# Exploring the link between employer needs, employability and postgraduate module design in a contemporary mining education framework

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*Lower metal prices since 2013 and the current global COVID-19 pandemic have resulted in reduced industry workforce numbers and started a discussion and review of the link between employer and workforce needs, graduate skill sets, and postgraduate module design in mining education. Relating student satisfaction and employability to contemporary teaching practices is a key factor, driving the current UK Teaching Excellency Framework (TEF). Geoscientific, project management, and operational logistics-related skill sets are reviewed and put into context with industry employability rates and strategies as well as research-inspired teaching philosophies in Geoscience Higher Education, and exemplified by a case study outlining the development of a new module on the MSc programme Exploration Geology at Camborne School of Mines, University of Exeter.*

*La baisse des prix des métaux depuis 2013 et la pandémie mondiale actuelle de COVID-19 ont entraîné une réduction du nombre de travailleurs de l'industrie et ont amené une discussion et un examen du lien entre les besoins des employeurs et de la main-d'œuvre, les compétences des diplômés et la conception de modules de troisième cycle dans l'enseignement minier. Relier la satisfaction et l'employabilité des étudiants aux pratiques pédagogiques contemporaines est un facteur clé qui anime l'actuel Teaching Excellence Framework (TEF) au Royaume-Uni. Les compétences liées à la géoscience, à la gestion de projet et à la logistique opérationnelle sont examinées et mises en contexte avec les taux et les stratégies d'employabilité de l'industrie, ainsi que les philosophies d'enseignement inspirées par la recherche dans l'enseignement supérieur en géosciences, et illustrées par une étude de cas décrivant le développement d'un nouveau module sur le programme MSc Exploration Geology à la Camborne School of Mines, Université d'Exeter.*

*Los precios más bajos de los metales desde 2013 y la actual pandemia mundial de COVID-19 han dado lugar a una reducción de la fuerza laboral de la industria y han iniciado una discusión y revisión del vínculo entre las necesidades del empleador y la fuerza laboral, los conjuntos de habilidades de los graduados y el diseño de módulos de posgrado en educación minera. Relacionar la satisfacción y la empleabilidad de los estudiantes con las prácticas docentes contemporáneas es un factor clave que impulsa el Marco de Excelencia Docente (TEF por sus siglas en Inglés) actual del Reino Unido. Los conjuntos de habilidades geocientíficas, de gestión de proyectos y relacionados con la logística operativa se revisan y contextualizan con las tasas y estrategias de empleabilidad de la industria, así como con las filosofías de enseñanza inspiradas en la investigación en la educación superior en geociencias, y se ejemplifica con un estudio de caso que describe el desarrollo de un nuevo módulo. en el programa de Maestría en Geología de Exploración en Camborne School of Mines, Universidad de Exeter.*

## Introduction

In many countries, the mining industry is a key contributor to Gross Domestic Product (GDP), but the EU and UK mining sectors are less visible. Nonetheless, mining and geoscience graduates from the EU and UK are amongst the highest qualified and educated professionals worldwide (Jeffrey *et al.*, 2016), and commonly enter this sector working as graduate geologists for internationally-based exploration companies, service providers and consultants, or as environmental and land surveying specialists, and technical staff in mining and quarrying operations. Recent surveys in the mining sector of some countries have highlighted an ageing workforce and the requirement for 145,000 (Canada) and 37,347 (Chile) skilled and degree-educated workers (Swann, 2020). 'Mining' in Europe is commonly associated with difficult and remote working conditions, alongside a wider public environmental concerns, despite the promotion of sustainable production of raw materials within the EU (Tost *et al.*, 2016). Further, mining is a cyclical business (***Figure 1***) currently experiencing a major downturn related to the oversupply of products on the global metals market due to the COVID-19 global pandemic, slowing the production of metals alongside a temporary reduction in their demand (Aleksahhina *et al.*, 2020). Employment in the mining industry is considered a function of several socio-economic factors (***Table 1***), which can lead to reduced geoscientific staff requirements, redundancies, a negative perception of career prospects in the mining sector, reduced intake of undergraduate and postgraduate students, and reduced industry funding towards sponsored student activities at university. How can universities best prepare students to enter this industry? Burton (2016) suggests that to increase the chances of employability

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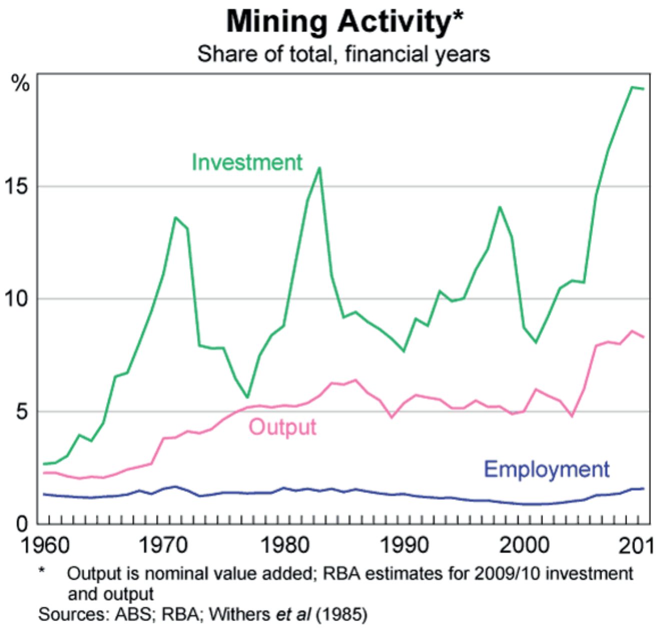


*Figure 1: Australian Mining Cycles 1960-2010 showing investment, mine output and mining employment (from: Connolly and Orsmond, 2011). UK and EU geoscience graduates seeking employment in the mining sector are affected by the global economic development, particularly in Australia, which is a popular first destination for many young professionals after graduation.*

universities should seek to expand the practical and applied skillsets of their geoscience graduates.

In this paper, we make a case that the development and improvement of skillsets, employability rates, and overall course module design are strongly linked with national educational guidelines, in this case illustrated by the UK's Teaching Excellence Framework (TEF). The TEF aims to assess and reward excellency in learning and teaching in Higher Education and to better inform students' choices about what is covered in their degree programmes, increase transparency in assessment and feedback of academic work, and improve the communication of industry's requirements to students. The TEF is also regarded as an instrument to promote the status of UK universities, which may have a direct influence on the financial status of degree programmes. We exemplify the link between the aforementioned factors and the conceptual design of a new 15 credits geoscience module, Exploration Targeting, on the recently established (2017) one-year, full-time (180 credits) MSc programme in Exploration Geology at Camborne School of Mines, University of Exeter, UK. The module runs over the course of 11 weeks, comprises 150 study hours, and aims to cover the practical and academic skills required by industry, improve the employment rates of graduates and support the delivery of research-inspired teaching, all considered to meet the expectations of TEF.

### Employer needs and skill sets in the mining and geological industries

A 2016 report by the World Economic Forum investigated the global impact of changes to business models and technological advances on the skillsets that are expected by industry from graduates in 2020. Gray (2016) summarises these fundamental changes as the 'Fourth Industrial Revolution' in which creativity and emotional intelligence will become ever more important whilst negotiation, flexibility and active listening will diminish from the list of required skills. Therefore, the ability to anticipate and prepare for those changes and related societal and employment-related effects will be key for governments and universities worldwide. For instance, as a result of the digital revolution and robotics, job losses might be predicted in administrative and machine assembly sectors, whilst job gains will occur in IT, engineering and sales (Gray, 2016). The report (World Economic Forum, 2016) concluded that social skills will gain importance over narrow technical skill sets, which as a consequence need to be supported by proficiency in collaboration. The need for specific technical, management and operational logistics skills differs throughout the life cycle of a mining operation (Jeffrey *et al.*, 2016), whereby the professional skillsets can be dictated by the scale of the operation as well as technical and administration processes within an organisation. For example, some competencies that have gained more relevance are the ability to work with, and manage, a multidisciplinary team (including geological, engineering and operational services professionals such as HR, procurement, public relations) along with leadership skills that are rooted in psychology and sociology (Swann, 2020) – e.g., ***Table 2***.

*Table 1: Socio-economic factors influencing employability rates in the mining industry.*

| *Factors influencing employability rates* | |
|---|---|
| ***Factor*** | ***Example*** |
| *Industry-cyclicity and macro-economic events* | *2008 Global Financial Crisis (GFC), 2020 COVID-19 global pandemic* |
| *Resource nationalism and governmental HR policies* | *Withholding of work permits can result in national shortages despite international oversupply of workforce and graduates* |
| *Availability of skilled staff* | *Predicted demographic and talent gap (Swann, 2020)* |
| *Discovery of new or revival of older mining districts* | *UK (e.g., SW England), Serbia and Balkan countries (revived interest in Tethyan metallogenic belt)* |
| *Scale of Operation and the 'Economics of scale and technology introduction' (Jeffrey et al., 2016)* | *Large (highly-skilled methods using complex technology) or small/ artisanal (low-skill methods)* |
| *Temporary workforce shortages* | *Large engineering projects consuming available technical staff and engineers (e.g., dam construction, China).* |

*Table 2: Specific technical and soft skills required in the geological and mining industries (Thompson and Hedenquist, 2016; Jeffrey et al., 2016; Tost et al., 2016; Swann, 2020).*

| *Geo-technical skills* | *Soft skills* |
|---|---|
| *a. Specific knowledge of advanced prospecting techniques in covered or transported terrain, along with the ability to operate 3D modelling packages that were not available in the 2000s.* | *e. Verbal and written communication skills that allow geoscience professionals to effectively convey a message not only to a team or management, but also to communities, governmental agencies and investors, and across multiple jurisdictions and cultures.* |
| *b. The ability to use proprietary and/ or pre-competitive governmental 'big data', often provided by geological surveys or data interpretation challenges (e.g. 'Frank Arnott Award'), such as using geochemistry and geophysics to interpret geology and the local and regional footprints of mineralisation systems.* | *f. The ability to foster a more inclusive workforce environment and to develop a practical understanding of diversity and community relationships in the workplace.* |
| *c. The ability to embrace but clearly understand the limitations of a range of new technologies and technological areas that have commercially appeared in the mining industry in the 2010s, such as commercially available drones in high precision mapping, artificial intelligence and simulations, automated engineering and remote mining applications.* | *g. The ability to recognise challenges and requirements in the mining industry and to proactively develop or provide solutions to these challenges.* |
| *d. An appreciation of a multi-disciplinary approach to mining and exploration, including an understanding of operational, logistical and health and safety aspects.* | |

Most countries with an established mining sector (or for whom mining contributes significantly to GDP) have specific mining-related councils, associations, and private research firms informing governmental institutions about the skillsets needed. In a study of mining education provision and skillsets, Jeffrey *et al.* (2016) evaluated surveys from a number of sources, including the Society of Mining Professors (SOMP), Education Commission of the International Mineral Processing Council (2008) and a mining engineering education survey commissioned by the International Institute for Environment and Development in 2000-2002. A key finding was that there had been a shift of applied BSc and MSc level course provision from North America and Western Europe to Eastern Europe, South America and SE Asia. In geosciences, professional associations, such as the Society of Economic Geologists (SEG), the Geological Society of London (GSL), or the Society of Geology Applied to Ore Deposits (SGA) regularly discuss and define the skillsets that are considered most important for recent graduates to possess. For example, as part of the GSL undergraduate and postgraduate accreditation scheme, the Geological Society of London have indicated their preference for degrees where students gain experience and insights directly relevant to chartership (Chartered Geologist, CGeol or Chartered Scientist, CSci), such as research methods and advanced instrumental techniques, communication and interpersonal skills, specialist disciplinary knowledge, quantitative interpretation and field skills and vocational awareness. Consequently, the directive from these groups is that graduates should have a solid foundation in natural sciences supported by reasonable fieldwork experience, i.e. transferable skills that can be employed in a variety of side-disciplines in postgraduate research and other geological industries (Thompson and Hedenquist, 2016). However, we recognise that some aspects of this skillset, not least those surrounding fieldwork experience, need careful scrutiny in the context of any adverse effect that this may have on inclusivity within the geosciences – fieldwork may not be accessible to everyone depending on their personal circumstances (e.g., Giles *et al.*, 2020). Overall, the specific ability to collaborate with other specialist disciplines and the awareness of automated data and engineering solutions, Health & Safety (HSE), environmental management and community relationships (CSR) are seen as key attributes of a modern geoscientist. Thus, the mining industry requires well-rounded geoscientists that are equally able to engage, communicate and negotiate with other stakeholders (Jeffrey *et al.*, 2016; Thompson and Hedenquist, 2016) and universities are encouraged to provide a multi-disciplinary undergraduate and postgraduate degree structure to mimic real-life scenarios as part of their educational layout.

## Research-inspired teaching and the development of skills-based educational modules

### *Fundamentals of research-inspired teaching*

In the 1990s, a link between research activity and teaching performance was highlighted and the synergies between both

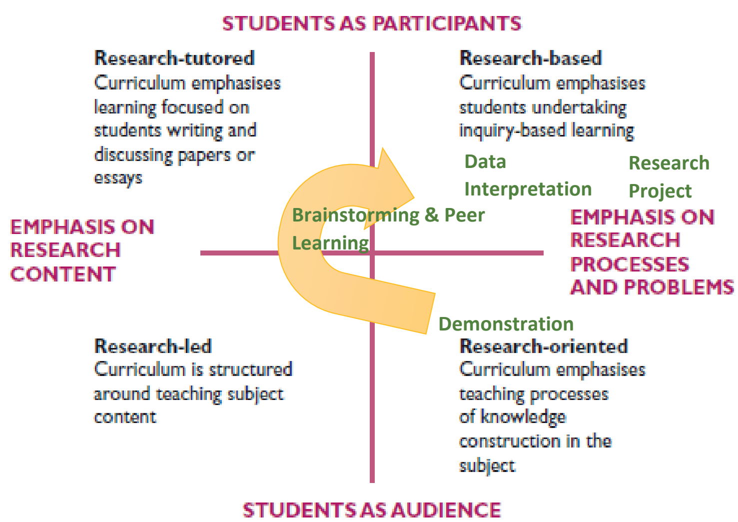


*Figure 2: Curriculum design and the 'research-teaching nexus' after Healy (2005), modified from Jenkins et al. (2007). See main text for further information on the teaching activities (green) developed in this illustration.*

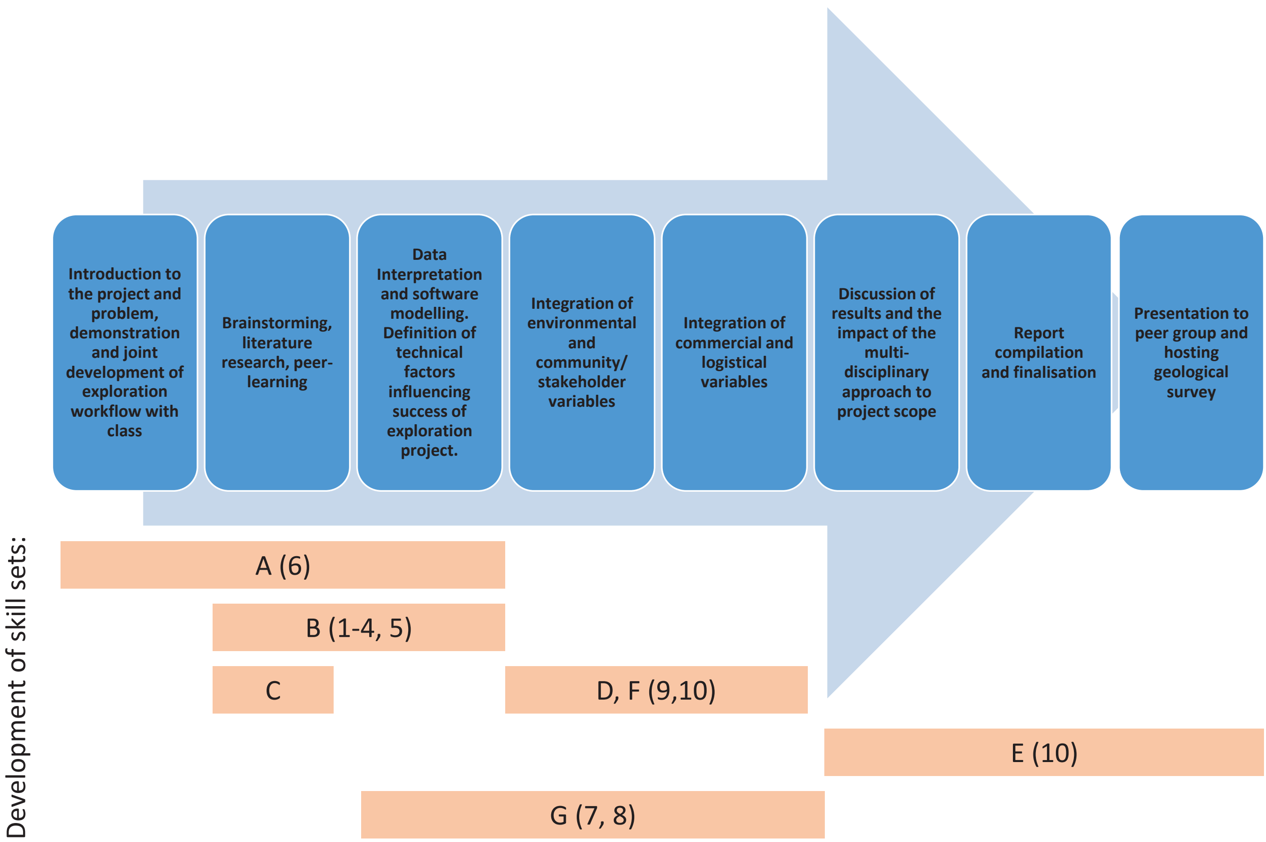


*Figure 3: Workflow illustrating the educational concept of the recently developed exploration targeting module. Skill sets and Intended Learning Outcomes (in numerical values, **Table 3**) are developed as part of a comprehensive research into a publicly available dataset and meet the requirements (in capital letters, **Table 2**).*

disciplines were discussed (Brew and Boud, 1995). Since then, academic institutions in the UK commonly assert that teaching and learning in higher education programmes are 'research-led' (Healey, 2005) and thus that research and teaching are mutually enforcing activities. The resulting 'teaching-research nexus' is therefore considered fundamental in higher education. Healey (2005) proposed that learners are likely to benefit most from research when they are involved in various forms of inquiry and problem-based learning, as exemplified by a number of UK geoscience departments actively offering project-based coursework and modules.

Healey (2005) and Jenkins *et al.* (2007) have developed an approach of inquiry-based learning that emphasises both research content as well as research processes (***Figure 2***). Students are considered as both audience and participants, and therefore are both passively and actively learning about research methodologies and outcomes. A move away from passive learning and instead embracing active learning by students being involved in research (i.e. enabling students to learn as researchers and contribute to and complement on-going research practices of the academic staff member) is preferred by the authors.

### *Case study: Design of the new module 'Exploration Targeting'*

In light of facilitating research-inspired taught postgraduate education and meeting the skillsets described previously, a highly applied MSc module was developed as part of the MSc in Exploration Geology at Camborne School of Mines. This seeks to develop sought-after exploration targeting skills by a combined provision of formal lectures, a residential field trip and a student coursework project.

### *Module Syllabus, Learning and Teaching Strategy*

As an MSc module, it is expected that students possess the necessary background knowledge of geosciences and academic working, for example, undertaking and evaluating literature studies, report and essay writing, and presentation of results to others (***Figure 3***). Coupled, the module targets a research-based learning approach (see ***Figure 2***, Jenkins *et al.*, 2007).

After an introduction to the concepts of exploration targeting, students attend a lecture outlining the aims, objectives, tools and methodology of the module, followed by a seminar discussion about the development of a tailored exploration workflow and a demonstration exercise showcasing current research carried out in this area. This is followed by the students working independently on a "Frank Arnott Award"-type public domain dataset obtained from the Geological Survey of Finland (GTK), which typically involves the compilation of a literature review and interpretation of geological, geochemical and geophysical data made available by governmental institutions. Importantly, socio-economic, financial and logistical aspects of designing and planning an exploration programme will be integrated so that students experience and develop an understanding of all angles related to a mining and mineral exploration project. Students therefore apply the research rationale presented during lectures and combine this knowledge in an individual study.

Team-based, and 'flipped classroom' learning approaches are incorporated in this teaching format. For example, online lecture material, which guides students through key concepts, is made available before introductory lectures. This material is then critically discussed in teams and applied to real-life geology scenarios. By using this educational method, students develop the ability to teamwork, critically assess and discuss learning material, and apply scientific knowledge to case studies.

After completing the research, students synthesise the available data in a work-authentic summary report describing the project outline, methodology, data interpretation and recommendations. The report also includes a critical evaluation of new target areas for follow-up studies. A verbal presentation (15-minute session) to a group of GTK experts familiar with the datasets aims to foster effective communication and presentation skills in an unfamiliar environment. Regular drop-in sessions and seminar-style meetings where students present their work in an informal setting form the formative assessment component of the course. These sessions also help the module leader to gauge overall progress and provide feedback and support.

*Table 3: Intended Learning Outcomes (ILOs) for the module 'Exploration Targeting'.*

| | |
|---|---|
| ***INTENDED LEARNING OUTCOMES (ILOs) (see assessment section below for how ILOs will be assessed)<br>On successful completion of this module the student should be able to:*** | |
| ***Module Specific Skills and Knowledge:*** | |
| *1* | *Understand advanced exploration methods, in particular GIS and spatial data handling and integration* |
| *2* | *Confidently use ArcGIS and ioGas software packages* |
| *3* | *Handle spatial data and generate maps, databases and interpretations for geological and general management* |
| *4* | *Understand how exploration targets are generated and interpreted from a number of spatial data sources* |
| ***Discipline Specific Skills and Knowledge:*** | |
| *5* | *Demonstrate a systematic understanding, and a critical awareness of the use of GIS for acquisition, analysis, interpretation and presentation of geo-scientific data relevant to the mineral exploration industry.* |
| *6* | *Apply a variety of exploration techniques in the targeting of mineral deposits. Sources of data will encompass literature, laboratory and field-based materials and information.* |
| *7* | *Synthesise and evaluate complex geological and socio-economic data, make sound judgments and communicate the results to others, along with an ability to make recommendations relevant to logistical and financial decision-making in the mining industry.* |
| ***Personal and Key Transferable/ Employment Skills and Knowledge:*** | |
| *8* | *Select and utilise a full range of online learning resources and software packages to analyse, synthesise and interpret data. This includes GIS and Remote Sensing software, academic papers, book chapters, discussion boards and online individual and group activities.* |
| *9* | *Demonstrate commercial and socio-economic awareness with regards to exploration techniques and exploration projects* |
| *10* | *Discuss complex geo-technical, financial, environmental and community-related issues, report on them and verbally communicate the results to others.* |

### *Development of skill sets*

A range of Intended Learning Outcomes (ILOs; ***Table 3***) were identified to involve the cognitive domain, i.e. the ability of the student to recall, apply and evaluate specific terms, methodologies and concepts. All skills were adapted to the 'soft' and geoscience-specific (geo-technical) skillset outlined above and supported by the lead author's personal experiences in the research methodology and knowledge of employers' needs. A summative assessment of the developed skillsets includes a 30- page targeting report (ILOs 1-10) as well as a verbal group presentation (ILO 10).

The design of this module satisfies the scientific and professional skills set out in Section 2 and ***Figure 3***. Based on a 'big data' exercise in covered terrain (A), students become familiar with the scientific concepts of researching and interpreting geoscientific datasets, starting from early literature searches to analysis, interpretation, spatial modelling and discussion of complex data of variable quality in the context of socio-economic and logistical factors (B-D). The production of an exploration targeting report, and the presentation of results to peers and industry professionals, support students to develop verbal and written communication skills and to gain confidence in developing products that can be presented to and evaluated by other professionals (E). Working in teams and learning about the culture and habits of other countries, in this case Finland, improves social and diversity awareness skills (F). Along with previous geoscientific considerations, this raises the awareness of challenges that the mining industry currently faces and requires students to consider and discuss possible scientific and socio-economic innovations (G).

This research-inspired approach to teaching not only prepares students for a role in postgraduate research, but it also has opened doors for graduate employment in the international mining industry. Particularly important in preparing students for future work in a multi-disciplinary environment, where geologists are required to seamlessly fit into a corporate structure characterised by multiple technical and support disciplines, is the ability to work with 'big data' – understanding trends in complex datasets and relating these to geological processes – and to integrate socio-economic and logistical aspects in a professional report. In addition, students are able to recognise the limitations of data and interpretation techniques as well as appreciate the non-geological aspects of a working environment, thereby developing into responsible members of the wider geoscience and professional community. For this reason, we suggest that a 'gold standard' in designing modules for vocational MSc programmes should be based upon a research-inspired teaching approach, integrating core geoscientific concepts with practical considerations and requirements of the geological employment sector, enabling students to develop a better understanding and awareness of scientific and professional skills alike.

### Conclusion

Key factors, such as employer and skillset requirements, employability rate, research-inspired learning and teaching philosophies, and student satisfaction are considered essential in postgraduate teaching module design. Applying a research-based teaching format based on the model of Jenkins *et al.* (2007) with reduced lecture hours and increased self-study and research time is considered an appropriate approach to communicating important advances in geoscience research methodology applied to an industrial setting. We have undertaken a review of these factors and used the case study of designing a new MSc-level module in the geosciences and mining disciplines to demonstrate one example of an effective route. This paper has shown that the Jenkins *et al.* (2007) model can be used to support the inclusion and development of multi-disciplinary skillsets, as required by employers, professional associations, and industry, leading to an improved geoscience curriculum.

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