From oil digger to energy transition enabler: the critical role of exploration geosciences education in Europe

Nils Jansson[1], Jukka-Pekka Ranta[2], Théo Berthet[3] and Leena Suopajärvi[4]*

Recent disruptions of raw material value chains during the COVID-19 pandemic have highlighted Europe's dependency on imports of metals and minerals. Meanwhile, the European Commission is establishing ambitious policy initiatives, aiming at making Europe climate neutral in 2050. In this contribution, we emphasise the critical role of geosciences education in this energy transition, in forming the next generation of mining professionals. In the Nordic countries, active industry–university collaboration in one of the most active mining hubs in Europe has allowed frequent student–industry interaction, access to real-life learning environments, and development of specialised educational modules. These have been made accessible to exchange students from other European countries via exchange programmes and innovative digipedagogical learning tools.

Les récentes perturbations des chaînes de valeur des matières premières pendant la pandémie du COVID-19 ont mis en évidence la dépendance de l'Europe vis-à-vis des importations de métaux et de minéraux. Entretemps, la Commission européenne met en place des initiatives politiques ambitieuses, visant à rendre l'Europe climatiquement neutre en 2050. Dans cette contribution, nous soulignons le rôle essentiel de l'enseignement des géosciences dans cette transition énergétique, en formant la prochaine génération de professionnels miniers. Dans les pays nordiques, une collaboration active entre l'industrie et l'université dans l'un des centres miniers les plus actifs d'Europe, a permis une interaction fréquente entre les étudiants et l'industrie, l'accès à des environnements d'apprentissage réels et le développement de modules éducatifs spécialisés. Ceux-ci ont été rendus accessibles aux étudiants d'échange d'autres pays européens via des programmes d'échange et des outils d'apprentissage digipédagogiques innovants.

Las recientes interrupciones de las cadenas de valor y comercialización de las materias primas durante la pandemia de COVID-19 han expuesto la dependencia de Europa en las importaciones de metales y minerales. Mientras tanto, la Comisión Europea está estableciendo iniciativas políticas ambiciosas, con el objetivo de lograr que Europa sea climáticamente neutral en 2050. En esta contribución, enfatizamos el papel fundamental de la educación en geociencias en esta transición energética, en la formación de la próxima generación de profesionales de la minería. En los países nórdicos, la colaboración activa entre la industria y la universidad en uno de los centros mineros más activos de Europa ha permitido la interacción frecuente entre los estudiantes y la industria, el acceso a entornos de aprendizaje de la vida real y el desarrollo de módulos educativos especializados. Estos se han hecho accesibles para estudiantes de intercambio de otros países europeos a través de programas de intercambio e innovadoras herramientas de aprendizaje digital y pedagógico.

Introduction

The European Union has an outspoken aim to become the world´s first climate neutral continent within 30 years. This will require more raw materials to unlock the full potential of cleaner energy technologies. However, even with scaled up recycling rates, today´s mineral and metal global production will be insufficient for production of technologies needed to phase out fossil fuels (Hund *et al.*, 2020). The establishment of European supply chains will thus be crucial in order to avoid replacing today's reliance on fossil fuels with dependence on imported raw materials. Meanwhile, Europe is the only continent where mining production has been declining since 2000 (Reichl and Schatz, 2019). This results in a growing dependency of metal import and an outsourcing of any environmental and/or social impacts from mining. Besides obvious ethical dilemmas, disruptions of metal and mineral supply chains during the COVID-19 pandemic has served to further highlight the limitations of this strategy in terms of building resilient societies.

[1]Division of Geosciences and Environmental Engineering, Luleå University of Technology, 971 87 Luleå, Sweden
[2]Oulu Mining School, University of Oulu, P.O. BOX 3000, FI-90014, Finland
[3]EIT RawMaterials North AB, 977 75 Luleå, Sweden
[4]Faculty of Social Sciences, University of Lapland, P.O. BOX 122, FI-96101, Finland
* niljan@ltu.se

Despite general geological appraisal for mineral potential in Europe and mining dating back to Neolithic times, exploration investments are currently low (***Figure 1***) and rates in mineral discovery and project development slow. In the Nordic countries, several advanced exploration projects have been halted by legislative or social factors rather than by traditional problems such as insufficient resources or technological challenges. Meanwhile, many geologists enter their careers in the exploration sector with little training in public affairs, despite commonly being at the forefront of the mining value chain.

In this contribution, we focus on the key role of geoscience education to increase the supply of minerals and metals within Europe with emphasis on three challenges: 1) providing geoscience students with the

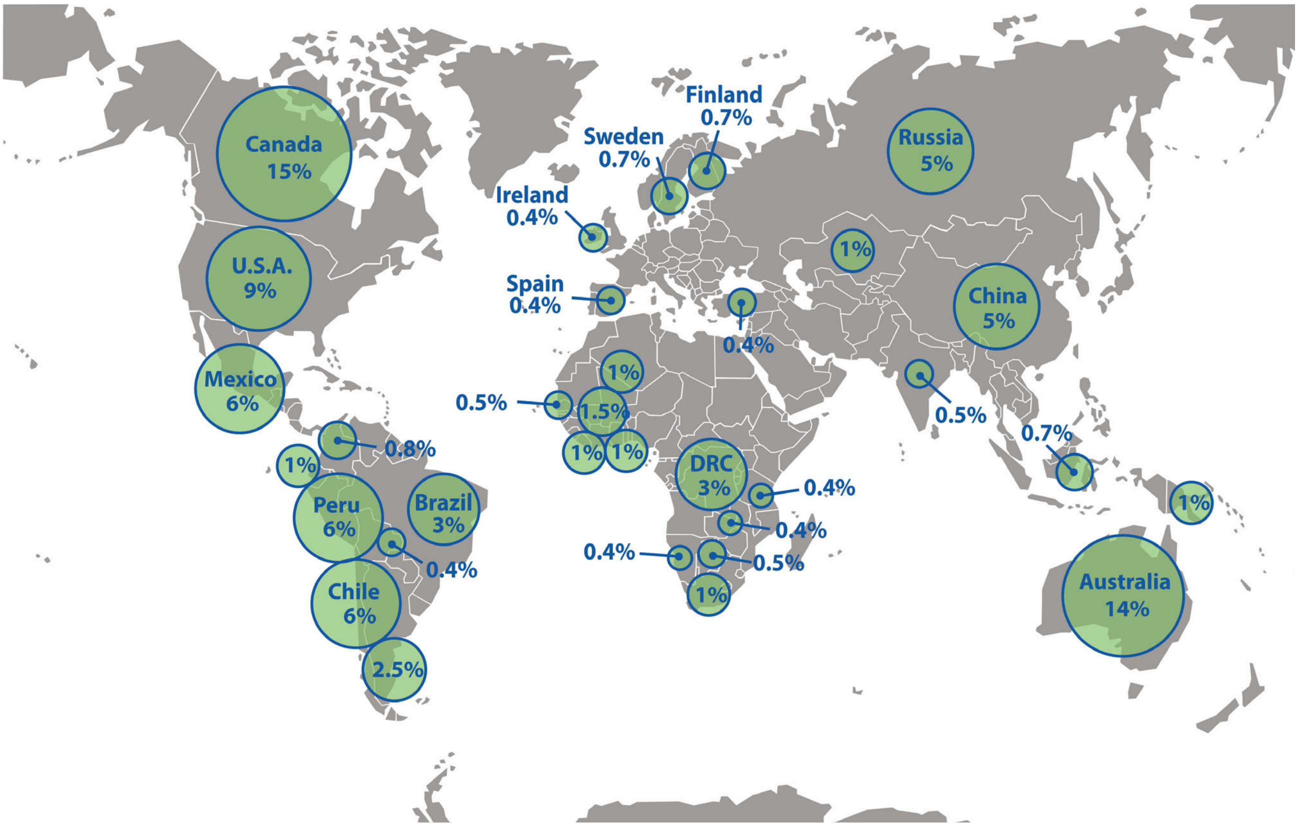

Figure 1: Global allocation of exploration costs in 2019 (excluding iron ore). Modified from Statistics of the Swedish Mining Industry (SGU, 2019).

hard and soft skills needed by the mining industry and society; 2) communicating the key role of extractive industry professionals for a responsible low carbon future; and 3) increasing the attractiveness of geoscience education by adapting curricula and pedagogic methods to a digital generation.

Supplying future mining and exploration professionals with skill sets that mirror actual needs

Historically, a main focus in geoscience education has been on subject depth and specialisation, and a key challenge has been to update curricula in pace with technological innovation and subject development. Whereas this strategy is still relevant for teaching students cost-efficient methods for target generation and resource delineation, it is insufficient for preparing students for the full spectrum of current challenges relevant in mineral exploration. This also include training students in the higher taxonomic level of Bloom (1956) – i.e. 'creating' and 'evaluating' – since mineral exploration requires its practitioners to integrate a wide range of geological and geophysical data, and design coherent geological models which can be used for target generation. This has become particularly important in recent decades, when a general depletion of easily accessible, shallow targets has forced exploration to go deeper, nowadays commonly being conducted at depths of about 1 km in established districts. The major uncertainties involved in extrapolation of mineralised units below cover or non-unique solutions to interpretation of geophysical data at depth furthermore requires its practitioners to weigh different, commonly conflicting datasets or interpretations against each other during targeting (Vidal *et al.*, 2013).

Further challenges arise from the application of the *modifying factors*, which are social, legislative, financial, environmental, processing and metallurgical factors that need to be resolved in order to convert

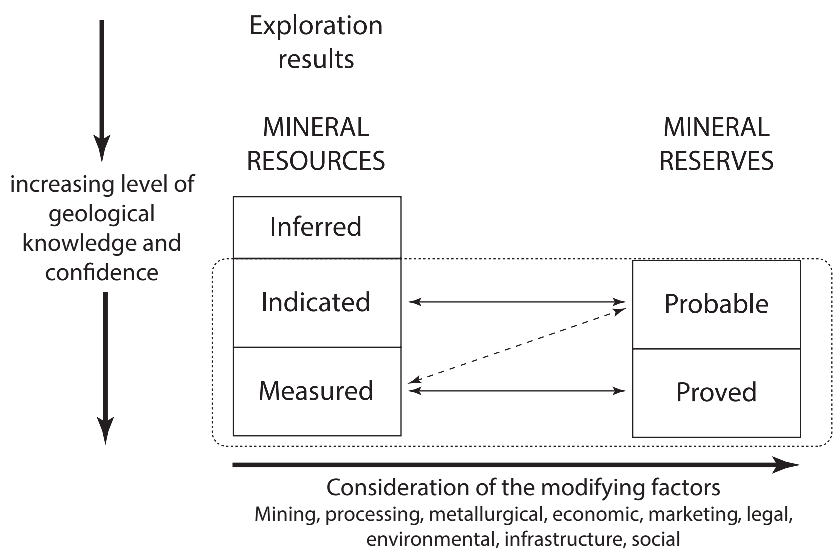

Figure 2: Diagram depicting the difference between mineral resources and mineral reserves according to the Joint Ore Reserves Committee (JORC, 2012). Conversion to mineral reserves requires consideration of all the modifying factors and solutions to any identified issues which would render mining sub-economic or non-feasible.

Figure 3: MSc students doing group excercises on legislation, social license to operate and modifying factors during a site visit to Kaunis Iron in northern Sweden in a Mining Geology course. The group included international students from two MSc programs in Exploration and Natural Resources Engineering at Luleå University of Technology, and the EXplORE and Emerald programmes supported by the EIT RawMaterials Academy. The background knowledge of students spanned a range from traditional earth sciences to process engineering.

mineral resources into mineable reserves (***Figure 2***). Mineral exploration and mining companies are not operating in a vacuum; the whole mineral sector is interlinked in a complex global system, despite operating locally. Understanding this context is crucial for geoscientists entering the business, as emphasised by a recent survey conducted by the EIT RawMaterials Academy, where the industry ranked "communications to stakeholders" as the first learning outcome desired in a master of science (MSc) programme in mineral exploration. Another illustration is lack of Social License to Operate (SLO), which continues to be the top risk for miners (Mitchell, 2019), referring to local acceptance of a mining project (e.g. Thomson and Boutilier, 2011). Geologists, field technicians and geophysicists are commonly the first people to interact with local communities in grass root exploration campaigns. Such interactions can either sow the seeds of fruitful collaboration or long-lasting opposition towards mining. Thus, a lack of basic understanding of the modifying factors at the early stage of exploration can lead to unnecessary costs or delays at a later stage, or even be fatal to project development (Thomson and Boutilier, 2011).

Medium to big mining companies generally have their own offices for social relations and corporate responsibility, but earning the social acceptance of local communities is the responsibility of each employee. This is especially the case in junior exploration companies operating with much smaller resources and workforce. Here, a greater responsibility is placed on the geoscientists, including frequent interaction with authorities, local groups, media and non-governmental organisations. From an educational standpoint, several themes need to be covered to prepare for such tasks: 1) jurisdiction, including stakeholder involvement in permit processes and social impact assessment (SIA) as a part of environmental impact assessment (EIA); 2) earning social license to operate, which includes strategies for corporate communication, stakeholder identification and engagement and corporate social responsibility (e.g. Jenkins, 2004); and 3) understanding current and future global drivers that may affect the operations of a single company as well as the whole mineral cluster.

An ideal arena for this type of training is multi-disciplinary student groups, working with assignments focusing on assessing exploration projects that have attained the pre-feasibility or definite feasibility stage (***Figure 3***). This will force students to think critically, not only about the quality of data and knowledge that go into resource models, but also about strategies to deal with the modifying factors (see ***Figure 2***).

Teaching this societal context of the mining and exploration sector requires multidisciplinary, constructivist collaboration between natural, technological and social sciences in the universities. Furthermore, the pedagogical approaches in courses addressing these topics need to be chosen carefully to maximise learning and to balance the time being re-allocated for these new subjects.

As an example, the course "Stakeholder engagement in exploration and mining", was held in the Oulu Mining School in 2019 as part of the EXplORE MSc exchange program. This course relied heavily on discussion-based learning, which promotes learning through interaction and communication with others (peer to peer). A theoretical lecture part was followed by discussion-based excercises in small groups and interactively with the teacher. Practical tasks were done at the end of the course, with each student having to prepare a Social Impact Assessment (SIA) or stakeholder engagement plan for an exploration project. Future development plans include: 1) a flipped learning approach with the theoretical part introduced via pre-lecture material (e.g. articles, books, videos) and 2) inclusion of the stakeholder point of view, e.g. via invited guest lecturers. This is important since a key point in stakeholder engagement is to listen to all different stakeholders, try to understand their views, and respect and balance differing, possibly opposing opinions.

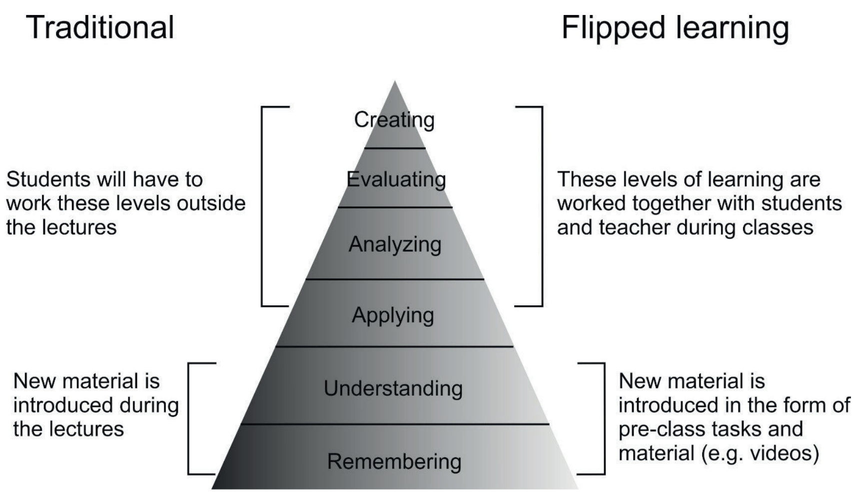

Figure 4: Bloom´s taxonomy (Bloom, 1956) related to the traditional lecture based teaching and the flipped learning method. Modified after Ouda and Ahmed (2016).

Figure 5: High-resolution, photogrammetric outcrop models generated using drones play a key role in the virtual course Applied Field Exploration generated in the EXplORE project.

Communicating the key role of mineral exploration in a low carbon future

The social license to operate problem is twofold, not only reflecting failure of companies in gaining social acceptance, but also failure in raising public awareness of the nature and importance of the mining value chain to society. As outlined in the introduction, the role of the mineral sector is becoming even more important and critical for several reasons. There are estimates that "many of the most important metals for human society may run into scarcity within the next decades" (Svedrup and Ragnarsdóttir 2014, p.277). A growing global population, growth of consumption and urbanisation are all factors that stress the importance of the sector, but this is not properly communicated, even to many students of geoscience. Since Europe and its citizens are to lead the way toward a low carbon future, supporting a supply of raw materials within the EU is necessary. It will not only enable the realisation of energy and climate targets with a limited environmental footprint but also avoid vulnerability to disruptions in supply chains and accelerate the technical innovation for decarbonisation of the entire value chain.

Increasing the attractiveness of geosciences education

Besides communicating the role of geoscientists in the energy transition, a critical point of geoscience education also lies in communicating a modern view of the mining industry and its key role in the transition to come. This involves changing public perception of mining as dirty, heavy work mainly carried out by men, to a technology-intensive and safe working environment characterised by increasing automation and digitalisation, and where gender equality is improving at all levels, albeit slowly (Duke, 2017). In the Nordic countries, this image change is currently being spearheaded by the industry itself, e.g. on social media, and ultimately, we foresee that this image change of the industry will attract more female students. Higher education institutions need to be more than just passive recipients of new students, but also contribute directly to this development. Even simple measures such as engaging female geologists in study visits to operating mines or exploration projects are valuable to meet these goals.

The challenges faced by our society and the mining industry need to be reflected in geoscience education. This also means adapting geoscience education to the needs of a digital generation of students and shifting pedagogical approaches from teaching-focused to learning-focused. The digital revolution has exponentially increased the possibilities for students to adapt and seek a vast amount of information related to the specific topics by themselves, allowing teachers to focus more on creating dynamic online learning environments. In the "flipped learning" approach, the theoretical material is introduced to the student before the lectures, for example as pre-recorded videos and reading assignments. The lectures/physical meetings are then interactive, where the students utilise the theoretical knowledge acquired pre-class in the form of tasks, peer-to peer teaching, problem-based groupwork and discussions. The role of the teacher in these physical meetings is to be a mentor and have more time to interact with the students in order to understand what are the difficult subjects and obstacles for the students that need to be addressed in more detail. Flipped learning has been found to increase learning compared to the traditional teacher-centred method (e.g. Mazur, 2009) and have been used in various disciplines, and published results include recently also geosciences (Huguet *et al.*, 2020). Hence, it is a more effective method for helping students to adance to the higher levels in the cognitive taxonomy of Bloom (1956; ***Figure 4***).

During the last few years and especially during the global COVID-19 pandemic, the rise of digital educational platforms (e.g. OreDepositHub) that offer webinars and workshops held by leading geological experts from around the world can and should be effectively exploited as an additional asset in the education, and are especially amenable to a flipped classroom approach. Innovative state-of-the-art research results are often presented in such web-based platforms, giving access to the newest information well before it might otherwise be added to higher education syllabi.

Seeing the actual rocks and outcrops in the field is one of the most important aspects of the past and future training of geoscientists. However, drops in the educational budget within many geoscience faculties have forced universities to reduce the number of field courses offered to the students. This is a serious loss for any education expected to meet the demands of the industry. Sweden and Finland host some of the most prospective areas in the world, albeit known deposits tend to occur in Precambrian, geologically complex areas with few outcrops. Exploration in these areas requires field skills in a number of disciplines, such as structural geology, stratigraphy, sedimentology, petrology and a understanding of hydrothermal alteration.

To help mitigate this issue, virtual fieldtrips – e.g. featuring remote sensing technology based data intergrated with 3D photogrammetry – offer a chance to visit field locations and mines globally without the logistical costs that traditional field courses involve (***Figure 5***). This type of virtual reality development in education is especially important in times of global crisis, e.g. COVID-19 where travel restrictions and social distancing have affected most if not all field education in Europe.

The EXplORE educational programme, funded by EIT RawMaterials, has specifically addressed these challenges by developing innovative teaching resources focusing on transmitting modern technical and social skills to students. These include a virtual field course using non-destructive technology, an online-based exploration targeting course, and course focused specifically on stakeholder engagement during exploration and mining projects. During the production of these teaching materials, Luleå University of Technology and Oulu Mining School have benefitted from being positioned within one of the most active mining sectors in Europe, operating within a strict and transparent jurisdictional framework, and ranking high with regards to technological innovation. Long- established collaboration with leading mining companies has allowed direct interaction and knowledge exchange with the industry and access to real-life scenarios, hence providing unique opportunities for course development and authentic learning environments. This has been particularly valuable for exchange students from other European countrieswhere mining and exploration is currently limited (see e.g. 2019 student and industry testimonies for the course Applied Field Exploration published at ***http://www.explore.agh.edu.pl/news_06_2019_field_exp_ltu.html***). For the course Stakeholder Engagement in Exploration and Mining, 91% of the students (N = 11) who responded to the course evaluation viewed the course as relevant to their future careers, and all responded that they would recommend the course to others.

It is debatable to what extent technologies such as photogrammetry, virtual reality, core scanning technology and remote sensing can fully replace classic exposure to active mine faces, drill cores and outcrops in education. Regardless, we believe that combining innovative digipedagogical with multidisciplinary approaches in learning environments close to the most active mining hubs in Europe is the key to meeting the demands and challenges for securing a future raw material supply in Europe.

References

Bloom, B. S. 1956. *Taxonomy of Educational Objectives. Vol. 1: Cognitive Domain*. New York: McKay.

Duke, S. 2017. The key to closing the gender gap? Putting more women in charge. World Economic Forum website. 2 November. ***https://www.weforum.org/agenda/2017/11/women-leaders-key-to-workplace-equality/***

Mitchell, P. 2019. Top 10 business risks and opportunities – 2020. Ernst and Young website. 24 September. ***https://www.ey.com/en_gl/mining-metals/10-business-risks-facing-mining-and-metals***

Hund, K., La Porta, D., Fabregas, T. P., Laing, T. & Drexhage, J. 2020. Mineral for Climate Action: The Mineral Intensity of the Clean Energy Transition. International Bank for Reconstruction and Development, The World Bank report.

Huguet C., Pearse, J., Noe, L.F., Valencia, D.M., Ruiz, N.C., Heredia, A.J. & Avedano, M.A.P. 2020. Improving the motivation of students in a large introductory geoscience course through active learning. *Journal of Geoscience Education*, 68 (1), 20-32. DOI: 10.1080/10899995.2019.1588489.

Jenkins, H. 2004. Corporate social responsibility and the mining industry: conflicts and constructs. *Corporate Social Responsibility and Environmental Management* 11, 23–34. DOI: 10.1002/csr.50

Joint Ore Reserves Committee (JORC). 2012. Australasian Code for Reporting of Exploration Results, Mineral Resources, and Ore Reserves (The JORC Code). 2012 Edition. The Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists, and Minerals Council of Australia. ***http://www.jorc.org/docs/JORC_code_2012.pdf***

Mazur, E. 2009. Farewell, Lecture?. *Science*, 323, 50-51. DOI: 10.1126/science.1168927

Ouda, H. & Ahmed, K. 2016. Flipped Learning as a New Educational Paradigm: An Analytical Critical Study. *European Scientific Journal*, 12(10), 417-444. DOI: 10.19044/esj.2016.v12n10p417

Reichl, C. & Schatz, M. 2019. World Mining Data, Federal Ministry for Sustainability and Tourism, Austria.

SGU, 2019. Statistics of the Swedish Mining Industry 2019. SGU Periodiska publikationer 2020:1, 1–88.

Svedrup, H.U. &Ragnarsdottir, K.V. 2014. Natural Resources in Planetary Perspective. *Geochemical Perspectives*, 3(2): 129–130.

Thomson, I. & Boutilier, R. G. 2011. The social license to operate. In: Darling, P. (ed.) *SME Mining and Engineering Handbook*. Third edition. Society for Mining, Metallurgy, and Exploration, Littleton, CO. pp. 1779–1796.

Vidal, O., Weihed, P., Hagelüken, C., Bol, D. & Christmann, P. 2013. ERA-MIN Research Agenda. HAL Id: insu-00917653. ***https://hal-insu.archives-ouvertes.fr/insu-00917653/document***