INTERMIN

ACTION PLAN TO CLOSE SKILL GAPS AND ENHANCE EXISTING EDUCATION AND TRAINING PROGRAMMES

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Executive Summary

Access to and sustainable use of mineral resources materials, particularly critical raw materials such as rare earths, have been identified as critical prerequisites to delivering the European Green Deal. However, raw materials industries face skills shortages (acknowledged by the industry as the second most significant risk to mining), and the contextual environment of the extractive industry, with increasing automation and a stronger focus on social and environmental performance, is changing the required skills' mix of the workforce. Attracting younger talent with the appropriate skills is difficult, since the raw materials sector is not in vogue and has to compete globally against many different industry sectors.

This report identifies the causes of the existing skills gap, maps the trends that will affect the raw materials workforce and, based on the analysis made, advances a vision for moving from industry-focused to future-focused skills in the EU mineral raw materials sector. This vision considers three priority areas:

1. Matching worker skills to available jobs;
2. Boost STEM training;
3. Strengthen public-private collaboration on education and lifelong training.

The Action Plan outlined in this document identifies four primary initiatives that should be developed jointly to advance the vision priority areas. To facilitate the implementation of the four initiatives, the Action Plan details, for each, the critical factors for success, main tasks, expected outcomes, performance indicators, milestones and responsibility for implementation. Lastly, a 5-step implementation plan, a timeframe and a cost estimation (for each initiative) provide a basis for budgeting (the total indicative budget of the Action Plan is 13 million Euros). The Action Plan also explores synergies between the initiatives and suggests a prioritisation that considers the easiness of implementation of the activities (assuming that less complex activities, i.e. having higher acceptance and few and less diversified stakeholders, are easy/simple to implement) and their expected impact (benefit/cost ratio). The four initiatives to be implemented are (by priority order):

1. Development of an across-the-board approach to employability skills in the raw materials sector (advancing a blueprint of core employability skills) coordinated across the employer and educational stakeholders;
2. Strengthen cooperation between business in the raw materials sector and higher education institutions and vocational education and training providers (business-led apprenticeships and intern programmes);
3. Reinforce public-private collaboration to enhance intelligence on labour market needs and develop consistent views on the immediate and mid-term skill needs, and how much is rapid training enabled vs long-term education (lifelong learning pathways);
4. Definition of the operational dimensions of quality credentials of education and training courses that are valued by employers in the raw materials value chain (attributes of standard-based credentials).

Implementing these initiatives calls for different stakeholders' engagement and requires active cross-collaboration and partnering to reconcile views on diverse (but interconnected) topics. For this reason, the governance of the Action Plan is its most critical aspect. It was assumed that the (about-to-be-created) International Network of Raw Materials Education and Training Centres would drive the implantation of the Action Plan. Therefore, its establishment is a crucially important factor for the success of this Action Plan.

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1. INTRODUCTION

Mineral raw materials are crucial for the sustained functioning of modern economies, and the future of the workforce is acknowledged as the second most significant risk to mining (Ernst and Young, 2019a). 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 the following specific objectives:

- Outline a comprehensive competency model for employment across the raw materials sector;
- Introduce an international qualifications framework for the raw materials sector;
- Develop standard metrics and reference points for quality assurance and recognition of training;
- Create a conceptual framework for the development of joint educational training programmes based on present and future skills' needs;
- 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;
- Facilitate the creation of joint international training programmes for the raw materials sector.

This report presents an action plan to close the skills gap in the raw materials sector, identifying initiatives that pave the way for the transfer of knowledge and best practice among education and training providers and industry stakeholders, and the incorporation of new knowledge into education and training programmes.

The initiatives presented are framed by a vision for closing the skills gap to ensure consistency and maximise synergies. The prioritisation of the initiatives considers their anticipated impact and complexity. Initiatives with higher impact and lower complexity are ranked first. The plan details each initiative's expected outcome, the corresponding critical factors for success, the key tasks, milestones, performance indicators, implementation sequence, and timeline. A cost estimate (that provides a basis for budgeting) and the responsibility for implementation are also defined.

Implementing the actions calls for engagement of different stakeholders and requires active cross-collaboration and partnering. It is assumed that this effort would be initiated and driven by the (about-to-be-created) International Network of Raw Materials Education and Training Centres.

2. THE SKILLS GAP IN THE RAW MATERIALS SECTOR

The work package two (WP2) of the INTERMIN project investigated the current and expected demand for raw materials professionals, paying particular attention to identifying the kind of professional skill sets that employers are looking for and that are likely to be in demand in the future. This section takes stock of the work made in WP2 and focuses on the short to medium-term skills gap and the corresponding causal linkages.

2.1 Contributors to the skills gap in the raw materials sector

Raw materials industries are facing skills shortages in many countries. This problem has been recognised as one of the significant challenges facing the sector [1] [2]. Skill shortages might happen because of a shortage of skilled professionals in a specific region and within a specific section of the value chain as compared to demand, or because of a fundamental lack of competent active professionals within a specific field of work[3] [4]. This in turn can be caused by the workforce having misaligned educational backgrounds[5] or low quality of education within a field (Sand and Rosenkranz, 2014). Typically, three factors drive skills availability in the raw materials sector: technological advances, market cyclicity and demographics.

Modern mining operations are highly automated, and equipment operators have largely replaced hands-on miners. Today's extractive companies are looking for graduates and technical specialists with not only mining knowledge but also the ability to use **sophisticated technology** and computing techniques while operating in challenging environments. The same is happening in the recycling sector. As industrial societies began to demand increasing varieties of raw materials to build up sophisticated equipment and devices, recycling of metals and minerals became much more complex. In the last 30 years, recycling took a leap forward,

[1] Mining is perceived as a "dirty" industry, responsible for significant environmental pollution. This is the root of several difficulties affecting the sector. See Ernst and Young, 2019b.

[2] Strategic Implementation Plan for the European Innovation Partnership on Raw Materials https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/strategic-implementation-plan-sip-0, retrieved on 30 January 2020.

[3] For example, a looming shortage of expertise in the field of tailings management was identified as a key concern in the recent Global Tailings Review compendium (Evans and Davis, 2020).

[4] Because of the unique nature of the activities, the number of active professionals in some areas of expertise in the minerals value chain never was significant (e.g. mineralurgy or mining ventilation), but it was stable. After 1990, with the declining of mining in Europe, and lower student enrolment in geoscience courses, staff renewal was affected (both in academia and industry).

[5] In many cases in Europe this is the consequence of a continuous fall in demand for geoscience courses (e.g. in the last five years the mining engineering course at the University of Lisbon and the economic geology course in the University of Naples have reduced the number of areas of specialisations offered, as a consequence of more than two decades of successive declines in the number of student enrolments – leading to reductions in the academic staff).

from basic scrap collection to a mix of operations supported by materials engineering and inverse manufacturing, fostered by the principles of the circular economy and eco-design.

Market cyclicity in commodity prices provokes an inconsistent supply and demand for skills. Regardless of location, all mines are competing on the cost of production and efficiency of the project capital. Supply and demand can change rapidly and, as a result, job security and long-term viability of individual mines is always an issue. Cyclicity in commodity prices also affects recycling operations and metals processing, and the industry has therefore recently seen rapid increases and decreases in the number of people it employs. Cyclicity results in skills shortages and demographic gaps, followed by over-capacity on a recurring basis as industry retrenches and expands. The cyclicity in the sector has caused endemic skills shortages and then oversupply that lags the commodity cycles and results in elevated costs and, with each contraction, loss of experience from the sector[6]. The cyclicity has also resulted in the sector becoming less attractive to new entrants, with young people pursuing more flexible and deployable qualifications.

Company retrenchment in many countries in the 2012-2017 commodities downturn caused a '**demographic gap**' in the raw materials sector, worsened by lack of recruitment during the 1980s and 1990s in similar downturns. In addition, increasing global competition for talent and migration are challenging the sector's ability to retain local talent and attracting talent from elsewhere. This is a real problem in the extractive and recycling industries, that is becoming critical in Europe, as senior staff retires and there are few mid-career staff available to replace them[7].

2.2 Trends affecting the raw materials workforce

The fundamental employability skills required by the raw materials sector at present (Correia *et al.*, 2019a) include interpersonal communication, self-management, ability to read and understand complex text, ability to learn, effective use of technology, capacity to solve problems and compliance with occupational health & safety regulations. Workers who do not

[6] For comparison, one major debate in the oil and gas (O&G) industry was this exact issue, since each contraction only led to a harder time expanding. As a consequence, the industry focused on retrenchment in universal skill areas (e.g. marketing, admin) while retaining technical talent. Much of this was dependent on the technical talent having other skills so they could be shifted in the company until expansion restarted. It worked for a while, but then, during a massive boom, when talent became really scarce, O&G companies outsourced to the major service companies to provide the capacity. So, it worked for some time, but seemed to be crushed when there was aggregate demand for talent in the next expansion cycle.

[7] There are certain decision responsibilities that many companies expect individuals with a certain amount of experience – such as a minimum of 20 years in the company before being eligible for Vice President positions. However, as the demographic gaps have emerged in the technical fields, a number of those senior-most positions which traditionally have been technical people are now being filled with people from other professions such as finance or management. This has clear implications for the technical workforce's position within the enterprise's value chain.

have this set of "generic" skills have difficulty navigating across rapidly changing job requirements, and the profile of fundamental skills is about to become even more extensive and technical. A recent report from the World Economic Forum (2019) identifies seven trends[8] that are expected to shape the future of mining:

1. **Transition to a low-carbon economy:** on the energy transition to renewables – sourcing different sets of raw materials and pushing the industry to reduce emissions;
2. **Access to resources:** lower quality and grades of deposits pushing for 'new frontiers';
3. **New ways to finance mining:** e.g. royalty and metal stream agreements;
4. **A social contract for mining:** social responsibility and local community acceptance;
5. **Big data and mining:** improving efficiency of operations and transparency of value chains;
6. **The geopolitics of mining:** dynamics of geopolitical risks and economic protectionism;
7. **Modern mining workforce:** evolving technologies will require employees to develop new skills. Competition with IT sector to attract talents, partnership with Governments for up-skilling, re-training and transitioning workforce to a more 'automated' mining sector.

Much of the expected impacts on the workforce will be driven by technological advances, and the report suggests that the speed at which extractive companies will be able to roll out new technologies (on site operations) will depend on the local stakeholders' (encompassing workers, labour unions, government and civil society) acceptance of reduced employment and procurement opportunities.

Mechanisation in the raw materials sector is not new, however the rate of technological development and digital innovations currently seen are expected to have a profound impact across value chains. Ernst and Young (2019b) research in Australia, summarises expected impacts from digital and technological innovations in three dimensions:

1. **Capability**: reduction in traditional operators and increase in demand for technologically savvy professionals. Core functional support will be provided by professionals who can combine technical mining skills with digital technologies competencies;
2. **Location**: Increase in remote operations shifting site-based workforce to remote operating centres in urban areas;

[8] Source: https://www.weforum.org/agenda/2019/03/seven-trends-shaping-the-future-of-the-mining-and-metals-sector/ (accessed 01.07.2019)

3. **Number**: a transition and re-definition of roles, as certain traditional ones will be reduced while new ones will be created.

The Future of Jobs Report (WEF, 2020) shows a clear acceleration of the willingness to adopt new technologies among companies from the mining and metals industries: more than 85% of the companies surveyed expressed their likelihood to adopt, by 2025, big data analytics, internet of things, nonhumanoid robots and cloud computing technologies (Table 1).

Table 1 – Technologies likely to be adopted by 2025, by share of companies surveyed in the Mining and Metals sector (source: WEF, 2020).

Technology adoption in the mining and metals sector (% of companies willing to adopt)	
• Big data analytics (90%) • Internet of things and connected devices (90%) • Robots, nonhumanoid (90%) • Cloud computing (87%) • Encryption and cyber security (83%) • Artificial intelligence (76%) • Text, image and voice processing (76%) • E-commerce and digital trade (62%)	• Augmented and virtual reality (57%) • Power storage and generation (57%) • Distributed ledger technology (e.g. blockchain) (50%) • 3D and 4D printing and modelling (48%) • New materials (37%) • Quantum computing (29%) • Biotechnology (16%) • Robots, humanoid (15%)

The same survey provides a glimpse of the expected changes to the workforce by 2025. The comparison of responses from the mining and metals companies with the overall average of companies surveyed (Table 2) shows that the raw materials sector is willing to embrace new technologies at a faster pace (probably making up for lost time), and this will have a very relevant impact on the sector's workforce on the short and medium-term.

The raw materials industries are going through a textbook example of capitalism's creative destruction process (Schumpeter, 1942) relative to the industry's operation modes. In this process, product and process innovation leads to the replacement (destruction) of outdated production systems. Entrepreneurs and workers in new technologies will create disequilibrium and benefit from new profit opportunities. Producers and workers committed to older technologies will be left stranded.

Table 2 - Expected impact on workforce (source: WEF, 2020).

Expected impact on workforce	(% of companies surveyed)	
	Mining & Metals	Overall average
Modify the composition of the value chain	62%	55%
Reduce its current workforce due to technological integration or automation	52%	43%
Expand its use of contractors doing task-specialised work	52%	42%
Modify the locations where the organisation operates	45%	38%
Expand its current workforce due to technological integration or automation	28%	35%
Reduce its current workforce	42%	15%

There are two aspects related to the described trends that must be highlighted:

1. The energy transition will rely on vast amounts of mineral raw materials, coming from mines and recycling centres. Constraints on the access to resources (either from the physical environment or from the geological endowment) will push operational effectiveness and the uptake of new technologies, while at the same time companies need to improve community relations to obtain the trust of investors, end-consumers, local communities and policymakers;
2. Skill gaps in the local labour market (mentioned by 73% of the companies surveyed in the WEF report) and the inability to attract specialised talent (mentioned by 57% of the companies surveyed) are the two main barriers to the adoption of new technologies by mining and metals companies.

Another aspect that cannot be forgotten is the impact of the current Covid-19 pandemic on jobs. According to the World Economic Forum (2020) the economic contraction caused by the pandemic would probably create a 'double-disruption' scenario for many workers. In the raw materials sector, plans to expand the use of contractors for task-specialised work and reductions in workforce due to technology integration will mainly affect jobs held by lower wage workers, and therefore deepen existing inequalities[9].

[9] See for example Holcombe, S. & Kemp. D. (2018) Indigenous Employment Futures in an Automated Mining Industry: An Issues Paper and A Case for Research. Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland: Brisbane.

2.3 Short and medium-term skills gaps

The widespread adoption of big data analytics, internet of things, nonhumanoid robots and cloud computing technologies, alongside increased automation and use of remote-controlled operational systems, will push demand for data and digital literacy skills across the minerals value chain (Table 3). This will redesign most occupations in the raw materials sector as the human-to-machine interface evolves and becomes more ubiquitous.

Table 3 – Digital technology impact on mining value chain workforce and skills requirements (adapted from Ernst and Young, 2019b).

Value chain stage	Workforce impacts and skills required
Exploration	• Reduction in drilling operators due to automation • Increased demand on advanced analytics and modelling skills • Increasing share of remote work
Mining Operations	• Reduction in drilling operators due to automation • Key skills shift from technical execution to decision support focus • Emerging roles: 'systems engineering' and 'data scientists' • Increasing share of remote work • More complex problem-solving ability to anticipate and plan activities • Managing human-to-machine interfaces • Advanced systems development and integration
Processing	• Increase in advanced analytics and 'big data' applications – i.e., 'data scientists'
Transport	• Upskilling of operators to manage human-to-machine interfaces • Advanced systems development and integration – management of autonomous systems and shipping platforms
Trading	• Shift on operating model from mining based on volumes to quality and customer requirement focus.
End-to-end	• Dealing with increased complexity of planning, scheduling and advanced decision-making – complex systems management for end-to-end optimisation • Technical modelling and advanced geological and geo-spatial capabilities.

Data from the Future of Jobs Report (WEF, 2020) on job roles identified as being in high demand or increasingly redundant within companies from the mining and metals industries confirm the impact of the uptake of technological innovations (Figure 1). The analysis of the data clearly shows that technology-driven job creation in the raw materials sector won't

outpace job destruction over the next five years. And since tech job growth is limited by insufficient supply, this calls for urgent proactive measures to reskill and upskill workers, and to create bespoke maps which orient displaced workers towards new jobs where they will be able to thrive.

Figure 1 – Emerging and redundant job roles in the mining and metals industries (source: WEF, 2020)

The skills identified in the Future of Jobs Survey (WEF, 2020) as being in high demand in companies from the mining and metals industries, ordered by frequency, are listed in Table 4.

Table 4 – Skills in high demand in the raw materials sector in the near future (source: WEF, 2020 and Ernst and Young, 2019).

Order	Skill	Skill descriptor
1	**Active learning and learning strategies**	Understanding the implications of new information for both current and future problem-solving and decision-making. Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.
2	**Complex problem-solving**	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
3	**Analytical thinking and innovation**	Utilising iterative and systematic solution-based approaches to problem solving, and being able to consider something in a new way.
4	**Technology use, monitoring and control**	Ability to utilise technology platforms/systems to support decision making and participation in workplaces.
5	**Technology design and programming**	Generating or adapting equipment and technology to serve user needs. Ability to write computer programs for various purposes.
6	**Systems analysis and evaluation**	Determining how a system should work and how changes in conditions, operations, relating systems and the environment will affect outcomes. Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
7	**Service orientation**	Actively looking for ways to help people.
8	**Quality control and safety awareness**	Conducting tests and inspections of products, services, or processes to evaluate quality or performance. Establish and maintain procedures for identifying hazards, and assessing and controlling risks
9	**Leadership and social influence**	Managing effective teams and workgroups through change events in a systematic way to achieve successful personal transitions and desired future-state outcomes aligned with the business vision and strategy.
10	**Emotional intelligence**	Being aware of others' reactions and understanding why they react as they do.
11	**Attention to detail, trustworthiness**	Ability to efficiently allocate cognitive resources to achieve thoroughness and accuracy when accomplishing tasks.

Order	Skill	Skill descriptor
12	**Management of personnel**	Motivating, developing, and directing people as they work, identifying the best people for the job.
13	**Resilience, stress tolerance and flexibility**	Ability to maintain (or regain) functionality and vitality despite trouble or setback. Capacity to work under pressure or uncertainty without becoming negative (e.g. hopeless, bitter or hostile) toward self or others, and to adjust to changes without creating stress.
14	**Reasoning, problem-solving and ideation**	Ability to recognize problems, to appraise evidence and recognize the existence of logical relationships between propositions, and to find workable means for meeting those problems. Capacity to render accurate judgments about specific things and qualities in everyday life.
15	**Critical thinking and analysis**	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.

The analysis made in the Future of Jobs Survey (WEF, 2020) focused on the impact of digital transformation, and does not consider the environmental and social dimensions properly (for the raw materials sector). This is a relevant gap, since social and environmental factors are becoming crucial to extractive activities (WEF, 2017), and as extractive companies align activities with the Sustainable Development Goals[10], jobs linked to environmental performance, social responsibility and local community acceptance will be on demand in the near future.

It is worth highlighting that the mineral raw materials sector is embracing environmental, social, and governance (ESG) criteria, pushed by investors. Companies recognise the value of social engagement to their performance and their social licence to operate, and communities increasingly expect it, given its positive link to environmental and social performance, transparency and accountability.

On the environmental dimension, the uptake of artificial intelligence and automation is creating operational efficiencies that leave a much smaller footprint than before. At the same time, the social dimension has become crucial, and the industry is making efforts to obtaining the 'license to operate' from local communities. However, despite the wider recognition that creating real benefits for communities near mine sites will be key for successful new projects,

[10] From the United Nations 2030 Agenda for Sustainable Development, see https://sdgs.un.org/goals.

managing all of the competing priorities of the internal and external stakeholders is a challenge[11], and requires visionary leadership supported by robust stakeholders' support.

A summary of the skills-demand shift that is starting to affect employment in the mineral raw materials sector, encompassing also the social and environmental dimensions, is represented in Figure 2.

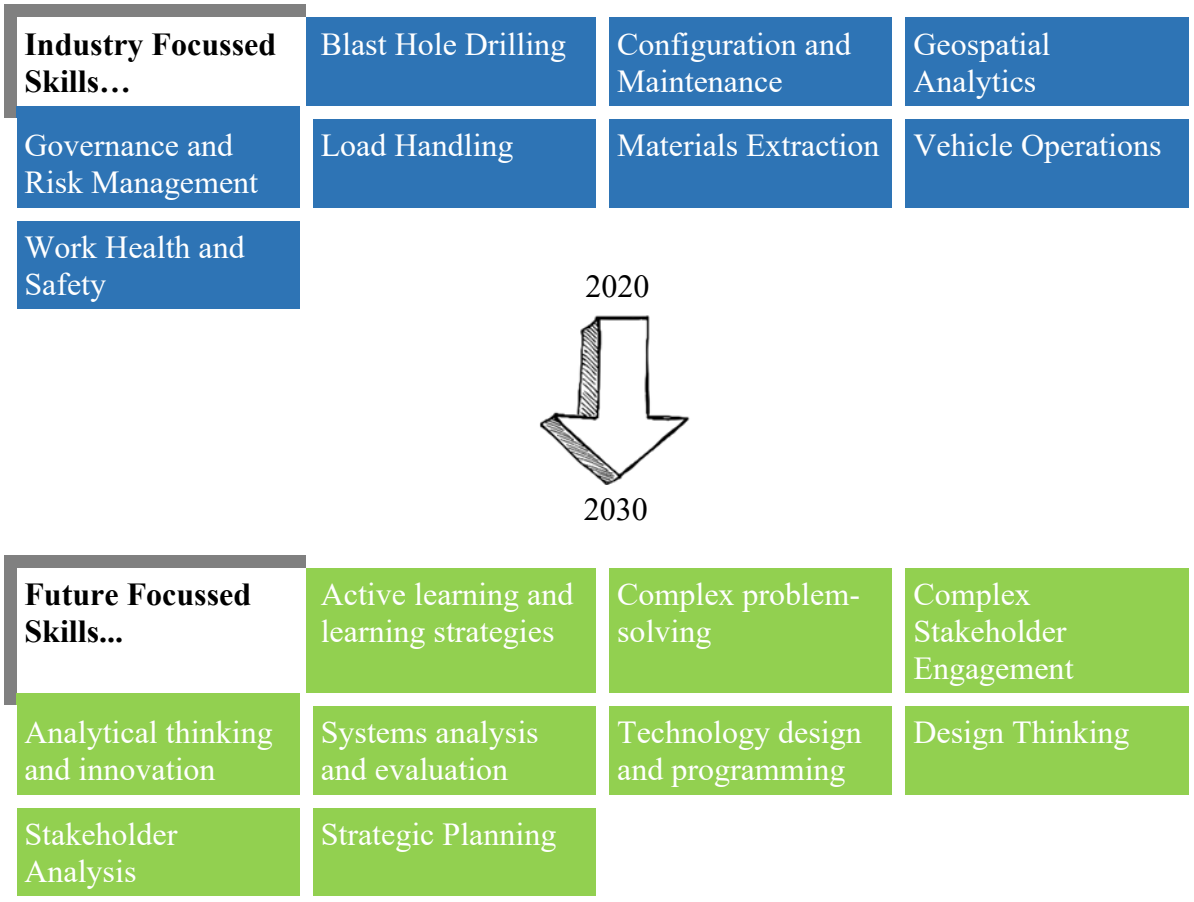

Figure 2 – Changes on skills demand in the mineral raw materials sector for this decade (adapted from Ernst and Young, 2019).

[11] In the case of mining, corporate governance includes treating all minorities fairly, aligning executive compensation with all stakeholders including workers and local communities, and creating strong policies and processes to combat corrupt practices (Burstow, 2020).

3. VISION FOR CLOSING THE SKILLS GAP

With increasing automation and a stronger focus on social and environmental performance, the contextual environment of the extractive industry is changing the required skills' mix of the workforce. Besides, the announced acceleration of the energy transition to tackle climate change, respond to the Covid-19 pandemic and reinvigorate the economy will dramatically change the amount and type of raw materials in demand. This entails a massive step-change in utilising and managing mineral raw materials, which requires the active involvement of a talented workforce. However, attracting new talent with the appropriate skills is difficult, since the raw materials sector is not in vogue with younger educated people[12]. Globalisation adds a layer of complexity to this problem, since the competition for talent is both global and between many different industry sectors.

In this framework, it is urgent to design and implement strategies to close the skills gap in the EU mineral raw materials sector. Tackling the problems and drivers that contribute to the skills gap and building a 21st-century workforce can only be made by developing a collaborative approach that would include European and national authorities and policymakers, the mining and recycling business communities and educational institutions and professional bodies. This role could/should be taken by the (about-to-be-created) international network of raw materials education and training centres, outlined earlier in this project (Correia, 2020).

This section assumes that cooperation is possible, and that the international network of raw materials education and training centres will be operational soon and will promote 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. If this assumption fails, the governance of the measures outlined below might be erratic or absent and would compromise the results.

3.1 Matching worker skills to available jobs

A comprehensive solution is needed to address the skills mismatch problem. First, it is necessary to define a qualifications framework that would be used as a reference point by both workers and employers. INTERMIN made an essential contribution to this aspect, by proposing an international sectoral qualifications framework for the raw materials sector (see deliverable D3.1), which establishes the foundational attributes that workers in the raw materials industry must demonstrate to succeed in the workplace at any skill level[13].

[12] Specially in Europe.

[13] Another example is using competency matrices to lay out what competencies are needed for what job. And as the work evolved and needs new competencies, add them to the master matrix so workers can see where their deficiencies are. European oil companies did some of this around 2010 to great effect. The rationale was technical skill change is ongoing and not usually a punctuated event. So, if the professional training matrix evolves in real-

An interesting example to mimic is the retraining done in the US of telephone lineman. The Sloan Foundation provided 20 million USD to the labour union for these workers to develop online training programs to retrain them from copper to optical fibre. The system was setup so that the workers paid a nominal amount for the training, and when they had all been trained, it amounted to about 20 million USD. The union repaid Sloan for the funds, and Sloan turned around and gave them another 20 million USD to start the training process to move for switched to IP systems. Because this was in sync with the labour groups, it was paced with the change in skill needs.

For workers in the raw materials sector, a sectoral qualifications framework lays the ground for informed choices on career paths by providing information on the range of knowledge and skills required to complete a job's particular level attributes (covering the knowledge, skills and autonomy/responsibility dimensions). Furthermore, a better self-assessment of skills and competencies and information on labour market needs helps workers maintain employability throughout their working lives and improves the uptake (and the outcomes) of education and training opportunities. One recent trend in the United States is having individuals work with employers, mentors, or educators to develop Individual Professional Development Plans (IPDPs), which map out goals, required skills and qualifications, and a scope and sequencing of development.[14] A critical motivator for promoting IPDPs is to empower workers to self-manage their careers, especially as fewer employers actively provide such supports, and technology is creating rapid changes in expectations for employees. For employers, a sectoral qualifications framework helps determine whether a person's qualifications are aligned with job requirements and enables comparisons of qualifications levels of different countries and different education and training systems.

Second, it is paramount to define the quality credentials of education and training courses (accreditation) that are valued by employers in the raw materials value chain. This would help universities and training centres align their courses and training programmes to the competencies required for industry-certified credentials[15]. There have been some attempts (still

time, the workforce can more readily adapt. For more information see https://www.spe.org/en/training/competency/

[14] The US is releasing the Vision and Change in the Geosciences report which was funded by the U.S. National Science Foundation, which outlines IPDPs as a critical action for building a stronger Workforce. https://www.americangeosciences.org/change

[15] In the oil & gas industry there is a good example on the benefits of accreditation programmes, provided by the International Association of Drilling Contractors (IADC), established as non-profit trade association in the USA in 1940. IADC offers a variety of accreditation opportunities for training institutions, providers and programs for both instructor-led classroom and computer-based courses, and IADC certified courses are recognised all over the industry, and help ensure quality assurance, consistency and standardization of training and continuing professional development courses. For more information see https://www.iadc.org/accreditation/.

restricted, despite being created more than a decade ago) to advance accreditation or certification schemes for geoscience courses. The most relevant examples are:

- In the UK, the Geological Society of London (GSL) offers an 'Accreditation Scheme for First Degree Programmes in Geoscience' to universities, that is valid for six years, aiming to link academic programmes with requirements of Fellowship and Chartered Geologist status. Fifty geoscience programmes/universities from the UK have this accreditation, alongside 5 universities from overseas[16]. The GSL also offers formal accreditation of companies training schemes, with the aim of enhancing the professional development of individuals who work in the field of geoscience. For the moment, 24 company training schemes have been accredited by the GSL (most of them UK based).
- In the US, ABET (formerly Accreditation Board for Engineering and Technology) accredits programs in applied and natural science, computing, engineering and engineering technology. ABET is a non-profit, non-governmental organization that groups 35 professional and technical societies, and it lists 22 accredited programmes/universities on geological engineering[17], two on mining engineering and one in mining technology engineering. For obtaining the ABET accreditation universities must demonstrate that graduates from their geoscience programme have the knowledge and skills to succeed in the workplace at the entry-level (for graduates). It worth pointing that ABET also accredits 100% online programmes (currently 24 programmes, most of them in IT areas)[18].
- In Canada, Engineers Canada (the national organisation of the 12 engineering regulators that license the country's 300,000 members of the profession) accredits Canadian undergraduate programs in engineering. It lists 35 accredited programmes on mining/mineral resources/mineral processing/geology. Students who receive a degree from an accredited geoscience programme meet the academic requirements needed to become licensed with Canada's engineering regulators. It worth pointing that in Canada it is mandatory to be registered at the provincial level with a regulator (professional organisation) in order to be allowed to work on geoscience professions.
- In Europe, the European Federation of Geologists (EFG) runs an endorsement programme of training courses that are considered relevant for continuing professional development of geologists. Participation in these training programmes is recognised as a relevant Continuing Professional Development activity[19].

[16] Two from Saudi Arabia, one from Oman, one from Hong Kong and one from Trinidad & Tobago.
[17] Some of the accredited university programmes are from outside the US: Escuela Superior Politecnica Del Litoral Ecuador), Istanbul Technical University and Middle East Technical University (Turkey), Universidad Nacional de Ingenieria (Peru) and Universidad Politecnica de Madrid (Spain).
[18] The capacity to accredit online programmes might become relevant as a consequence of the Covid 19 pandemics.
[19] Annual records of Continuing Professional Development activities are required to maintain the professional title (EurGeol) awarded by the European Federation of Geologists, which recognises the ability to deliver a high

- In Australia, similar roles to the above examples are carried out by Engineers Australia and the Australasian Institute of Mining and Metallurgy, with both organisations providing recognition and accreditation mechanisms for University-level and continuing professional development activities.

Third, educational institutions must be attuned to the labour market, collaborate with the industry and expand or modify programs when needed. The lack of good intelligence on industry labour needs and the corresponding skillsets prevents the definition of a truthful picture of the supply and demand for particular jobs, resulting in misdirected educational offers and shortages of workers for high-demand jobs. A possible explanation for the educational institutions' inability to overcome this combines two factors: a) educational institutions tend to be focused on education and not explicit training; and b) it takes real resources (people, time and money) for an educational institution to develop new courses that may not draw sufficient paying enrolment if the industry does downcycle or the area is superseded. Employers should also play a role in defining, evaluating, and hosting competency-based learning opportunities, such as apprenticeships and work-and-learn programs that complement formal instruction. In this context, universities and training providers already engaged in industry collaboration are better positioned to provide education offers that correspond to (the labour) market needs, and to develop effective learning methods that combine lectures with practical experience.

A common critic of accreditation programmes is that they tend to stifle innovation, and this a relevant shortcoming in the 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. Micro-credentials recognise employability skills and professional expertise on specific topics (normally 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 also by employers) for soft and hard skills, and subject areas are unlimited (a micro-credential can be awarded in anything, ranging from driving a dumper to creating a website). Despite the attractiveness of the concept, most people do not have a clear idea or have very 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 (Oliver, 2019), some of which might be credit-bearing (i.e. earn admission towards a formal qualification).

quality of services within the practice of geology. This is a common request of geoscience professional organisations that recognise chartered status across the world.

3.2 Boost STEM education

The digitalisation of the raw materials sector will increase the demand for science, technology, engineering, and mathematics (STEM) knowledge and skills. A tight labour supply of individuals with STEM competencies affects the raw materials sector disproportionally because it has to compete with appealing, fast-growing industries reliant on such skills. In this context, it is vital to increase children (and adults) interest in STEM topics.

Many western countries are making efforts to enhance STEM education, focused generally at primary and secondary education levels. Yet, STEM education can be promoted in all learning contexts, including formal (from preschool to university and workforce training) and informal (e.g. museum exhibits, television programmes and competitions)[20]. Exciting examples of increases in STEM learning associated with flexible and remote working conditions have been flagged in the US Midwest (Varsity Tutors, 2019). Other examples of STEM education led by industry players that have proved to be successful include the 'Mining Matters' programme in Canada, that uses prime quality educational resources (for students and educators, and for online and in-school activities) to educate young people to develop knowledge and awareness of Earth sciences, the minerals industry, and their importance to society. A similar initiative involving industry and government support can be found in the 'Oresome Resources' project[21] led by the Queensland Minerals and Energy Academy and involving organisations across Australia.

Educational resources and tools are relevant to improve STEM learning outcomes and justify the efforts being made in STEM education to foster the uptake of innovative technologies (such as serious games, virtual reality and gamification) in learning contexts. It is worth pointing that more robust STEM competencies increase the workforce's capacity for adaptation, making reskilling[22] and upskilling[23] efforts in the raw materials sector easier and more effective. For this reason, the raw materials sector push towards reskilling and upskilling of its workforce employers and academic/training institutions delivering courses on STEM topics.

[20] The Covid19 pandemic will most probably have impacts on STEM education. The push to move to online education is making educators design activities and exercises that are online-friendly. These might be more attractive to students because of the digital tools/capacities they use. The same is happening in industries across the world; forced to work from home, many workers had to learn how to take advantage of computers and communication apps, pushing forward STEM skills. Working from home also provide the flexibility that adults normally require from learning activities, and to take advantage of the many open educational resources available online as videos on HippoCampus.org and lessons on OERCommons.org.

[21] See https://www.oresomeresources.com/

[22] Typically, reskilling is a program that requires employees to be sent to a vocational education and training or higher education institution to earn a degree or certification in a different field.

[23] Upskilling focuses on improving worker's skills so they can work within the same job. Unlike reskilling, that requires to earn a completely new certification, upskilling will require an employee to enhance their value to his/her organisation by improving their current skill set.

Investing in STEM education is considered critical for the economic success of a country, because science and technology are considered the most relevant drivers of innovation capacities, playing a central role in the growth dynamics of successful economies. In the US, the 2013 5-year strategic plan for STEM education (NSTC, 2013) advanced by the Obama administration states *that for the United States to maintain its preeminent position in the world it will be essential that the Nation continues to lead in STEM*. The list of countries with a specific focus on STEM education includes Australia, Canada, China, the EU, Hong Kong, India, Singapore and the United States.

3.3 Strengthen public-private collaboration on education and lifelong training

A recent report from the World Economic Forum (2017) on the workforce reskilling points out that, despite the growing need for adult reskilling and upskilling, opportunities for broad-based lifelong training are currently not available at the appropriate levels of accessibility, quality and scale of supply in most countries. Despite recognising that progress has been made in the access to more significant amounts of low-cost digital training across many countries, the same report highlights that public and private sources of adult training and learning are often disengaged and lagging behind expectations of both individuals and businesses. To address this disconnect, it is crucial to bring together all the relevant stakeholders and to build bridges between formal, non-formal and informal learning.

Government actors are best positioned to coordinate all the stakeholders needed for setting an inclusive lifelong learning system, and to laying its infrastructure and regulatory foundations (WEF, 2017)[24]. One of the best examples of public-private collaboration to collect intelligence on skills' needs comes from Denmark, where the Danish skills anticipation system integrates a cohort of relevant stakeholders for compiling accessible and detailed information on labour market trends and skills demand for approximately 850 occupations (WEF, 2017). The approach ensures the involvement of sectorial and social organisations and guarantees high-level political engagement. The skills anticipation activities include (Skills Panorama, 2017): skills forecasting (e.g. statistical forecasting of education status and the demand and supply of labour in the public sector); skills assessments (e.g. quantitative sectoral assessments on

[24] This naturally assumes well organised and functioning societies. The example provided by the WEF (2017) is from Singapore, where the SkillsFuture Singapore Agency, the Workforce Singapore Agency, and the Employment and Employability Institute under the National Trades Union Congress help to identify key skills, develop training programmes and work with training institutions and employers to participate in workforce development through various measures such as funding.

imbalances in the labour market); skills foresight (e.g. sectoral assessments on future needs in the labour market); and employer surveys.

In Europe, CEDEFOP, the European Centre for Development of Vocational Training, is developing Skills-OVATE (Online Vacancy Analysis Tool for Europe)[25], an EU-wide tool that displays information from various national sources and vacancy portals, aiming to provide complete and detailed information on skills demanded at the national, regional and local levels. This is an unprecedented centralisation of information about real-time vacancies and skills demanded at the EU level, made available to inform career and vocational education and individuals and businesses' training decisions.

In Australia, there are several examples of public-private collaboration on education and lifelong training in the raw materials sector. Recent reforms to the VET system at a national level saw the creation of Skills Service Organisations for different sectors, with a mandate of researching what skills are needed; identifying and understanding current and emerging trends; revising qualifications and training programs to better match what people learn with the skills needs of industries and businesses; and providing the population the best possible chance of developing work ready skills. For the minerals sector this role is currently undertaken by PwC.[26] In addition, the Australian Government has also recently commissioned the Minerals Council of Australia (MCA) to run a Mining Sector Skills Pilot to coordinate a national vocational training approach for the sector[27].

In the United States, the Department of Labor supported the development of the 'Career OneStop' system[28], which brought together specific technology sectors (e.g. geospatial, power generation) to develop master skills pyramids to cover the forecast needs from entry level technician to corporate CEOs for each technical sector. These pyramids have been used by various NGOs to develop training and support networks and to build strategies for worker retraining and lane-shifting.

In short, for harmonising strategies to address the skills gap in the raw materials sector is crucial to work with businesses, worker unions, professional organisations, universities, training providers and government agencies, and to reconcile their views of skills' needs.

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[25] See https://www.cedefop.europa.eu/en/data-visualisations/skills-online-vacancies/online-job-advertisements-providers.

[26] See https://www.skillsforaustralia.com/industries/mining-and-drilling/ for detailed information on current skills and training packages.

[27] At the tertiary level the MCA has also recently supported through industry funding a number of individual projects focussed on alternative credentials. The Australian Research Council supports a public/private partnership program of Industrial Transformation Training Centres, which Universities submit competitive bids for in particular sectors with industry support. One example from the minerals sector is in the area of mine rehabilitation, involving a 5–7-year programme and several cohorts of PhD students working around particular themes, aiming to produce specialists who go on to work in the industry.

[28] https://www.careeronestop.org

4. ACTION PLAN TO ADDRESS THE SKILLS GAP

4.1 A global approach to addressing mineral-related skills gap

The minerals industry has adopted an increasingly global focus to its activities over the last two decades, both through the emergence of large multinational and diverse companies as well as through the activities of coordinating organisations such as the ICMM[29]. However, the area of human capital development through education and training 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.

The challenges highlighted in this and previous INTERMIN reports will require the involvement of many of the actors involved in these existing initiatives, and critically will require the ability to promote active engagement between industry, governments, professional bodies and education and training providers. As many of these groups are currently pursuing their own objectives in this space, and there are various legal and commercial aspects influencing current initiatives, this will not necessarily be an easy process.

There are several models whereby a collaborative network could be established. These could include the creation of a permanent forum, coordinated through a secretariat body which acts as a clearinghouse for member activity; the creation of a formal member-based organisation charged with responsibility for advancing the agenda of its members; or a looser distributed network with a commitment to supporting specific initiatives[30]. The sections that follow outline four principal initiatives that such a network should pursue. In designing such a network including any formal coordinating entity, early consideration should be given to the barriers that might exist in implementing such projects.

4.2 Main initiatives

Four main initiatives should be jointly considered for the implementation of the vision outlined in the previous section (Figure 3):

[29] International Council on Mining and Metals, an industry association that brings together the world biggest mining companies. For more information see https://www.icmm.com/

[30] On the possible options, see INTERMIN Deliverable 4.1 – Strategic Plan of the International Network of Raw Materials Training Centres.

1. Development of an across-the-board approach to employability skills in the raw materials sector (advancing a blueprint of core employability skills) coordinated across the employer and educational stakeholders;
2. Definition of the operational dimensions of quality credentials of education and training courses that are valued by employers in the raw materials value chain (attributes of standard-based credentials);
3. Strengthen cooperation between business in the raw materials sector and higher education institutions (HEI) and vocational education and training (VET) providers (business-led apprenticeships and intern programmes);
4. Reinforce public-private cooperation to enhance intelligence on labour market needs and develop consistent views on the immediate and mid-term skill needs, and how much is rapid training enabled vs. long-term education (lifelong learning pathways).

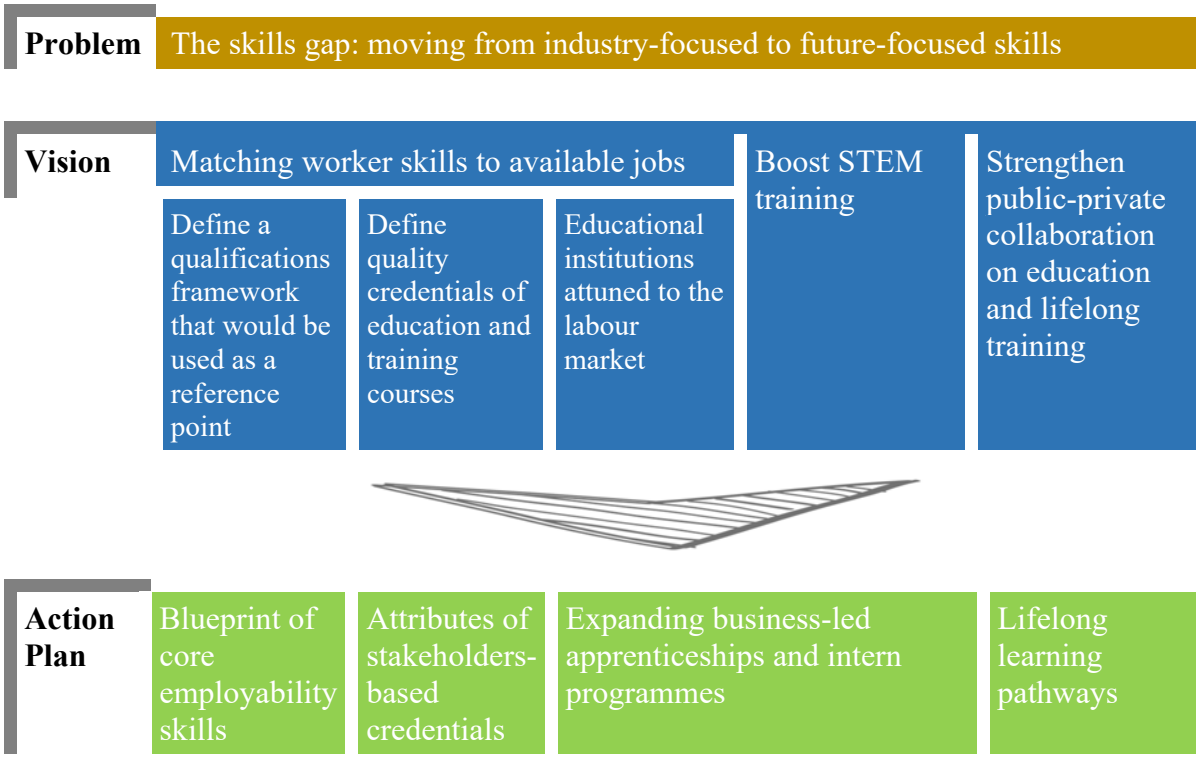

Figure 3 – Linkages between the vision and the four action plan initiatives.

It must be stressed that short-term benefits will accrue by upskilling and reskilling the active workforce through education and training opportunities that address current job market needs. Long-term benefits will occur if an improved education and training pipeline gives new

workers entering the job market a firm foundation for growth throughout their careers and existing workers a path for lifelong learning, so their skills and training remain up to date with changing workforce demands – the initiatives outlined below address both the short- and long-term perspectives.

The initiatives and the corresponding sub tasks defined below are aligned with the Strategic Plan of the International Network of Raw Materials Training Centres, detailed in the INTERMIN deliverable D4.1 (Correia, 2020).

4.2.1 Blueprint of core employability skills

This route considers the uptake of the raw materials sectoral qualifications framework and the roadmap on skills provisioning developed by INTERMIN (Correia *et al.*, 2019a) to start a dialogue on skills needs, educational and vocational curricula and educational programmes for the next decade with the most innovative industry representatives (e.g. Rio Tinto, Anglo American, Umicore), relevant universities and training providers.

This would enhance skills anticipation and the exchange of information and knowledge between raw materials' education and training centres, thereby encouraging and supporting value-creation, innovation and good practice. The international network of raw materials training centres could host these dialogues, acting in a fair and balanced way and ensuring that all parties are equally heard and respected.

The significant steps to progress on this route are: 1) the launch of an extensive consultation with the most relevant professional associations on the raw materials international sectoral qualifications framework developed by INTERMIN; and 2) the setup of a global network/discussion forum[31] encompassing the mining and recycling business communities, educational institutions, professional bodies and relevant government authorities to validate a blueprint of core employability skills for the raw materials sector.

Relevant milestones to access progress on this route are: 1) stakeholder mapping and global consultation performed; 2) first (draft) report on employability skills for the raw materials sector circulated between members of the global network/discussion forum.

4.2.2 Attributes of standards-based credentials

Credentialing systems are born from a source of authority on a topic. With the advent of new technologies, there has been an explosion of valid credentialing providers, often being the same

[31] It is unlikely that all the major business players would sign up to something that seeks to take control of the skills provisioning process, or even agree on a single competency framework. Still, it is assumed they would be interested in share and collaborate where it suits them.

organisation that developed the technology. Groups like Amazon Web Services and Microsoft have long built a credential process in support of their technologies. The critical component of these credentials' validity is the acceptance by third parties to their validity for employment. However, for fields where there are legal implications, such as for fiduciary, health, or public safety, governmental baselines are often established. In some cases, these baselines are enforced through licenses by a governmental organisation, such as those held by professional engineers, others are held as professional certifications awarded by recognised bodies of expertise in a field, such as for professional geologists.

For most license or profession-based credentials, the educational and training processes must adhere to core standards. For those derived from formal education, awarding of a recognised degree from a university might suffice[32]. For most credentialing systems, ongoing recognition requires continued education, usually provided by organisations who are members of the International Association of Continuing Education Training, which defines basic standards for professional development[33].

In the end, standards-based credentials are built on a system of verification of need, process, and competence. Training providers are assessed on their qualification to provide the educational process, either through an accrediting body of higher education or a professional education group like IACET (IACET, 2016). From there, the training must be aligned, accurate, and assessed. Commonly, credit has been given for active participation based on time-in-attendance. Increasingly, professional credential credits are being evaluated as competencies, driven by formal assessments or direct observations of an expert of a learner's application of the skill at issue.

The significant steps to progress on this route are: 1) the launch of a broad process of consultation on the quality assurance (QA) system for education and training in the raw materials area developed by INTERMIN (Correia *et al.*, 2019b), encompassing governments (country legislators and regulators), industry, unions, accrediting agencies and providers of education and training from different countries and regions; 2) advancing a reference system (to be adopted by the network members) to enable the mutual recognition of micro-credentials based on professional development units, such as Continuing Education Units (CEU[34]); and 3)

[32] Recognition of individual competency and skills across-borders without guidelines that can be used as a reference is problematic and hinders the mobility of people, ideas and knowledge. Acknowledgement of this reality pushed the start of the Bologna Process and the reform of the European Higher Education Area (EHEA), that began in 1999, and the creation of European Standards and Guidelines for quality assurance in the EHEA, encompassing the 48 countries of the European continent.

[33] Members of the International Association of Continuing Education Training are expected to be assessed on: 1) Organisation, Responsibility and Control; 2) Learning Environment and Support Systems; 3) Planning and Instructional Personnel; 4) Needs Analysis; 5) Learning Outcomes; 6) Content and Instructional Requirements; 7) Assessment of Learning Outcomes; 8) Awarding credit and Maintaining Learner Records; and 9) Evaluation of Learning Events.

[34] In the case of IACET one Continuing Education Unit (CEU) is defined as *ten contact hours of participation in an organised continuing education experience under responsible sponsorship, capable direction, and qualified instruction*. The primary purpose of the CEU is to provide a permanent record of the educational accomplishments

the allocation of the governance and management of the QA system for education and training in the raw materials area to an independent international agency dealing with education and labour – such as the International Labour Organisation (ILO) or the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Pertinent milestones to access progress on this route are: 1) validation of the quality assurance system for education and training in the raw materials area developed by INTERMIN by relevant accrediting agencies; 2) allocation of the governance of the quality assurance system for education and training in the raw materials to an organisation having appropriate experience and resources.

4.2.3 Expanding business-led training, apprenticeship and intern programs

Business-led training, apprenticeships and internships are hands-on, task-oriented learning programmes. Business-led training and apprenticeships are usually industry-driven and either framed by reskilling/upskilling efforts or by introducing programmes and admission schemes.

In the last years the industry has been pulling back on their training processes as it is considered a non-core competency expense. Companies are increasingly relying on external providers or employees pursuing the education themselves with the incentive of expected promotion or retention of employment[35]. Some companies are investing on this approach, and establishing learning infrastructures that allows individuals to curate their own material from a wide range of sources.

Apprenticeships are generally a full-term commitment for an extended on-job training period (one or more years), designed to relate classroom instruction and occupation. In some EU countries apprenticeships are common (e.g. Austria, Germany, Switzerland) and part of a high-quality apprenticeship system supported by the government. According to Lerman *et. al.* (2019) apprenticeship programs improve the learning process (as students directly apply what they learn), encourage student engagement, increase incentives for students to perform well in academic courses, improve the match between workers' skills and labour market demands, encourage employers to upgrade their mix of jobs, and widen access to rewarding careers for workers who prefer learning by doing over the traditional classroom and four-year college models. An apprenticeship credential documents a worker's competence in a profession and provides apprentices with a deep sense of pride when completing their programme. Despite these advantages, apprenticeship programs are not common in many countries (e.g. the US, south European countries), and this explains the European Union efforts to promote

of an individual who has completed one or more significant non-credit educational experiences (see https://www.iacet.org/standards/ansi-iacet-2018-1-standard-for-continuing-education-and-training/continuing-education-unit-ceu/about-the-ceu/).

[35] A possible solution to expanding business-led training is to change the ROI calculus – assuming that mastery of own skill/talent pool (in-house capabilities) is a strategic asset, overarching support for increasing profit.

apprenticeships through the European Alliance for Apprenticeships[36], a multi-stakeholder platform aiming at strengthening the quality, supply and image of apprenticeships in Europe and promoting the mobility of apprentices[37].

Internships are one of the most effective cooperative arrangement between industry and educational institutions. They tend to have a shorter duration, do not have any classroom instruction attached, and are typically designed for college/university students (college or university-driven) as they transition to the world of work. However, internships do not need to be only for students in formal education, and one can define three fundamental types of "internships":

- Traditional term internships where an individual is brought into a full work position, learning job skills to build on their prior education and training. This is often aligned with formal education programs or 'sabbatical' style continuing education efforts where extended full-time educational activities are ongoing;
- Micro-internships, as brief interludes of on-job training and experience, often for show periods (days to a week or two). These are run both for students but also internal to organisations where skill distribution is not even;
- On-loan tasks, where professionals are seconded to new roles/skill spaces for a defined period. This used to be a major way oil companies developed professionals by having multi-year rotations of individuals for a couple of months in different business units. Skill development was broadened, and the aptitude of the individuals for additional training is better identified.

A key challenge in managing internships is the placement process. Evaluating internship candidates and knowing what the best practices are for internships is a real burden for employers. In case the placement is international, obtain visa permits makes the process more difficult[38]. And for learners, the challenge is to discover internship opportunities and have a predictable process for identifying and applying for such opportunities. The development of an internship clearinghouse that supports both populations, as part of the international network of raw materials training centres, with the focus on developing at-need skills, is a major impactful opportunity[39].

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[36] See https://ec.europa.eu/social/main.jsp?catId=1147&langId=en.

[37] Many jobs in the raw materials sector do not need advanced degrees but need substantial training and experience (e.g. drillers, field collectors, soils and rocks lab technicians). And since there are no dedicated education pathways into these professions, most positions are filled with university graduates, who are both educationally overqualified and extremely underqualified in skills.

[38] Naturally, this is not a problem inside the European Union, but it is recognised as a problem that hinders the global search for talent. For this reason, visa rules for overseas students in Australia were relaxed some years ago to encourage a period of work in the country following graduation. Harmonisation of cross-border labour rules for learner-workers, such as interns, could greatly ease employer burdens and broaden the scope of opportunities.

[39] This clearinghouse could develop not only individual skills but also institutional skills and knowledge, as it happens in the US 'Vision and Change in the Geosciences' project funded by the National Science Foundation,

Many existing tertiary engineering programmes around the world require students to acquire a certain quantum of work experience prior to graduation. There are examples in the US, Canada and Australia of partnerships between industry partners and Universities, for example in the US where some companies will employ entire classes as interns during school breaks. These internships start in the first year, and are coordinated as part of the educational sequence. Examples include schools that had phasing of students to the Waste Isolation Pilot Project in their first summer, then to Yucca Mountain their second, all in cooperation with the US Department of Energy. Another example saw students placed with the State Highway Department working on roadbed issues the first summer, then with a private company working on surface water/run off issues their second summer. These were explicitly scoped and sequenced relative to the classes those students would have taken. In Australia, such engagement has extended to a semester spent on a research project while embedded within a mining operation.

Relevant milestones to access progress on this route are: 1) mapping of best practice on internships and apprenticeships in the raw materials sector completed; 2) setup of a clearing house supported by the global collaborative network/discussion forum for education and training in the raw materials area; 3) membership of the European Alliance for Apprenticeships.

4.2.4 Lifelong learning pathways

At the core of sustaining a robust raw materials workforce in a changing world is not just enabling retraining during the ongoing transition to new technology-driven modes, but to have a responsive system that promotes and values ongoing learning by workers so they can evolve with the industry.

As core standards already exist for CEU awards, and action is underway to better defining micro-credentials, a systemic approach is needed for the definition, management, and recognition of these products of life-long learning. Without consistent and persistent recognition of learning efforts by workers, it will disincentivise those workers to further evolve until an existential crisis arises for their employment becomes a serious problem, as witnessed in the current labour deficiencies. Actionable steps to sustaining lifelong learning to ensure a robust workforce and a valued worker over their entire career are:

that seeks employers interested in developing cooperative agreements with companies and agencies to enable faculty to work with them and for their employees to work with the academic programmes.

1. Definition of an industry-agreed competency matrix. A systemic approach to define not just what skills and competencies are within the scope of the field, but providing consistent definitions to ensure transferability and mobility. Such a matrix is not just for every worker, but rather, individuals would possess skills and competency with a scope of the matrix that aligns to their goals and employer needs.
2. Just as industries define data model and similar operational standards, either a single recognised entity or network of entities is needed that can maintain and cross-recognise learning credits, competencies, and credentials, including the need to grow or deaccession specific areas as the sectors needs evolve[40].
3. As sectorial needs evolve, structures such as committees or task groups need to be empowered to recommend changes to the scope and definitions of a competency matrix or credential recommendations.
4. Either a clearinghouse or data standard needs to be developed for the retention of learning/skills management/tracking that is independent of, but in coordination with employers, so that workers retain mobility between companies. Such a clearinghouse can then work to integrate across nations and accelerate worker international mobility within companies, especially when government licensure/reciprocity issues are involved.

Appropriate milestones to access progress on this route are: 1) launch of consultation with industry stakeholders on competency matrices; 2) allocation of the governance of the system for the cross-recognition of learning credits, competencies, and credentials to a single recognised entity or network of entities.

Key professional organisations in the minerals sector are increasingly focussed on the encouragement of lifelong learning, and the establishment of platforms and processes to support this. Recent developments have seen the launch of online 'Mining Academies' by both the Australasian Institute of Mining and Metallurgy (AusIMM; see https://www.ausimm.com/courses/) and the Canadian Institute of Mining, Metallurgy and Petroleum (CIM; see https://academy.cim.org/), offering their members opportunities to record Continuing Professional Development activities, and in some cases partnering with other organisations to deliver specialised courses. Simultaneously, mining and metals companies are implementing Human Resources and Organisational Development management systems that curate publicly available content and increasingly encourage staff to take control of their own development. The growth of global educational platforms such as Coursera or EduMine, alongside an increasingly diverse range of providers, are disrupting more traditional lifelong learning pathways.

[40] An example in the United States at the university level is the American Council of Education (ACE) which coordinates the transferability and comparability of college and university courses between institutions.

4.3 Implementation of the initiatives

This section provides details for the rollout of the four initiatives outlined. The key factors of each initiative are described in an information sheet, in a sequence ordered accordingly to their priority level. The description of the initiative and corresponding tasks includes the minimum time frame necessary to obtain measurable results, alongside the expected level of stakeholders' acceptance, the number and diversity of stakeholders, the estimated costs and expected benefits according to the preliminary evaluation. The description also includes a summary of the initiative, the expected results (outcomes), the synergies with other initiatives, the critical factors for success, the responsibility for implementation, key performance indicators to measure results and a 5-step implementation plan.

The cost estimates for each initiative are an approximation, prepared for budgeting and planning. The estimates are not accurate enough for firm commitment, and were made to provide a basis for budgeting, accordingly with the authors understanding of the scope and expense of what needs to be done. Assuming that there will be resource constraints of the international network of raw materials training centres, it is key to maximise the synergies of the initiatives, and to launch them in a sequence that maximises success and prevents shortcomings. In this context, the prioritisation of the implementation of the initiatives considers two criteria (Table 5):

1. The easiness of implementation of the initiatives (assuming that actions less complex, i.e. having higher acceptance and few and less diversified stakeholders, are easy/simple to implement); and
2. The benefit/cost ratio of the action (equivalent to the corresponding impact).

Table 5 – Definition of priorities for implementation (sequence) of actions according to their impact and easiness of implementation.

		Benefit/Cost	
		Low	High
Easiness of implementation	Easier	**Third**	**First**
	Harder	**Fourth**	**Second**

Table ranks the easiness of implementation of the initiatives and their expected impact. Table 7 presents the sequence (numbers order) of the implementation of the initiatives, considering the two criteria described.

Table 6 – Definition of easiness of implementation and impact of the initiatives.

Initiatives	Easiness of implementation		Impact	
	Acceptance	Stakeholders	Benefit	Cost
Blueprint of core employability skills			++	$
Attributes of stakeholders-based credentials			++	$$
Expanding business-led apprenticeships and intern programmes			+++	$$
Lifelong learning pathways			+++	$$$

Legend:

Stakeholders acceptance:	Antagonism		Indifference		Support	
Number and diversity of stakeholders:	Few and uniform		to		Numerous and diverse	
Cost:	Less than 1 million €	$	1 to 5 million €	$$	More than 5 million €	$$$
Benefit:	Somewhat effective	+	Effective	++	Very effective	+++

Table 7 – Definition of the sequence of implementation (priority levels – numbers in blue dots) of the actions selected.

		Benefit/Cost	
		Low	High
Easiness of implementation	Easier	Lifelong learning pathways 3	Blueprint of core employability skills 1
	Harder	Attributes of stakeholders-based credentials 4	Expanding business-led apprenticeships and intern programmes 2

4.3.1 Blueprint of core employability skills

Priority level: 1	Blueprint of core employability skills			
Timeframe for results	Stakeholders' acceptance	Number and diversity of stakeholders	Estimated cost (Euros)	Expected Benefits
18 months			1-2 M	++

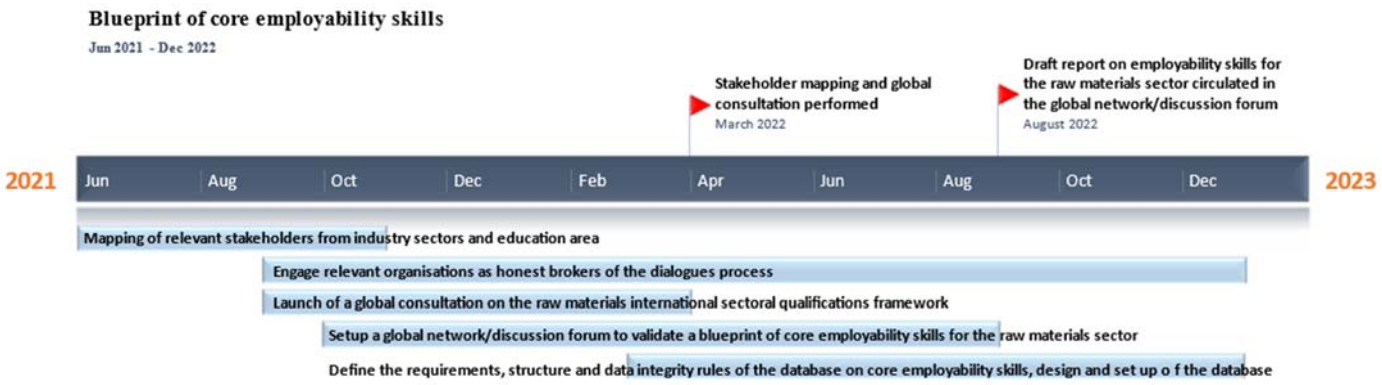
Summary	This initiative aims at starting dialogues on skills needs, educational and vocational curricula and educational programmes for the next decade with the most innovative industry representatives, relevant universities and training providers. The raw materials sectoral qualifications framework and the roadmap on skills provisioning developed by INTERMIN (Correia et al., 2019a) will be used to set up a reference context for the dialogues.

Key tasks	• Launch of a global consultation on the raw materials international sectoral qualifications framework developed by INTERMIN. • Setup of a global network/discussion forum to validate a blueprint of core employability skills for the raw materials sector.
Outcomes	A structured database on core employability skills for the next decade (for the raw materials sector) with information on knowledge, cognitive skills, practical skills, responsibility and autonomy by industrial areas/functions, aligned with the reference levels of the European Classification Framework.
Synergies	This initiative has obvious synergies with the initiatives on lifelong learning pathways and on business-led training and apprenticeships.
Critical Factors for Success	The most critical factor for success (CFS) is the engagement and active participation of relevant stakeholders in the dialogues process. Other CFS include the broad sectoral and geographical representation of stakeholders, and the governance/management of the stakeholders involved.
Milestones	1. Stakeholder mapping and global consultation performed. 2. Draft report on employability skills for the raw materials sector circulated in the global network/discussion forum.
Responsible	International Network of Raw Materials Training Centres.
Key Performance Indicators	• More than 25 stakeholders engaged per industrial sector (exploration/extraction and processing/materials engineering and recycling) and area (industry/higher and vocational education). • Launch of the first version of the structured database on core employability skills 18th months after the start of this initiative.

4.3.1.1 5 Step implementation sequence

1	Mapping of relevant stakeholders from industry sectors and education area.
2	Engage relevant organisations (e.g. UNESCO, SOMP[41], TG-GGP[42], IOM3[43], ICMM[44], BIR[45]) as honest brokers of the dialogues process.
3	Launch of a global consultation on the raw materials international sectoral qualifications framework developed by INTERMIN.
4	Setup a global network/discussion forum to validate a blueprint of core employability skills for the raw materials sector.
5	Define the requirements, structure and data integrity rules of the database on core employability skills, design and set up of the database.

4.3.1.2 Timeline



[41] Society of Mining Professors, https://miningprofs.org/
[42] Task Group on Global Geoscience Professionalism, https://tg-ggp.org/
[43] Institute of Materials, Minerals & Mining, https://www.iom3.org/
[44] International Council on Mining and Metals, https://www.icmm.com/
[45] Bureau of International Recycling, https://www.bir.org/

4.3.2 Expanding business-led apprenticeships and intern programmes

Priority level: 2	Expanding business-led apprenticeships and intern programmes			
Timeframe for results	Stakeholders' acceptance	Number and diversity of stakeholders	Estimated cost (Euros)	Expected Benefits
24 months			3-5 M	+++

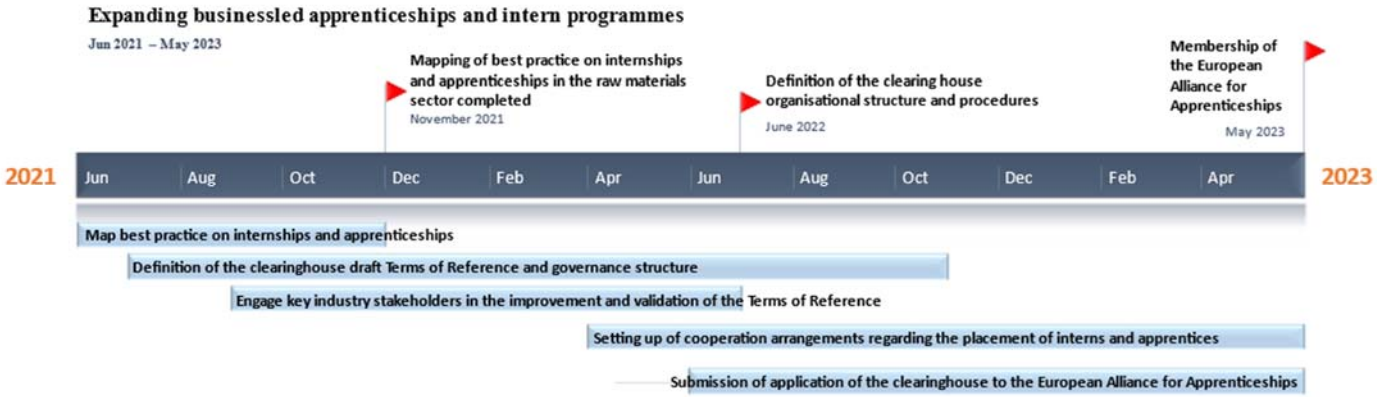
Summary	This initiative will establish a clearinghouse as part of the international network of raw materials training centres to provide information on internships and apprenticeships opportunities on at-need skills, supporting the placement process for both employers and learners.
Key tasks	• Definition of the Terms of Reference of the internships and apprenticeships clearinghouse. • Validation of the governance structure of the clearinghouse by the members of the International Network of Raw Materials Training Centres. • Setting up of cooperation arrangements regarding the placement of interns and apprentices with industry and providers of education and training from different countries and regions.
Outcomes	Streamlined placement processes for national and international internships and apprenticeships, leading to extensive employment opportunities.
Synergies	This initiative has strong synergies with the initiatives on the blueprint of core employability skills and on the attributes of stakeholders-based credentials.
Critical Factors for Success	The success of this initiative depends on the trust of the industry on the clearing house procedures and standards.
Milestones	1. Mapping of best practice on internships and apprenticeships in the raw materials sector completed. 2. Definition of the clearing house organisational structure and procedures. 3. Membership of the European Alliance for Apprenticeships.

Responsible	International Network of Raw Materials Training Centres.
Key Performance Indicators	• More than 20 industry stakeholders offering internships and apprenticeships opportunities through the clearinghouse. • First batch of internships successfully completed.

4.3.2.1 5 Step implementation sequence

1	Map best practice on internships and apprenticeships in the raw materials sector.
2	Definition of the clearinghouse draft Terms of Reference and governance structure.
3	Engage key industry stakeholders in the improvement and validation of the Terms of Reference of the clearinghouse and applicable operational standards.
4	Setting up of cooperation arrangements regarding the placement of interns and apprentices with industry and providers of education and training from different countries and regions.
5	Submission of application (of the clearinghouse) to the European Alliance for Apprenticeships.

4.3.2.2 Timeline



4.3.3 Lifelong learning pathways

Priority level: 3	**Lifelong learning pathways**			
Timeframe for results	Stakeholders' acceptance	Number and diversity of stakeholders	Estimated cost (Euros)	Expected Benefits
36 months			>5 M	+++

Summary	This initiative aims to develop a systemic approach for the definition, management and recognition of life-long learning products (encompassing the cross-recognition of learning credits, competencies, and credentials).
Key tasks	• Leveraging the blueprint of core employability skills to establish a standard definition of outcomes for learning efforts. • Establish standards for cross-recognition of skills and competencies developed through learning activities. • Establish a clearinghouse for credentials so workers can have authenticated, independent portfolio of credentials independent of their employer.
Outcomes	Workers will be empowered and value ongoing education and credential qualifying to ensure their long-term development is positively motivated for future growth, not reactionary to negative pressures of redundancy.
Synergies	This effort builds totally from the blueprint of core employability skills efforts, but provides sharper operational definitions.
Critical Factors for Success	Recognition by employers and licensors of credentials that align with this process, and increased motivation of workers to increase skills to develop new opportunities.
Milestones	1. Development of an operation set of skills and competencies across the spectrum of needs in the raw materials sector. 2. Definition of clear occupational spaces within the skills matrix and definition of training opportunities to enable success in that space. 3. Roll out of a credential management system.

Responsible	Ideally, the global collaborative network/discussion forum for education and training in the raw materials area? Until this network is established, the International Network of Raw Materials Training Centres.
Key Performance Indicators	• Successful operationalization of the blueprint by more than 25 stakeholders per industrial sector (exploration/extraction and processing/materials engineering and recycling) and area (industry/higher and vocational education). • Recognition of credentials transparently between more than 25 employers.

4.3.3.1 5 Step implementation sequence

1	Definition of an industry-agreed competency matrix.
2	Definition of standards for cross-recognition of skills and competencies developed through learning activities.
3	Launch of a global consultation on a standard definition of outcomes for learning efforts.
4	Definition of the draft Terms of Reference and governance structure of a clearinghouse for credentials so workers can have authenticated, independent portfolio of credentials independent of their employer.
5	Establishment of the clearinghouse for credentials with the support of key industry stakeholders.

4.3.3.2 Timeline

4.3.4 Attributes of stakeholders-based credentials

Priority level: 4	**Attributes of stakeholders-based credentials**			
Timeframe for results	Stakeholders' acceptance	Number and diversity of stakeholders	Estimated cost (Euros)	Expected Benefits
24 months			1-2 M	++

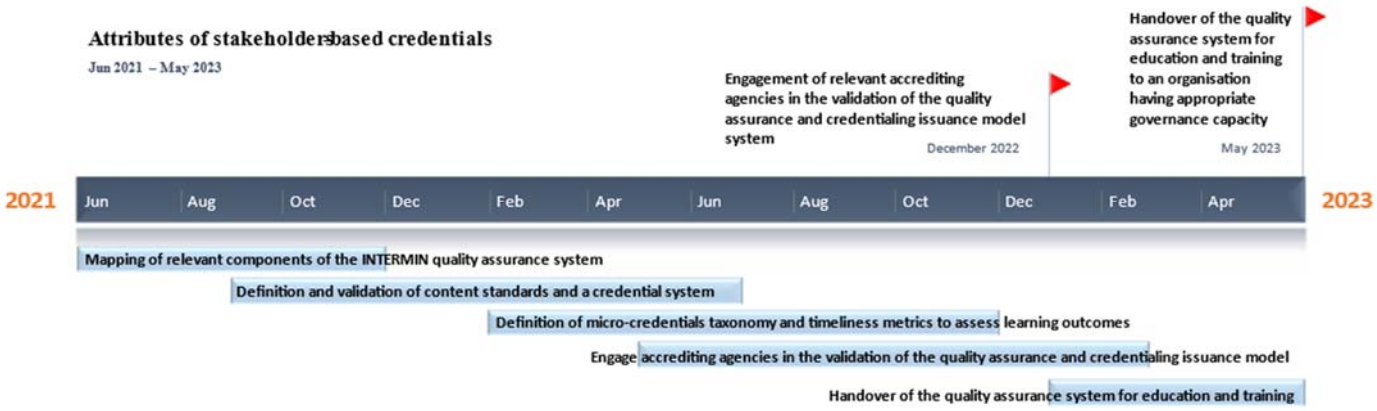
Summary	This initiative aims at advancing a reference system to enable the quality assessment and the recognition of qualifications across diverse education and training systems.
Key tasks	• Launch of a broad process of consultation on the quality assurance system for education and training in the raw materials area developed by INTERMIN.

	• Advancing a reference system (to be adopted by members of the international network of raw materials training centres) to enable the mutual recognition of education and training outcomes (based on acquired skills) certified by micro-credentials. • Allocation of the governance and management of the QA system for education and training in the raw materials area to an independent international agency.
Outcomes	Enhanced professional mobility in the raw materials sector, supported by a quality assurance system for education and training focused on acquired skills, that facilitates the permeability of learning paths between VET, general education and higher education.
Synergies	This initiative has strong synergies with the initiatives on lifelong learning pathways and on business-led training and apprenticeships.
Critical Factors for Success	Despite the high significance and applicability of stakeholders-based credentials in the raw material area, its success depends on its governance. The governance model advanced by INTERMIN (Correia *et al.* 2019b) assumes that the international recognition of training systems and outcomes (based on acquired skills) should be led by an independent international organisation dealing with education and labour.
Milestones	1. Engagement of relevant accrediting agencies in the validation of the quality assurance and credentialing issuance model system for education and training in the raw materials area. 2. Handover of the quality assurance system for education and training in the raw materials area to an organisation having appropriate governance capacity.
Responsible	International Network of Raw Materials Training Centres.
Key Performance Indicators	• More than 5 independent accreditation agencies engaged in the enhancement/validation on the quality assurance system for education and training in the raw materials area developed by INTERMIN. • More than 25 micro-credentials (in the raw materials area) recognised by at least 10 geoscience professional organisations from at least 3 continents.

4.3.4.1 5 Step implementation sequence

1	Mapping of relevant components of the INTERMIN quality assurance system, including accrediting agencies, providers of education and training and existing education and training programmes.
2	Definition and validation of content standards and a credential system that will provide a consistent structure to education and vocational training curricula.
3	Definition of micro-credentials taxonomy and timeliness metrics to assess learning outcomes (through acquired skills).
4	Engage accrediting agencies in the validation of the quality assurance and credentialing issuance model for education and training in the raw materials area.
5	Handover of the quality assurance system for education and training in the raw materials area to an organisation having appropriate governance capacity.

4.3.4.2 Timeline



5. CONCLUSIONS

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[46] 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. Concurrently, a stronger focus on social and environmental performance entails a massive step-change in utilising and managing mineral raw materials, changing the traditional skills' mix of the workforce.

In this context, it is urgent to close the skills gap in the mineral raw materials sector. The vision to attain this goal, which sets the background of the Action Plan, considers three priority areas:

1. Matching worker skills to available jobs;
2. Boost STEM training;
3. Strengthen public-private collaboration on education and lifelong training.

The Action Plan outlined in this document identifies four main initiatives that should be developed jointly to advance the above priority areas:

1. Development of an across-the-board approach to employability skills in the raw materials sector (advancing a blueprint of core employability skills) coordinated across the employer and educational stakeholders;
2. Definition of the operational dimensions of quality credentials of education and training courses that are valued by employers in the raw materials value chain (attributes of standard-based credentials);
3. Strengthen cooperation between business in the raw materials sector and higher education institutions and vocational education and training providers (business-led apprenticeships and intern programmes);
4. Reinforce public-private cooperation to enhance intelligence on labour market needs and develop consistent views on the immediate and mid-term skill needs, and how much is rapid training enabled vs. long-term education (lifelong learning pathways).

These initiatives have strong synergies and can start to bear fruit within two to three years. To facilitate the implementation of the four initiatives, the Action Plan details, for each one,

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

synergies with other initiatives, the critical factors for success, key tasks, expected outcomes, key performance indicators, milestones and responsibility for implementation. Lastly, a 5-step implementation plan, a timeframe and a cost estimation (for each initiative) provide a basis for budgeting (the total indicative budget of the Action Plan is 13 million Euros).

The critical aspect of the implementation of the Action Plan is its governance. The initiatives' rollout requires a collaborative approach that includes businesses, worker unions, professional organisations, universities, training providers and government agencies. It also calls for proactive efforts to reconcile views on different (but interconnected) topics such as skills' needs, credentials, apprenticeships, internships and lifelong learning pathways. This effort would be taken by the (about-to-be-created) International Network of Raw Materials Education and Training Centres, and its establishment is a crucially important factor for the success of this Action Plan.

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