.2.2 Industry-led initiatives

It is significantly easier to assess inter-university collaboration because these formal education routes are in a limited number of institutions. However, the availability of industry-led vocational courses, trades, technician training and apprenticeships is more difficult due to the multiple combinations and levels of formality.

A unique industry/academic initiative was launched in 2007 by Sandvik Mining and six universities: Helsinki University of Technology, Camborne School of Mines, Colorado School of Mines, the University of New South Wales, the University of the Witwatersrand and Montanuniversität Leoben. The 'Sandvik International Mining School' offered six modules that combined theoretical education and practical fieldwork. Each university provided courses on their unique field of expertise and Leoben coordinated the programme. The course content has focused on knowledge-building within the areas of hard rock, soft rock and surface mining,

together with geology, project management and environmental health and safety within mining, across a truly international environment. The 'Sandvik International Mining School' is now closed; the final group of students graduated as International Mining Engineers in 2016 (Sandvik, 2016).

More commonly, universities have a range of continuous professional development short courses, vocational programmes and some distance learning provision, often developed in partnership with mining companies, accessed by those in the industry to address specific skills needs or for professional development. For example, Anglo American sponsored the *Advanced Sustainability Management Programme*, a customised training programme developed by the Centre for Social Responsibility in Mining and the Sustainable Minerals Institute of the University of Queensland in collaboration with the University of Cambridge (Cambridge Institute for Sustainability Leadership, 2019).

Collaboration between industry and universities is typically bilateral (one university-one company) because of intellectual property issues and confidentiality of joint projects. The Rio Tinto Centre for Mine Automation, a research cooperation venture between Rio Tinto operations and the University of Sydney, active since 2010, is an excellent example of this, encompassing applied research in autonomous vehicles, fleet planning and scheduling and orebody modelling (The University of Sydney, 2019). One notable exception, driven by concern regarding falling enrolments, was the development of the Mining Engineering Australia (MEA) initiative funded by industry through the Minerals Council of Australia. This featured the four principal Universities teaching Mining Engineering in Australia collaborating on the development of a standard curriculum and course materials.

University-industry collaboration projects usually include, from the university side, provision of training, research capabilities and engineering staff. Companies normally commit themselves to offer internships to students, recruit staff from among University graduates[12] and enable students to write their thesis on topics related to company operations. Research activities are customarily covered, even if research aims are different[13]. In several countries such as Australia, Germany, India, Indonesia, Poland and Sweden, cooperative training programmes in this regard have been identified as the key to sustainable development in the mining and mineral processing industry (Mooimana, Sole, and Kinneberg, 2005; Ghandi, 2014; Rajibussalim and Pillay, 2016 in Ndlovu, 2017).

The recognition (or accreditation) of prior learning usually is facilitated when universities provide the training since these organisations have in place systems and standards to recognise

[12] The attraction of talent is probably a significant driver for the *China-Australia University tour* promoted by the Fortescue Metals Group. Every year, this mining company receives a group of undergraduate and post-graduate university students from two West Australian and two Chinese universities to its iron ore operations in Western Australia to showcase Fortescue's operations and assets (Fortescue Metals Group, 2019).
[13] Industry, in most cases, seeks solutions to existing problems (applied research); universities, on the other hand, may only value research outputs in the form of publications (fundamental research).

advanced standing or for assigning academic credits. This is a competitive advantage of universities compared to other vocational training providers and industry's in-house training programmes. To overcome this obstacle, VET providers and mining companies seek the accreditation of the training courses they provide by meeting established standards[14] and earning Continuing Professional Development (CPD) recognition. CPD is critical to the maintenance of professionalism and professional standing that individuals keep abreast of the latest tools, techniques and thinking in their chosen field of speciality. Recognised professional organisations typically make CPD recognition (for geologists and mining engineers), that can assume an authoritative role through the endorsement of specific training courses.

In some cases, industry associations are also active in skills development and recognition of prior learning; in Canada, a unique industry-led initiative developed a certification programme, the Canadian Mining Certification Programme (Figure 2) to validate skills, knowledge and experience of workers in the mining sector[15], using as benchmarks the Canadian National Occupational Standards (MIHRC, 2019). Other industry associations (e.g. the Minerals Council of Australia and the Minerals Council South Africa) are also active on skills development and certification of training, although not explicitly with an international focus.

Partnerships between industry and 'official' training or geoscience institutions are an alternative route to solve courses accreditation/recognition. An exciting example of this approach comes from Australia, where ten technical and further education (TAFE) institutions provide a wide range of predominantly vocational courses. Some of these courses are positioned on the technological high-level, such as the South Metropolitan TAFE partnership with the Western Australia government, Rio Tinto, FMG, BHP, Komatsu, Scitech and the University of Western Australia (named Resource Industry Collaboration), to deliver Australia's first Certificate IV in remote operations, creating a pathway to jobs in the field of automation (Government of Western Australia, 2019).

The recognition of CPD for geoscientists and mining engineers who work for the raw materials industry by recognised professional organisations is implicitly transnational, since 26 Recognised Professional Organisations (RPOs) from Australia, Canada, Chile, Europe the U.S. and South Africa have in place a mutual recognition of qualifications system (Bayley, 2016). These RPOs:

a) Are independent and self-regulated, representing geoscience professionals active in a sector or industry;

b) Admit members primarily based on their academic qualifications and professional experience;

c) Require compliance with the professional standards of competence and ethics, established by the organisation, anywhere in the world; and

d) Have disciplinary powers, including the ability to suspend or expel a member for breaches of professional standards of competence or ethics anywhere in the world.

Figure 2 – Occupations eligible for certification in the Canadian Mining Certification Programme (adapted from Imbeault, 2018).

Examples of collaboration between two or more industry players to develop and deliver vocational education and training are scarce and generally limited to partnerships between technology/equipment providers and industry clients (where staff training is part of a commercial transaction). Collaboration on (international) training also happens between global mining companies and their subsidiaries, in line with efficiency-seeking strategies. This collaboration can include external (i.e. delivered by universities or VET institutions) or in-house provision of education and training for knowledge transfer, and is typically associated with reducing costs and accessing public funding.

2.2.3 Government-led initiatives

Education and training programmes in the raw materials sector are also a tool for external diplomacy. They are used by several governments and governmental agencies to facilitate international cooperation and enable trade. One of the best examples of this approach was the International Mining for Development Centre (IM4DC) from Australia. IM4DC was a joint venture of the University of Western Australia and the University of Queensland in partnership with the Australian Government through an Australian Aid initiative, that ceased activities in 2015, at the end of the Government grant (IM4DC, 2016). Between 2011 and 2015, IM4DC offered capacity building through education and training, fellowships, institutional

partnerships, action research, and advice to governments on minerals governance and regulation, community and environmental sustainability and operational effectiveness. This diplomatic effort was made accordingly to Australia's strategic and investment interests in the Asia-Pacific region (Indonesia, Philippines, Mongolia, Papua New Guinea), in Africa (Ghana, Mozambique, Tanzania, Zambia) and Latin America (Peru).

The IM4DC example is not unique. Japan's International Cooperation Agency runs the KIZUNA Program, offering Master's and Doctorate courses in Japanese universities and internship programmes in Japanese companies, government agencies, universities and research institutes. The courses and internships are offered to governmental officials, educators and researchers from research-rich countries, including Cambodia, the Democratic Republic of Congo, Malawi and Mozambique. The explicit goal of the programme is 'to build a good relationship in the mining sector with developing countries, and through it, to ensure a stable mineral resources' supply' (JICA, 2019). South Korea, also a resources import-dependent economy, has a similar approach, offering in the Korea Institute of Geoscience and Mineral Resources (KIGAM) regular courses on Exploration and Development of Mineral Resources for CCOP[16] member countries, creating the foundations for future cooperation between CCOP member countries and KIGAM. The network of mineral resources professionals created by KIGAM is maintained and developed for future collaborative activities within the region (KIGAM, 2016).

In the EU, despite the existence of a policy document establishing that access to resources in third countries is key to the stable supply of mineral raw materials to the EU industry (the Raw Materials Initiative; European Commission, 2014) there are no examples of international education and training initiatives led directly by the European Commission. But two important pan-European public-funded organisations are active in this field. One is the EIT RawMaterials, an organisation funded by the EU. The EIT RawMaterials is the largest consortium in the raw materials sector worldwide[17], encompassing leading businesses, universities and research & technology organisations from over 20 EU countries. Its mission is to enable sustainable competitiveness of the European minerals, metals and materials sector along the value chain by driving innovation, education and entrepreneurship. On the education side, the EIT RawMaterials supports education activities across the entire ecosystem of learners – PhD students, Masters' students, industrial partners, professionals within the raw materials sector, and broader society. Typically, these activities are jointly developed by a group of

[16] The Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) is an intergovernmental organization whose mission is to facilitate and coordinate the implementation of applied geoscience programmes in East and Southeast Asia, in order to contribute to economic development and the improvement of the quality of life in the region (CCOP, 2019). CCOP has fifteen member countries: Cambodia, China, Indonesia, Japan, Korea, Lao PDR, Malaysia, Mongolia, Myanmar, Papua New Guinea, Philippines, Singapore, Thailand, East-Timor and Vietnam. It is supported by fourteen cooperating countries namely Australia, Belgium, Canada, Denmark, Finland, France, Germany, The Netherlands, Norway, Poland, Russian Federation, Sweden, United Kingdom and the United States of America.

[17] With over 300 partners (for more information see https://eitrawmaterials.eu/about-us/partners/).

partners from at least three different EU countries and, in some cases, are open to learners from non-EU countries (even though the EIT RawMaterials does not fund organisations from non-EU countries).

The overarching brand of all the education activities of the EIT RawMaterials is the EIT RawMaterials Academy. The activities the EIT RawMaterials Academy encompass the entire ecosystem of learners – PhD students, Masters' students, industrial partners, professionals within the raw materials sector, and wider society – and foster new ways of learning and teaching by connecting academia, industry and research organisations. The RawMaterials Academy offers education programmes through four collaborative pathways (RawMaterials Academy, 2021): 1) Master's Education; 2) PhD Education; 3) Lifelong Learning; and 4) Wider Society Learning. Typically, these pathways involve more than one partner of the EIT RawMaterials.

The other institution promoting international training on geosciences is the EuroGeoSurveys, an organisation representing 37 National Geological Surveys and some regional Surveys in Europe. National Geological Surveys are public sector institutions carrying out operations and research in the field of geosciences, and 12 of them, under the banner of EuroGeoSurveys, were active in the PanAfGeo, an EU funded programme that supported the training of geoscientific staff from African Geological Surveys. Training topics included satellite imagery analysis, creation of digital maps, geochemistry and analytical chemistry, economic geology, mineral exploration and geological mapping. PanAfGeo ended in December 2019, after enhancing the technical competence of 1,074 trainees from 49 African countries (all except Burundi, Libya, Mauritius, Seychelles and Somalia). No other EU training programme on geosciences had such pan-African coverage, overcoming language, cultural and political barriers (PanAfGeo, 2019).

Several European countries promote international cooperation and capacity building with third (normally resource-rich) countries through their Geological Surveys. The most active in this field has been the French BRGM, the German BGR[18], the British Geological Survey and the Spanish IGME. IGME, with the active support of the Spanish Agency for International Development and Cooperation, was a founding member of ASGMI, the Association of Iberoamerican Geological and Mining Surveys, a not-for-profit organisation encompassing 22 countries that promotes scientific and technical collaboration (through training) between geological surveys' staff.

[18] Between 2006 and 2016 the BGR managed a cooperation programme named GIRAF - Geoscience Information in Africa, primarily supported by the German Federal Ministry for Economic Cooperation and Development (BMZ), BGR, UNESCO Nairobi, the Geological Society of Africa, Australian Aid, the United Nations Development Programme, the Commission for Geoscience Information (CGI) of the IUGS (International Union of Geological Sciences). GIRAF successfully engaged over 400 members from more than 30 African and 12 non-African countries (see http://giraf-network.seamic.org/index.php/en/).

3. CHALLENGES OF DEVELOPING JOINT EDUCATION PROGRAMMES

Developing joint education programmes[19] is a typical outcome of international cooperation activities of HEI and VET providers, sometimes under a broader governmental framework or having industry support.

In the case of HEI, joint education programmes typically award a double degree or a joint degree. In double degree programmes, students obtain two diplomas from two different universities after spending part of their study programme in each of the universities. In joint degree programmes, students receive one single diploma, jointly awarded by the universities (Härkönen and Ngouateu-Bussemaker, 2013). There also triple degree programmes (although less common), in which students receive three diplomas from three different universities (e.g. EMMEP's European Mining Course and EMerald's master – see the previous section).

In the case of VET, there are no examples of the awarding of double or joint degrees. But the examples of bilateral cooperation activities between VET providers seeking to expand their student base and/or to exchange or complement knowledge are abundant and diverse. Existing cases include (Oberheidt *et al.*, 2015):

- The design of VET curricula abroad on the basis of companies' needs (e.g. the German-Thai Dual Excellence Education program);
- The delivery of VET abroad (e.g. Bühler, a Swiss manufacturer of equipment and services for processing basic foods and for manufacturing advanced materials has technology and training centres in Uzwil (Switzerland) as well as in the USA, South Africa, China and India);
- Multilateral cooperation between VET institutions (e.g. The East Asia TVET Network's led by TAFE Directors Australia and the Korean Research Institute for Vocational Education and Training, brings TVET providers from 18 East Asian countries together);
- Bilateral cooperation between companies (e.g. in 2009, GDF SUEZ and Gazprom signed a cooperation agreement in the field of the training and development of their employees, in order to assist each other in the organization and implementation of the training of their respective employees in Russia and in France.

Creating joint education programmes is a complex task that requires the alignment of curricula and learning outcomes, a solid programme structure and a robust administrative support system. But the resulting talent attraction and growing numbers of international students'

[19] Joint education programmes have an integrated curriculum coordinated and offered jointly by different HEI or VET providers from different countries.

enrolment has economic, knowledge-sharing, quality assurance and quality control advantages that provide a significant competitive edge to HEI and VET providers.

However, there are 'context' challenges that must be considered, and that have an impact on the development of joint education programmes, being the most relevant the recognition of the qualifications obtained, the emergence of new reference systems and teaching methods and the expanding range of professional paths in the raw materials sector.

3.1 Recognition of qualifications obtained

The recognition of qualifications obtained in a foreign country can be made through academic or professional recognition. Academic recognition is the process by which a foreign academic qualification is compared to a domestic qualification concerning a course level, duration and curriculum. Thanks to the virtually automatic recognition of academic qualifications in the EHEA, cases of complex and time-consuming recognition procedures in Europe are rare and tend to disappear with the adoption of the 'Global Convention on the Recognition of Qualifications concerning Higher Education 2019' by UNESCO. However, the recognition of academic qualifications obtained in different regions (e.g. Asia, South America, Oceania) is complicated, expensive, and in many situations inconsistent. This happens because, in most cases, decisions on recognition are left to the discretion of HEI. The development of joint training programmes between HEI from different regions will provide essential contributions to the academic communities of the regions engaged (on topics such as curriculum design and quality assessment/quality control), hence providing a substantial incentive to streamline the recognition of academic qualifications across the world.

Professional recognition is the authorization by a competent authority (e.g. Ministry, Professional Association) to practise a profession or regulated professional activity, and when it is required/mandatory by legal systems or market practice, is normally more challenging than the recognition of academic qualifications. The existing national approaches to professional recognition of professions in the raw materials sector can be classified into two distinct models:

1. Mandatory registration or licensure (legally required and enforceable by law); and
2. Systems based on the award of professional titles and voluntary registration, operated by professional geoscience organizations and with assessment by peers (normally driven by common market practice).

These different models reflect cultural and legal differences in approaches to regulation and the extent to which the exercise of geoscience (or aspects of it) is considered to have the potential for significant harm within a country's jurisdiction (Fernández-Fuentes *et al.*, 2020).

Professional recognition was prompted by the introduction of mineral reporting requirements in the mid-1990s, when the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) developed an International Minerals Reporting Code Template that formed the basis for mineral reporting codes and guidelines set in Australasia (JORC), Brazil (CBRR), Canada (CIM), Chile (National Committee), Colombia (CCRR), Europe (PERC), India (NACRI), Indonesia (KOMBERS–KCMI), Kazakhstan (KAZRC), Mongolia (MPIGM), Russia (NAEN), South Africa (SAMREC), Turkey (UMREK) and the USA (SME).

Afterwards, codifications in many areas of the geosciences in Europe and elsewhere in the world occurred in the oil and gas sector (the Petroleum Resource Management System), in engineering geology (the Eurocodes suite) and in geothermal and water resources classification (the United Nations Framework Classification for Resources; UNECE 2020). Globalisation and the increased demand for the international recognition of qualifications have boosted this trend (Fernández-Fuentes *et al.*, 2020).

The globalisation of the economy and the increased codification of geologists' work will continue to boost the professional mobility of geoscientists. However, because of cultural and legal differences and the extent to which the practice of geoscience is considered to impact society within a country jurisdiction, systems that are based on mandatory registration or licensing limit geoscientists' mobility. In contrast, the award of professional titles and voluntary registration, operated by professional geoscience organisations and with assessment by peers, is more effective in the facilitation of professional mobility, as justified by business players through their demand or relative preference on professional title holders at work contracts (Hámor *et al.*, 2020).

In this context, whenever possible, joint education programmes should seek the endorsement or accreditation of professional associations that award professional titles.

3.2 Emergence of new reference systems and teaching models

A common critic of accreditation programmes is that they tend to stifle innovation, and this a relevant shortcoming in the raw materials industry context of rapid innovation and technological progress. A potential solution to this problem, that fosters the rapid upskilling that is required by technological developments and increasing social and environmental responsibility demands, is provided by micro-credentials (Correia *et al.*, 2021). A micro-credential is proof of the learning outcomes that a learner has acquired following a short, transparently-assessed learning experience (A European approach to micro-credentials, 2021), recognising employability skills and professional expertise on specific topics (usually narrower

in range than traditional qualifications), and several qualifications frameworks (e.g. Australia, New Zealand and Europe) are assessing how to enable them. Micro-credentials can be awarded by education and training providers (and employers) for soft and hard skills. Subject areas are unlimited (a micro-credential can be awarded in anything, ranging from driving a dumper to creating a website). Despite the concept's attractiveness, most people do not have a clear idea or have little knowledge of what the term micro-credential might mean (Uggeri, 2019). The key to the success of micro-credentials seems to be dependent on enabling formal qualification and training systems to include short-form credentials, some of which might be credit-bearing, i.e. earn admission towards a formal qualification (Correia *et al*., 2021). This is something that new joint education programmes should consider in their curriculum design.

Because of the increasingly competitive context, many leading universities and VET providers developed courses to be provided online (for distance learning). This approach has become popular among mining professionals and companies because of lower costs and convenience (time- and delivery-wise). These courses can typically be tailored (often by selecting the most relevant training modules) to address specific industry needs, and the customisation process is easier, faster and economical. The University of British Columbia in Canada successfully pioneered the development of a consistent offer of online courses in 2000, through EduMine, a well-known programme on distance learning provision. Edumine quickly expanded with the support of the industry through endorsement and peer review of courses (Mining.com, 2016), and currently offers more than 180 online courses for the raw materials sector.

The definition of micro-credentials varies across different countries/regions (Kato *et al*., 2020):

- In the United States, micro-credentials are understood as learning activity consisting of ‘more than a single course but less than a full degree’, and are labelled differently across learning platforms/providers, such as MicroMasters (edX), Nanodegree (Udacity) and Specialisation (Coursera) (Pickard, 2018);
- In the European Higher Education Area (EHEA), an emerging definition of micro-credentials is a “sub-unit of a credential or credentials that confer a minimum of 5 ECTS, and could accumulate into a larger credential or be part of a portfolio” (MicroHE Consortium, 2019);
- Oceania uses a wider definition, and both of the above-mentioned types of micro-credentials, ranging from 5-40 credits, are regarded as micro-credentials (New Zealand Qualifications Authority, 2019).

Online courses gained popularity over the last years. Many high-profile VET centres and HEI embraced eLearning platforms and developed (additional) courses to be provided online, hosted in learning management systems such as Coursera or edX[20]. Simultaneously, massive open online courses (MOOCs) have become common, expanding distance learning offerings[21]. MOOCs have been conceptualised to be free of charge, openly licensed and open entry. However, MOOC providers usually charge a fee for additional services, such as certification, tutoring, individual coaching and providing follow-up resources.

The certification issue has uttermost importance, and many MOOCs provide micro-credentials aligned with the European Credit Transfer System (ECTS) for potential recognition by other higher education institutions through existing credit transfer arrangements[22]. The European Union actively supports MOOCs because they fit into the EU vision of open education (the OpenEdu Framework – Figure 3).

Figure 3 – The 10 dimensions of the EU holistic approach to open education – OpenEDU Framework (adapted from the The OpenEdu Framework, 2021).

[20] Some HEI, including the Massachusetts Institute of Technology, the University of Michigan, Stanford University, the Indian Institute of Technology Kharagpur, and the University of Naples Federico II, each offer more than 150 MOOCs (Shah, 2019).

[21] MOOCs are designed for, in theory, unlimited participants and, as such, are related to the scalability of education services.

[22] The credibility of a MOOC content and completion is easier when the MOOC is produced by an HEI. In this case, the recognition of credits can be automatic.

This vision considers that contemporary open education goes beyond open educational resources and open research outputs to embrace strategic decisions, teaching methods, collaborations between individuals and institutions, recognition of open learning and different ways of making content available (The OpenEdu Framework, 2021). It must be highlighted that the use of ICT platforms to deliver the OpenEDU Framework has enormous potential for innovation and reach, which was recently boosted by the impact of the COVID pandemic[23].

MOOCs provide a relevant opportunity for innovation, can significantly lower the cost of developing and delivering courses and respond to the needs of global markets, interconnected in learning platforms. Some of the HEI that have been partnering to provide joint degrees in the raw materials area (Montanuniversität Leoben and TU Bergakademie Freiberg are already offering MOOCs), proving the concept works and deserves to be explored.

There is of course the need of using quality control/quality assurance procedures to ensure that MOOCs and the micro-credentials provided would be accredited, to ensure the uptake by learners, the raw materials' industry and professionals. This creates a relevant opportunity for industry associations and recognised professional organisations.

In April 2021, leading professors and researchers of seven European universities from six countries (including Montanuniversität Leoben and TU Bergakademie Freiberg) started offering an online free lecture series under the banner of the European University Alliance on Responsible Consumption and Production covering, among other topics, responsible production and consumption, circular economy and sustainable development goals. Participants received a certificate of attendance and could obtain 5 European Credit Transfer and Accumulation System (ECTS) credits if at least 11 lectures were visited, took an online test, and produced a written paper.

On the same date, of the 60 courses offered by the EIT Raw Materials Academy, 34 were held online (more than one quarter for free), covering a diverse array of topics (from mining and circular economy to leadership and management).

[23] In 2020, 950 HEI were offering MOOCs across the world, and of all the learners that ever registered on a MOOC platform, one third did so in 2020. In April 2020, Coursera, edX, and FutureLearn attracted as many new users in a single month as they did in the entirety of 2019 (Shah, 2020b). This was a straightforward consequence of the COVID pandemic.

3.3 Expanding range of professional paths in geosciences

As shown in previous INTERMIN reports (deliverables 2.1, 2.3, 4.1), evolving technologies will require professionals to develop new skills. Current trends point to an increase in demand for advanced IT skills and complex problem-solving abilities and a decrease in manual and repetitive tasks. The convergence of different digital technologies, artificial intelligence and automation is driving the workforce towards higher cognitive tasks. Another driver pushing the development of new competencies is the introduction of environmental, social and governance (ESG) considerations in the development of raw materials projects, a must-do to strengthening community relationship and social responsibility.

It must also be pointed that retrain and upskill are among the strategies the industry uses to face skill shortages (or the workforce will become redundant), placing professional development at centre stage. This is a direct consequence of the long time it takes to change academic preparation (if universities decide to change programmes in preparation for the future workforce, the absolute shortest time to see that change in the new hires is five years, most probably seven to twelve years given ramp-up time for the schools (Correia *et al*., 2021).

Considering the ongoing changes of the raw materials sector context, affecting the required skills' mix of the workforce, the development of joint education programmes for the raw materials sector must respond to three different but interconnected dimensions (Correia, 2021):

1. 21st-century qualification frameworks and curricula, centred on industry needs;
2. Alignment with lifelong learning pathways, optimising available training potential through competency-based approaches and individualisation of training;
3. Provision of relevant specialised education certified by micro-credentials that could be stacked into a coherent skills' development path.

4. DEFINING PRIORITIES AND OBJECTIVES

Human capital development through education and training in the raw materials sector has in the main been addressed through national approaches such as Australia's Minerals Tertiary Education Council or discipline-specific initiatives such as the Society of Mining Professors or the International Mineral Processing Congress (IMPC) Education Committee. The area of VET-level skills development has, until recently, seen even less activity in most countries. The majority of existing initiatives are (appropriately) limited in scope in terms of geography, education level and discipline focus. Relatively few of these initiatives are connected or engage with each other. This section advances priorities, objectives and key indicators for the development of joint training programmes targeting the raw materials workforce, aiming to facilitate international cooperation between HEI, VET providers and industry stakeholders.

The development of joint education and training programmes for the raw materials sector should consider the actions outlined in the INTERMIN Action Plan to close skill gaps (INTERMIN deliverable 3.4). The Action Plan defends a substantial adaptation of raw materials educational programmes to deal with the demand for new skills that will increase as a consequence of the adoption of new technologies (combining increasing levels of automation, big data, the internet of things and artificial intelligence) coupled with increasing social and environmental responsibility demands by the raw materials sector.

The four action areas the Action Plan outlines to tackle future skills mismatches and promote excellence in skills development are:

1. Definition of 21st-century qualification frameworks and curricula, centred on industry needs;
2. Definition of lifelong learning pathways, optimising available training potential through competency-based approaches and individualisation of training.
3. Provision of relevant specialised education certified by micro-credentials;
4. Reinforce learners' digital fluency and science, technology, engineering and mathematics (STEM) skills by focusing on the junior secondary phase of schooling to reinforce students' interest and motivation to engage in STEM.

The priorities and objectives outlined in this section reinforce the first three actions areas of the INTERMIN Action Plan to close skill gaps (INTERMIN deliverable 3.4). Whenever possible, the International Network of Raw Materials Training Centres should seek the validation of the themes and instruments defined herein by existing EU international cooperative frameworks, namely Erasmus+ and the OpenEDU Framework.

4.1 Prioritising themes and challenges

The high-priority themes for education and training in the raw materials sector fall into two broad areas (Martins and Bodo, 2019; Correia, 2020):

1. Digital technologies (as a consequence of the adoption, by the industry, of increasing levels of automation, big data, the internet of things and artificial intelligence);
2. Environmental and social governance, including community's engagement, communication and outreach.

On the first area, and according to Sánchez and Hartlieb (2020), core technologies that represent the pillars of the (ongoing) digital transformation in the mining industry include:

- Automation, Robotics, and Remote Operation;
- Internet of Things (IoT), Smart Sensors/Real-Time Data Capture;
- Analytics, Artificial Intelligence/Machine Learning; and
- Digital Twinning.

The same authors also point out three future trends that can have a complementary impact in the raw materials sector, and that can affect the future industry paths:

- Electromobility (i.e. the development and use of electric-powered transport equipment by the industry);
- Invisible Zero-Waste Mining (advances on underground mining and *in situ* leaching methods);
- Continuous Mining (taking stock of automation and robotics to increase productivity, reduce costs and improve safety).

Education and training in the core technologies and trends mentioned, applied to the raw materials sector, is very scarce. Obvious explanations for this supply shortage include the "emergent" status of the technologies and the cross-fertilisation effort that is deemed necessary to develop curriculum content merging different technological areas (that are evolving at a fast pace) with geoscience.

This creates a great opportunity for the establishment of alliances between HEI (from different areas of knowledge), VET providers, providers of equipment and machinery and companies from the raw materials sector to design, test and deliver new curricula and course materials adapted to different competency profiles and functions.

In the area of environmental and social governance, the education and training offer has increased in the last years, driven by the international finance push to address these dimensions

in new extractive projects. However, the response of HEI providing raw materials courses has remained slow, and generally speaking, fresh university graduates still lack fundamental knowledge on environmental and social governance[24]. HEI that provide business courses, and VET institutions, often pushed by the industry, responded faster, and there is already a comprehensive offer of training (aimed at upskilling efforts) for executives interested in the fundamentals of environmental, social and governance principles.

Nevertheless, because professional skills related to environmental and social governance also include communication, economics, regulatory compliance and project management (alongside the environmental/social disciplines related skills), there are opportunities for HEI and VET providers to partner with industry and professional organisations to deliver courses and develop training materials adapted to different competency profiles and functions in the raw materials sector. Moreover, since the advance of best social and environmental practice benefits from the exchange of experiences across different geographies and contexts, partnerships between HEI/VET providers from different regions would bring a broader range of experience and knowledge to the courses developed.

4.2 Prioritising instruments

The contextual environment of the mining industry, with increasing automation, a stronger focus on social and environmental performance, and talent competition, is rising changes in vocational and education courses delivery, structure, duration and curricula. Spearing and Hall (2016) suggest that flexible pathways via staged qualifications in mining-related disciplines (including automation and social management) will become more relevant since reskilling via four- or five-year degree programmes is unlikely. The authors also stress that recognition of prior learning and skills will be necessary within much shorter diploma or post-graduate qualifications and assert that the traditional method of attending classroom lectures during a whole semester needs to change, so that learners can work nearly full-time with short (week-long) bursts of intensive contact time for classes and laboratories. Massive open online courses (MOOCs), hosted in increasingly popular eLearning platforms (such as Coursera or edX), and the provision of micro-credentials, seem particularly adequate to respond to those changes effectively, and can simultaneously expand the range of education and training choices.

In this new context, MOOCs (i.e. short duration courses and options for continuing professional development, delivered in a convenient way – online) open new possibilities to the provision of education and training programmes. The global and free access to a large number of courses offered to anyone who has accessibility to the Internet by world-renowned institutions creates

[24] A quick scan over the courses' offer of the RawMaterials Academy confirms this perspective: of the 60 courses provided, there's only one on sustainable business models and operations and another on corporate social responsibility.

equal opportunities for all learners, and to benefit from this new framework VET providers and HEI must develop educational offers that reflects learners' interests and that provide micro-credentials or ECTS credits.

And because certification is a crucial issue for the recognition of skills obtained in MOOCs, this creates a vast space for cooperation between HEI (from different areas of knowledge), VET providers and professional organisations willing to cooperate in recognition of micro-credentials that could be stacked into a coherent HEI course curriculum, or aligned with into a coherent professional development path.

4.3 Objectives for international cooperation

International cooperation in education and training accelerates the dissemination of best practice, supports innovation, and enables the definition of common reference points (for quality assessment/quality control) in skills' development[25], which are key for the recognition of qualifications and the mobility of professionals. Hence, the specific objectives to materialise joint training programmes and cooperation strategies between HEI, VET providers industry stakeholders are:

1. Identification of education and training needs in the INTERMIN network, to support analysis-based decision-making[26];
2. Development of joint educational and training courses that are theme- and problem-oriented, in line with the priorities set in the previous sections;
3. Provision of education and training tools and resources that meet the needs of learners (namely MOOCs that award micro-credentials) adapted to different competency profiles and functions in the raw materials sector;
4. Promotion of peer-to-peer collaboration and best practice exchange between participants in the INTERMIN network;
5. Development of INTERMIN's network inter- and multi-disciplinary support capacity to foster innovation on education and training;
6. Reinforcement of capacity-building linkages between HEI and VET providers in developing countries.

[25] Supporting cooperation among HEI and VET providers contributes to strengthening skills acquisition and development, in line with the United Nation's Sustainable Development Goal 4: Quality Education.

[26] Also benefiting from the dialogues on skills needs, educational and vocational curricula and educational programmes for the next decade with the most innovative industry representatives prescribed in INTERMIN's Action plan to close skill gaps and enhance existing education and training programmes (deliverable 3.4).

Attaining these objectives would contribute to expanding excellence in skills development and tackle skills mismatches, building inclusive and connected higher education and vocational systems to address the needs of the mineral raw materials area.

4.4 Key Performance Indicators

A key performance indicator (KPI) is a metric used to gauge performance on dimensions or factors that are important to the success of a project or organisation. Defining KPIs is important because they keep objectives at the forefront of decision-making and provide a precise picture of the progress made in developing joint training programmes and enhancing cooperation between HEI, VET providers and industry stakeholders.

The figures advanced for the KPIs herein prescribed consider a time horizon of two years (i.e. two years after the formal set up/launch of the International Network of Raw Materials Training Centres created by INTERMIN). It is also assumed that the International Network of Raw Materials Training Centres would actively foster the international exchange of information and knowledge between raw materials education and training centres, thereby encouraging and supporting value-creation, innovation and good practice and the attainment of the international cooperation objectives outlined in the previous section.

The KPIs that should be considered to gauge the development and provision of joint training programmes and cooperation strategies between HEI, VET providers industry stakeholders in a two-years timeframe are:

- Three multilateral partnerships/joint ventures established to create/deliver joint training programmes, recognised by the EU OpenEDU Framework;
- Six joint training programmes created;
- 12 academic staff/trainers trained;
- Six MOOCs created;
- 200 learners trained;
- Three staked micro-credentials created;
- Fifty micro-credentials granted.

These KPIs provide a framework for the International Network of Raw Materials Training Centres to track and improve its performance as the structure of reference on cross-border knowledge-sharing and dissemination of effective innovation on raw materials education, training and professional development practices[27].

[27] This is the vision statement of the International Network of Raw Materials Education and Training Centres, as defined in INTERMIN deliverable 4.1.

5. CONCLUSIONS

Enhanced cooperation between VET providers and HEI and the development of a large offer of joint training programmes can provide a decisive push to close the skills gap in the mineral raw materials sector. There are, however, challenges that must be considered, being the most relevant the recognition of the qualifications obtained, the emergence of new reference systems and education methods and the expanding range of professional paths in the raw materials sector.

Differences in metrics and reference points for quality assurance of education and training prejudice the international recognition of education and training programmes and hinder the worldwide mobility of students and professionals from the raw materials sector[28]. To overcome this obstacle, HEI and VET providers engaged in the development of (or offering) joint training programmes should use, whenever possible, the European Credit Transfer and Accumulation System (ECTS), allowing the transfer, recognition and accumulation of learning outcomes to obtain a qualification through credit transfer arrangements. Another route that should be exploited (especially in training programmes designed for upskilling and aligned with continuing professional development) is the certification/endorsement or accreditation of courses and learning outcomes by professional associations that award professional titles.

In addition, and to address the increasing pace of change in the industry, flexible pathways via staged qualifications are becoming more relevant, and there is an increasing demand for recognition of learning and skills within much shorter diploma or post-graduate qualifications. Micro-credentials provide a solution to this need, since they can be awarded by HEI and VET providers (and employers) for soft and hard skills, for unlimited subjects. The key to the success of micro-credentials seems to be dependent on enabling formal qualification and training systems to include short-form credentials, some of which might be credit-bearing, and this is something that new joint education programmes should consider in their curriculum design.

The COVID pandemic boosted the popularity of online learning management systems and massive open online courses (MOOCs), conceptualised to be free of charge, openly licensed and open entry. The European Union actively supports MOOCs (through the OpenEdu Framework) because they fit into the EU vision of open education. Again, the certification issue has uttermost importance, and many MOOCs provide micro-credentials aligned with ECTS credits for potential recognition by other higher education institutions. There is, of course, the need to use quality control/quality assurance procedures to ensure that MOOCs and the micro-credentials provided would be accredited. This is an opportunity to improve cooperation with industry associations and recognised professional organisations.

The range of professional paths in the raw materials sector has been expanding, driven by technological advances and increasing environmental and social concerns. Because of this,

[28] The exception to this is the European Higher Education Area, which uses European Standards and Guidelines for quality assurance in 48 countries of the European continent.

digital technologies and environmental and social governance are high-priority themes for education and training in the raw materials sector. This calls for establishing alliances between HEI (from different areas of knowledge), VET providers, providers of equipment and machinery and companies from the raw materials sector to design, test and deliver new curricula and course materials adapted to different competency profiles and functions.

Enhanced cooperation between VET providers and HEI and the development of a large offer of joint training programmes (including MOOCs providing micro-credentials) will have three significant consequences:

1. Expansion of the variety of education and career paths on geosciences, thus increasing the capacity of professionals to adapt /respond to changes;
2. The democratisation of the acquisition and spread of advanced knowledge amongst geoscientists; and
3. Enhanced mobility and interconnection of raw materials' professionals, contributing to close the global (geographic and time) gap between demand and supply of practitioners.

Attaining the objectives for international cooperation and KPIs outlined in this document would contribute to expanding excellence in skills development and tackle skills mismatches, building inclusive and connected higher education and vocational systems to address the needs of the mineral raw materials area. Still, the critical aspect of developing joint education and training programmes for the raw materials sector its governance. This effort should be taken by the (about-to-be-created) International Network of Raw Materials Training Centres, and its establishment is a crucially important factor for the success of this endeavour.

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