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Let's become geologists! Challenges and opportunities in geoscience education in Europe

Contents

We would like to express a particular thanks to all those who participated in the peer reviewing of this issue and thus contribute to the improvement of the standards of the European Geologist Journal. The topical articles of this issue have been reviewed by Renata Brezinscak, Ollie Bonham, Vitor Correia, Pierre Christe, Ferenc Mádai, János Földessy, Gareth Ll. Jones, Andreas Hoppe, Máté Osvald, Joan Poch, Péter Scharek, Mónica Sousa, Pavlos Tyrologou, and Federica Zaccarini.

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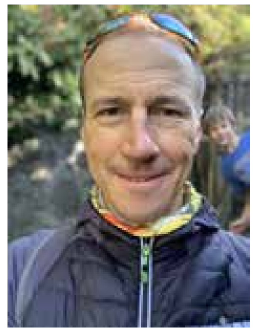
Foreword

EurGeol. Marko Komac, EFG President



Dear Reader,

Welcome to the 50th issue of the *European Geologist* journal! It's a great honour to present you with this anniversary issue that reminds us of the productive past of the journal, looks at the same time into the future of the challenges our profession faces and offers several good approaches on how to address them.

The topic that we're covering in this anniversary issue is the education of a mainly young(er) generation, but not only them. In addition to very formal approaches proposed there are also some less formal and innovative solutions that enable long-life learning processes for all of the geoprofession groups. All of these are presented in the seventeen articles accepted for this issue, ranging in two educational dimensions and one domain – the first covers various age groups, the second covers various techniques, from more traditional to purely digital approaches, and the third covers the domain challenges where more strategical questions are addressed, such as the needs of industry, geotourism, professional stereotypes and future areas of profession. As you'll surely notice, there's a clear link to the consequences of the current COVID-19 pandemic and the restrictions related to it. Although this has profoundly affected social and live/personal interactive processes, partially also in a negative way, still the community has responded innovatively and approaches presented in the latest EGJ represent an excellent example of the application of virtual and online tools using hybrid or completely digital means of knowledge transfer. I'm strongly convinced that the focus groups of the novel, ingenious and well-thought-out solutions presented in this issue will show that geoscience education and the profession as a whole have a bright future and many good things to offer to the society in the coming decades.

In the name of the *European Geologist* journal's Editorial Board, let me warmly thank the outgoing EGJ Editor-in-Chief, Professor Éva Hartai, PhD, who's been one of the key protagonists of the rebranding of this publication from a magazine to a scientific journal and the strongest pillar of building its good reputation. Her contribution to the geoscience community's outreach and its proper dissemination of knowledge has had and will continue to have a strong and long-term impact on our scientific community. For this let me again thank our esteemed colleague for her valuable legacy and her devoted volunteer work that sets very high standards for all geoscientists. Thank you, Éva!

Dear reader, I sincerely hope that the 50th issue of the *European Geologist* journal will be as interesting, stimulating and mind-opening to you as it was to me. Enjoy reading it and learning new things along the journey!

Marko Komac

Farewell message

by Éva Hartai

Dear Colleagues and Readers,

The 50th issue of the *European Geologist* journal is memorable for several reasons. It is an anniversary publication which has the most contributions in its history, and personally for me, it is the last issue I manage as the Editor-in-Chief.

I began in this position in 2011. As a voluntary activity, it allowed me to connect to colleagues from all over the world and benefit from communicating with people from a large variety of nations and cultures.

It was an amazing experience being in this position. I appreciate the opportunity to have worked with layout editor Anita Stein, copy editor Robin Lee Nagano, members of the EGJ Editorial Board, the EGJ Reviewers Board and the entire EFG staff. The enthusiasm and the extreme preciseness and thoroughness of Anita and Robin truly motivated me to do my best.

The experience I gained while working for the *European Geologist* is invaluable. I had an opportunity to develop and use my skills in communication, organisation and coordination. I also learnt to understand an audience, its needs and interests. During the past nine years, our journal has developed from a magazine to a recognised, peer-reviewed, professional periodical which provides a platform for geo-professionals in Europe to share their knowledge. With our thematic issues, we have been able to touch a wide range of fields, from sustainable land use through mineral raw materials and energy transition to geological heritage.

It has been a privilege to work in this environment, and it was my honour and pleasure to be the Editor-in-Chief in the past nine years. This anniversary issue is a good occasion for me to resign and give the floor to younger generations. With that, I leave the journal in the very competent hands of the new Editor-in-Chief, Pavlos Tyrologou.

Coming out of such an inspiring working environment, I want to thank the authors for their valuable contributions and the readers for their interest and positive feedback. I am proud to have been the Editor-in-Chief of this publication.

Good luck to everyone,

Éva Hartai - the crucial source of energy for EGJ

by the Editorial Board of the European Geologist journal

The *European Geologist*'s long-time Editor-in-Chief, Honorary Professor Éva Hartai, has decided to "give the floor to younger generations", as she put it herself.

For almost ten years now, Éva has always been the crucial source of energy in transforming the European Federation of Geologists' bi-annual *European Geologist* from a "magazine" to a "journal", as we know it today. Looking back to where we started, it is evident that it has been a long and strenuous process to reach the point we are at now, after the publication of 18 issues coordinated by Éva Hartai.

After taking up the position of Editor-in-Chief in December 2011, Éva ensured that in the future all issues of *European Geologist* would be thematic, linked to the activities of EFG's Panels of Experts. Since May 2013, articles have been peer reviewed as well as being checked by a copy editor for linguistic and formal consistency; these measures have contributed to the higher standards of the publication.

During Éva's term as Editor-in-Chief, a new section on "EFG Member initiatives" was introduced. It features short articles about the EFG National Association's initiatives that promote geosciences to society. As European Union projects began playing an increasingly important role in EFG, another new section was established to showcase projects it is involved in.

Considering the changes in the character of European Geologist (thematic issues, guidelines for contributors, articles being peer reviewed and proofread by a linguist), Éva's endeavour to rebrand the former magazine into a journal, starting from May 2012, was fully appropriate, as it meant a higher quality publication with more attention to scientific aspects. Since May 2017, all articles receive DOI numbers, which has contributed to raising the journal's reputation and broadening its readership.

In close collaboration with the EFG office, a major effort was also made to increase the journal's visibility and enforce the digital transition. In addition to the journal's online reading mode, which has been available since October 2010, from May 2016 all articles are also published on their own webpages. This improves their electronic readability and allows them to be shared more easily via EFG's digital communication tools, including social media and the weekly newsletter *EFGeoWeek*, which was launched in January 2017 with the aim of boosting the outreach of *European Geologist*.

For all of us in the EFG family, it will be hard to see Éva leaving the position she has been running successfully throughout the years. Maintaining the standards she put in place during the past decade will be a challenge.

Thank you, Éva, for your effort over all these years! Your devoted work really made a difference!

Service learning in geoscience education

Marta Mileusnić*

Service learning (or community-based learning) is an educational approach that combines learning objectives with community service in order to provide a pragmatic, progressive learning experience while meeting societal needs. Students apply the structured knowledge and skills acquired in the academic course while developing a project that deals with a specific social problem while working in a team. In this article, characteristics of a good service learning syllabus and methods for student evaluation are discussed, the roles of students, teachers as well as external partners are described, and the benefits and challenges of this teaching method are listed for the field of geoscience education. Although this approach is more common in social studies curriculum, geosciences have a broad range of suitable topics, some of which are given as examples.

Le Service-Learning (ou apprentissage communautaire) est une approche éducative qui combine les objectifs d'apprentissage avec le service communautaire afin de fournir une expérience d'apprentissage pragmatique et progressive tout en répondant aux besoins de la société. Les étudiants utilisent les connaissances et les compétences structurées acquises dans le cours académique en développant un projet qui traite d'un problème sociétal spécifique et en travaillant en équipe. Les caractéristiques d'un programme de Service-Learning efficace et les méthodes d'évaluation des étudiants sont discutées dans cet article. Les rôles des étudiants, des enseignants ainsi que des partenaires externes sont également décrits et les avantages et défis de cette méthode d'enseignement sont répertoriés pour le domaine de l'enseignement des géosciences. Bien que cette approche soit plus courante dans les programmes d'études sociales, les géosciences ont un large éventail de sujets appropriés, dont certains sont donnés à titre d'exemple.

El aprendizaje - servicio (o aprendizaje basado en la comunidad) es un enfoque educativo que combina los objetivos de aprendizaje con el servicio comunitario para proporcionar una experiencia de aprendizaje pragmática y progresiva al tiempo que satisface las necesidades de la sociedad. Los estudiantes aplican los conocimientos y habilidades estructurados adquiridos durante el curso académico mientras desarrollan un proyecto donde tratan un problema social específico mientras trabajan en equipo. En este artículo, se discuten las características de un buen plan de estudios de aprendizaje en servicio y métodos para la evaluación de los estudiantes, se describen los roles de los estudiantes, maestros y socios externos. Se enumeran los beneficios y desafíos de este método de enseñanza para el campo de la educación en geociencias. Aunque cuando este enfoque más común en el currículo de estudios sociales, las geociencias tienen una amplia gama de temas adecuados, algunos de los cuales se dan como ejemplos.

Introduction

Service learning (or community based learning, community based service learning) is a teaching method by which students apply the structured knowledge and skills acquired in an academic course to the development of a project that tackles a specific social problem, with the aim of enriching the process of acquiring knowledge through critical reflection on the complex social issues and mutual cooperation on a joint project (Preradović, 2009).

This method is innovative, as it changes the learning and teaching experience. Beside the better understanding of the importance of subject studied, this method allows the transfer of knowledge to the wider society. Higher education institutions get the opportunity to approach the local community and influence it actively and positively. When talking of service learning projects related to geoscience education, the problems are mostly topics related closely to environmental or sustainability issues.

Service learning must not be understood only as internship/fieldwork or volunteering (service). It has components of both, but it is much more than that (***Figure 1***). In volunteering, students are engaged in the community and gain practical experience without the component of learning outcomes specific for the certain study programme. During internships and fieldwork students gain practical experience fulfilling learning outcomes of a study programme without any civic engagement. Correctly implemented service learning programmes are based on a curriculum achieving both specific learning outcomes and community wellbeing.

For example, risk management of earthquake hazard has important social aspects. Helping in clearing rubble or supplying groceries after an earthquake is service, while measuring active faults in the field is learning. When university students help local civil protection authorities in designing and implementing activities as part of a project on seismic hazard mitigation to reduce the impact of earthquakes on the community, it is service learning.

The objectives for implementing service learning practice in geoscience courses are: (1) to foster student interest in earth sciences through community service; (2) to enhance university outreach through interactions with communities by helping to solve local geological and environmental problems; (3) to enhance students' learning ability by applying course knowledge to real-world problems; and (4) to encourage the student-centred learning process and team-work as cooperative learning (Liu *et al.*, 2004).

The aim of this article is to: (1) discuss characteristics of a good service learning syllabus with examples of social problems in geosciences; (2) describe stages of a service learning project and stakeholders (students, teachers and external partner) and their roles; (3) discuss student assessment and evaluation; (4) present benefits (together with generic learning outcomes) of service learning; and (5) consider challenges of this teaching methods.

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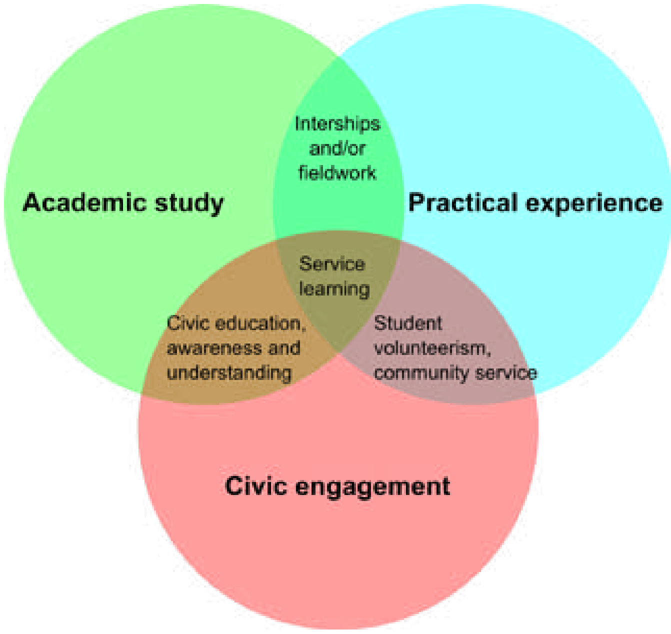

Figure 1: Service learning chart (taken from Fresno State University ***http://www.fresnostate.edu/csm/arc/service-learning.html*** *and modified).*

Implementation of a service learning programme

A service learning component can be implemented as part of an obligatory course, part of an elective course, part of courses' cluster which connect students from different study programmes or as a one-person project for a bachelor's or master's thesis. In any case, successful implementation of service learning component means meeting three principles: (1) ***reality*** (student engagement must be based on detected and previously researched real problems or needs in a particular community which is related to specific learning outcomes of the course); (2) ***reciprocity*** (exchange of knowledge must be ensured and all parties have to benefit from the program); and (3) ***reflection*** (revision of the link between engagement and educational content must be ensured).

Service learning in geosciences aims to solve a particular, well-defined geological, engineering, or environmental problem that geoscience students can solve with the knowledge learned in their courses and with supervised guidance from the teachers and local community leaders (Liu *et al.,* 2004). The geosciences are in a central position to promote scientific literacy in our society (Mogk & King, 2018). Real problems or needs in a particular community related to geosciences can be: (1) natural hazards (e.g. volcanic activity, seismic activity, floods, mass movements, erosion, tsunami, tropical cyclones, etc.), (2) unsustainable utilisation of natural resources (soil, water, energy resources, non-energy mineral resources); (3) contamination/pollution of water and soil, waste management, landfill placement and design; (4) problems related to medical geology (e.g. natural depletion of nutrient elements or enrichment of potentially toxic elements); (5) geological heritage (e.g. design of an educational geological trail); (6) consequences of climate change, etc. All of these topics provide a clear connection between the physical, life and social sciences. Hence, almost all courses in the geoscience's curriculum can implement a service learning component.

Every course syllabus with a service learning component should include service as an expressed goal; it should (modified after Heffernan, 2001):

- clearly describe how the service experience will be measured,
- specify the roles and responsibilities of students in the project;
- specify how students will be expected to demonstrate what they have learned in the project;
- include a description of the reflective process; and
- include a description of the expectations for the public dissemination of students' work.

It should be borne in mind that this teaching approach requires a significant amount of time for all parties involved. Hence, when planning a syllabus, it is important to anticipate student workload in preparing and implementing service learning project and assign the appropriate number of ECTS credits (1 ECTS credit indicates 25-30 hours of student workload).

Success of the service learning project depends on all stakeholders, students, teachers, and external partners. External partners can be found based on the specific project from the pool of non-profit and non-governmental organisations, public institutions, educational institutions, etc. The external partner can be chosen by joint agreement between teacher and student; by independent selection of students; or by independent selection of the teacher.

For social problems/needs related to geosciences, good external partners could be public nature protection institutions (e.g. for geological heritage projects); schools and libraries (for projects with the goal to raise the awareness of wider society about natural hazards); or environmental associations. Clear guidelines for external partners are necessary for successful project implementation.

Five stages of service learning project

Using the work of Berger Kaye (2010), the process of service learning can best be understood through the five stages (***Figure 2***): (1) investigation; (2) preparation; (3) action; (4) reflection; and (5) demonstration. They are linked together and often experienced simultaneously.

Investigation includes both the list of student interests, skills, and talents, and the social analysis of the topic (related to the course-specific learning outcomes) being addressed. ***Preparation*** includes the acquisition of knowledge that addresses any questions that arise from the investigation (e.g. academic content; identification of external partner; project management with clarification of roles, responsibilities and timelines; etc.). ***Action*** includes the implementation of the project, which can be in the form of direct service, indirect service, advocacy or research. ***Reflection*** is the link between each stage of service. Through reflection students consider their thoughts and feelings (cognition and affect), which helps in their future plans and self-awareness. Students can use discussion or journal writing for reflection. ***Demonstration*** captures or contains the totality of the experience including what has been learned, the process of learning, and the service or contribution accomplished. Students can demonstrate this to their peers, faculty, parents, and/or community members in the form of a report, article, web site, presentation, etc.

Stakeholders roles and student assessment

Each group of stakeholders has its own role; however, the communication inside the student team as well as between students and teacher and external partner is crucial. Students are responsible for project planning and managing. All members of the student team must be involved in project activities, keep a work diary and communicate with other stakeholders regularly. The teacher is obliged to define learning outcomes, monitor the quality of goals set and activities, encourage critical thinking, and ultimately evaluate students. The external partner defines the social problem/need, supervises and monitors the progress of students, and evaluates them.

Critical thinking and reflection are the key to successfully mastering service learning. Hence, students should autonomously or with the teacher decide which activities to use for reflection and to report on the progress of their projects. These can include a work diary; oral discussion, listening and reading about mutual experiences; written analysis of the relation between experiences and course objectives, and many more options. It is important to reflect on everything before, during and after the project.

As it is not necessarily the case that every service learning project succeeds, the assessment of students by teachers must be based on the evidence provided by the students themselves, and not only on evidence of socially beneficial activities performed. The evaluation of the service learning project can therefore be carried out as follows (Begić *et al.*, 2019): (1) interview with a mentor from the partner institution; (2) interview with a student project leader; (3) analysis of project documentation and time log; (4) evaluation of student products/services; and (5) assessment of students in the team on the engagement of other team members.

Benefits of service learning implementation in the curriculum

The general value of service learning is fact that this method affects students, teachers, and the community equally. Students get an insight into the ways of implementing the acquired knowledge in practice which have benefits for the community. Teachers gain deeper insight into the skills and competences of students which are not always so easily recognisable in the traditional educational environment. The community gains academic help in dealing with some of its problems.

The main benefit of service learning for students, beside acquiring subject-specific competences, is the development of generic (key) competences, i.e. a set of skills, attributes, and values which should be acquired by all graduates regardless of their discipline or field of study. These include such qualities as critical thinking, intellectual curiosity, problem solving, logical and independent thought, effective communication and related skills in identifying and managing information; personal attributes such as intellectual rigour, creativity and imagination; and values such as ethical practice, integrity and tolerance. As the students work on a geological problem relevant to the local community in a way that is project based, they gain the ability to design and manage projects (which includes abilities to identify, pose and resolve problems; to plan and manage time and finances; to work in a team; to take initiative; to apply knowledge in practical situations). Since service learning projects are focused on local community problems, students gain interpersonal and interaction skills that are difficult to obtain in the traditional higher education environment. Those skills are the ability to communicate with non-experts on themes from geosciences; to adapt to and act in new situations; to motivate people and move toward common goals; to act with social responsibility and civic awareness.

As the social problems related to geosciences are mostly connected to environment-related issues such as pollution, geohazard and risk management, and resource utilisation, through work in service learning projects students acquire a commitment to the conservation of the environment. Ultimately, they become more aware of their own profession – geologist/engineering geologist/geological engineer.

The benefit for higher education institutions, beside raising awareness of the impact and application of academic knowledge to the community and its needs and understanding and structuring one's own social responsibility, is building a positive image of a higher education institution.

The external partner benefits, as through implementation of the service learning project, it gains the ability to deal with problems in the community with the help of academic knowledge and to detect new opportunities and spaces for action.

In service learning projects students become equal actors in the teaching/learning process as they are encouraged to engage in critical thinking about the world around them. This type of engagement facilitates simultaneous involvement in social and business processes because students collaborate with organisations outside education system. The end result is, beside a better quality of knowledge, sometimes even provision of a workplace (Begić *et al.*, 2019).

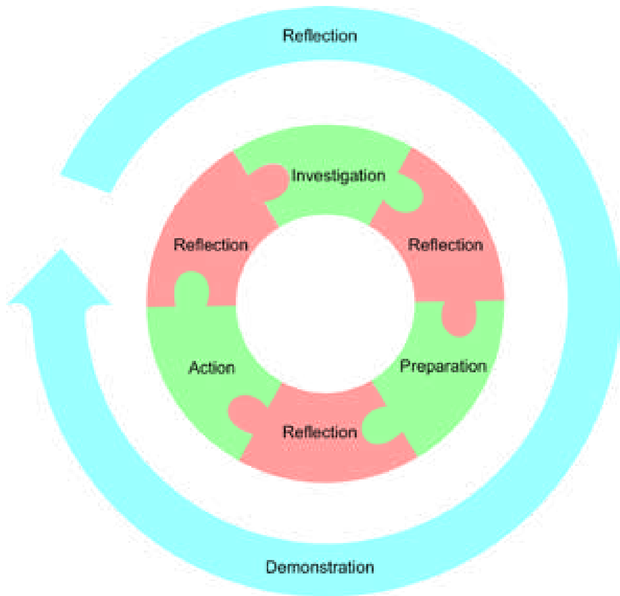

Figure 2: Five stages of service learning, modified after Cathryn Berger Kaye (2010).

Challenges of service learning

Implementing a service learning program requires careful planning and allocation of time and effort, as well as reflection on the chosen problem. That can become very challenging for all stakeholders involved.

The main challenges for students could be the collision of planned activities in service learning project with other obligations; lack of time for implementation of all designed activities for the duration of course; fear of unknown associates; logistical challenges; poor interpersonal relationships and team organisation; and unequal participation of all team members in project planning and implementation.

The main challenges for higher education institutions could be a possible lack of control over students' knowledge acquisition, organisation and implementation of student's activities; more demanding forms of student assessment; lack of time to help all students with challenges they face.

The main challenges for external partners could be a lack of time for preparation, training, work and supervision of all students; insufficient understanding of the benefits that a service learning programme provides; difficulties in recruitment of students; difficulties in defining service learning activities that are clearly associated with learning outcomes.

Examples of good practice

The National Academies (2017) organised a workshop where perception of experts in geoscience education research was explored and key goals and strategies for integrating service learning in the geosciences were identified. The study found that service learning, in the geosciences, falls at the intersection of practical experience, community involvement, and academic study. Two primary strengths of service learning instruction identified by participants included (1) promoting 'different kinds of learning' and (2) engaging 'faculty and communities' (Donaldson *et al.*, 2020).

Service learning practice has been implemented in several upper division geoscience courses (engineering geology, environmental geophysics, exploration seismology, and geology and geophysics field schools) taught at the University of Connecticut. The participating students and local community leaders found it effective to improve geological undergraduate learning. It has the capacity to foster learning, teaching, and undergraduate research, and facilitates multi-lateral interactions among students, faculty members, and local town public work professionals (Liu *et al.,* 2004).

There are many such examples from the USA in the literature. Unfortunately, service learning in geosciences in Europe is not so visible, although it certainly exists in some forms. Still, service learning is recognised in European higher education in general. The *European Network of Service learning in Higher Education*, launched in 2017, is an intersectoral, international and multicultural network of European professionals that promotes service learning as a pedagogical approach based on scientific evidence that embeds and develops civic engagement within higher education students, staff and the wider community (***www.eoslhe.eu/history/***).

Conclusions

Service learning is an innovative teaching method because it changes the learning and teaching experience - for both students and teachers. It integrates profound community service or engagement into the curriculum, offering academic credit to students for active engagement within the community on a real-world problem which leads to learning outcomes achievement. It brings together students, teachers and the community, whereby all become teaching resources, problem solvers and partners. In addition to enhancing knowledge, the overall purpose is to implant in students a sense of civic engagement and responsibility leading to positive social change within society.

Service learning has been widely adopted in the social sciences and humanities at the higher education level. Unfortunately, this is not the case with natural sciences and engineering, especially geoscience. There is a broad range of specific learning outcomes in geosciences study programs which could be achieved by implementing this teaching approach. Unfortunately, when searching the literature and Internet resources, it seems that it is much more recognised by teachers in geosciences in the USA than in the European Union.

Nowadays, when geoscience study programmes in Europe face a serious challenge to attract students, service learning with real science and engineering at its centre has the potential to raise the awareness of the study programme and interest in geosciences in the wider society.

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EGU (European Geosciences Union) Education Field Officer programme: teachers' appreciation, perceptions and needs

Giulia Realdon[1], Guillaume Coupechoux[2], Gina P. Correia[3], Xavier Juan[4], Ramanathan Baskar[5], Yamina Bourgeoini[6] and Chris King[7]*

Whilst geoscience plays a critical role in society and in sustainable development, it is nevertheless a neglected subject in many European countries. To address this issue, the European Geosciences Union (EGU) launched an initiative for the dissemination of professional development workshops aimed at teachers with limited or no academic background or teachers training in geoscience. The initiative included the training and funding of six Education Field Officers in 2019, who would then run practical workshops in France, India, Italy, Morocco, Portugal and Spain. The workshops were based on the experience and teaching resources developed by the Earth Science Education Unit (ESEU, Keele University). In this article we focus on the outcomes of the workshops and on the perceptions and needs of the teachers who attended.

Si les géosciences jouent un rôle critique dans la société et le développement durable, elles restent néanmoins un sujet négligé dans de nombreux pays européens. Pour résoudre ce problème, l'EGU a lancé une initiative pour la diffusion de workshops de développement professionnel destinés aux enseignants de formation académique limitée ou inexistante ou des enseignants formés en géosciences. L'initiative comprenait la formation et le financement de six agents de terrain de l'éducation en 2019, qui organiseraient ensuite des ateliers pratiques en France, en Inde, en Italie, au Maroc, au Portugal et en Espagne. Les ateliers étaient basés sur l'expérience et les ressources pédagogiques développées par l'Unité d'Education aux Sciences de la Terre (ESEU, Université de Keele). Dans cet article, nous nous concentrons sur les résultats de ces workshops et sur les perceptions et les besoins des enseignants qui y ont participé.

Si bien las geociencias desempeñan un papel fundamental en la sociedad y en el desarrollo sostenible, son sin embargo, un tema descuidado en muchos países europeos. Para abordar este tema, la Unión Europea de Geociencias (EGU por sus siglas en inglés) lanzó una iniciativa para la difusión de talleres de desarrollo profesional dirigidos a profesores con escasa o nula formación académica o con formación de profesores en geociencias. La iniciativa incluyó la formación y financiamiento de seis oficiales de educación de campo en el año 2019, que luego realizarían talleres prácticos en Francia, India, Italia, Marruecos, Portugal y España. Los talleres se basaron en la experiencia y los recursos didácticos desarrollados por la Unidad de Educación en Ciencias de la Tierra (ESEU, Universidad de Keele). En este artículo nos enfocamos en los resultados de los talleres, en las percepciones y necesidades de los profesores que asistieron.

Introduction

In the 1990s a widespread lack of geoscience knowledge and understanding among students of different ages emerged in Europe and beyond (King *et al.*, 1995). Since then this issue has been repeatedly investigated by the International Geoscience Education Organisation (IGEO) through international surveys, which confirmed the result of previous studies, with increasing negative trends in recent years (King in UNESCO, 2019). Another independent international assessment – covering 47 countries – TIMSS 2015 – demonstrated that among students aged 9-10 Earth science results overall were poorer than those of the other areas of science (Martin *et al.*, 2016).

In Europe the problem of improving geoscience education was addressed by the European Geosciences Union (EGU) through its Committee on Education with the development of a 'Strategy for Enhancing Geoscience Education', based on two main teachers' professional development initiatives: an annual international workshop (GIFT – Geoscience Information For Teachers), running since 2000 in Vienna and elsewhere, and the EGU Geoscience Education Field Officer (FO) programme, launched in 2019.

Six Geoscience Education Field Officers (four in Europe supported by EGU, and two in Morocco and India, supported by the International Union of Geological Sciences (IUGS) and by IGEO) were trained in 2019 and funded to give in-service and pre-service teacher training workshops in their respective countries. The target was stated as *"Teachers of science or geography in schools and colleges who have some geoscience in the curricula they teach but who have poor geoscience backgrounds and have received no training in geoscience teaching"*. This description is likely to fit tens of thousands of teachers across Europe (EGU-CoE, 2019, p. 8).

EGU FO workshops are based on the methods and resources developed by ESEU – the Earth Science Education Unit, originally based at Keele University in the United Kingdom. They are targeted at the national curriculum of the relevant countries, are

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based on the constructivist approach and are interactive and hands-on.

Following the first year of activity of the EGU FO programme, its outcomes have been assessed through specific tools: FO periodic reports and teachers' questionnaires (Correia *et al*., 2020).

The data collected are both quantitative and qualitative.

In this article we aim to explore the impact of the workshop on the participants, as perceived and expressed in their own words. In particular, we seek the optimisation of the EGU FO programme in the future. We are interested in understanding:

- what participants perceived about the workshops;
- what they appreciated in the workshops and the reasons for appreciation or complaint;
- what they needed from teacher training and expected from this kind of workshop.

Materials and methods

This study was performed as part of the assessment of the first year of activity of the EGU FO programme. The study sample was the participants in the professional development workshops run by EGU FOs between May 2019 and April 2020 in France, India, Italy, Portugal and Spain.

The attendants filled in a questionnaire asking:

- for demographic and professional data;
- three closed questions (5-point Likert scale) about participants' general interest in the workshop, professional interest in the workshop and interest in attending future workshop of the same type;
- two open questions asking for general comments on the workshop and suggestions for future workshops.

The questionnaires were anonymous and did not contain any sensitive information. The participants were informed in advance about the purpose of the evaluating study, were asked for written consent to use their responses and were given an opt-out choice.

The present investigation is focused on the open answers, analysed by means of conventional inductive content analysis (Bengtsson, 2016). Content analysis allows "an interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005, p. 1278). Our analysis is defined as conventional, because it is aimed at describing phenomena, and inductive, because it is not based on pre-conceived categories, allowing the categories to emerge from the data. The phases of the analysis are outlined in ***Figure 1***.

Open answers in the questionnaires were first translated into English by the FOs and checked by national colleagues to ensure fidelity to the original texts. The analysis was performed adapting the methodology proposed by Haney *et al.* (1998, as cited in Stemler, 2001). First, two researchers independently repeatedly reviewed the answers and drafted a category checklist. Second, they compared their initial checklists and reconciled any differences. Then the researchers, together with a third researcher, used the consolidated checklist to independently code the answers. Finally, the coders met (online) and discussed the points where disagreements had emerged, reaching a consensual analysis, whose outcomes are detailed in the next section.

Table 1 provides an example of the scheme of the analysis process from raw data to results.

Results

Since the start of the FO program 21 workshops have been run (***Figure 2***) and 12 more were planned before the outbreak of the COVID-19 pandemic and the adoption of lockdown measures in the FOs' countries,

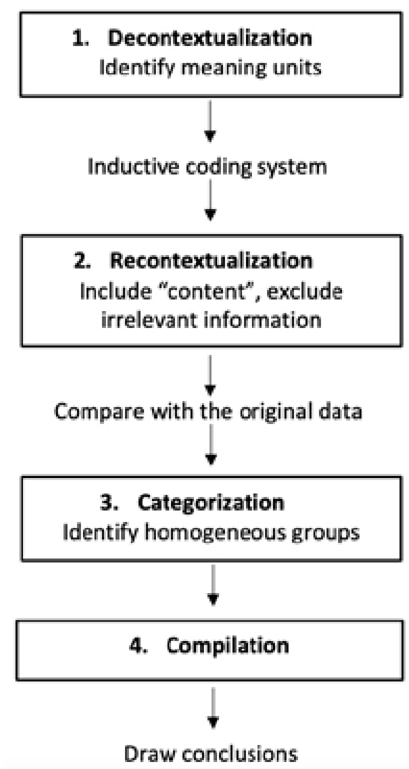

Figure 1: Flowchart: phases of the content analysis (adapted from Bengtsson, 2016).

leading to the interruption of classroom activities and to the cancellation of all teacher events. The number of workshop participants was 379, of whom 296 completed the evaluation form and gave their consent for the use of the collected data.

Among the respondents, 82% were female, and teaching experience ranged between 1 and more than 40 years, with 53% of them in the 7-to-25-year band. Confirmed teachers accounted for 73%, hired (supply) teachers for 19% and trainee teachers for 6% of the sample.

The participants' school level was the secondary school for 74% and the primary school for 26% of the sample, with differences between countries: primary school teachers were 100% in France and 38% in Italy; secondary school teachers were 100%

Table 1: Example of the coding process.

Meaning unit	*Condensed meaning unit*	*Code*	*Category*
Perfect format: neither too long nor too short	*perfect format*	*Satisfaction about the training*	*General appreciation for the course and the trainers*
I learnt a lot about sciences, thanks	*I learnt a lot*	*Learning opportunity*	*Impact on the attendant teacher*
Highly valuable the practical approach of the proposals…	*highly valuable the practical approach*	*Appreciation for the practical labs*	*Comments on the practical knowledge*
… without omitting precise information	*precise information*	*Appreciation for the provided information*	*Comments on the theoretical/pedagogical knowledge*

Figure 2: Location of the workshops run between May 2019 and April 2020.

in India, Portugal and Spain, and 61% in Italy.

Most of the participants (81%) taught Natural Sciences/ Biology/Geology, followed by Physics/Chemistry (9%) and Geography (6%).

The topics addressed in the workshops were agreed with the organizers in accordance with national curricula. Ranked in order of occurrence in the countries, they were seismology (in all 5 countries), volcanism, plate tectonics, Earth structure and magnetism, fossils and geologic time, rock identification (in 4 countries) and rock cycle, outdoors Earth science (in 3 countries).

The outcome of the workshops was assessed as described above. Participants' quantitative evaluation of the workshop included general interest, professional interest and interest in attending other similar workshops. The results were very positive in the four European countries (no evaluation data was available from the Indian sample): these three aspects of the training were rated at the highest level (5 out of 5) by respectively 84%, 81% and 81% of the respondents.

Open questions obtained 117 general comments on the participants' experience of the workshop and 59 suggestions for future workshops. General comments included answers ranging from very concise remarks to very detailed considerations addressing different issues. The process of content analysis on these texts led to the identification of six major categories of comments.

In order of frequency among the respondents, the categories identified were:

- comments on the practical knowledge provided by the workshop (53%),
- general appreciation for the course and for the trainers (51%),
- comments on the theoretical and/or pedagogical knowledge provided by the workshop (28%) and
- comments on the workshop's impact on the participant (27%).

A minority of respondents made critical comments on the workshop (6%) or shared their considerations about geoscience teaching in general (4%).

Within these major categories we identified further trends worth presenting. In the category "general appreciation for the course and for the trainers" (***Figure 3***), in which about half of the respondents wrote positive comments, the organisation and methodology of the workshop were most appreciated, followed by the interest of the activities and their usefulness. The trainers' skills and the pleasure of participation were also praised.

Examples for this category are: *"Perfect format: neither too long nor too short", "Clarity in presentation, friendliness and availability of trainers", "All the subjects covered were adequate and relevant. Topics were*

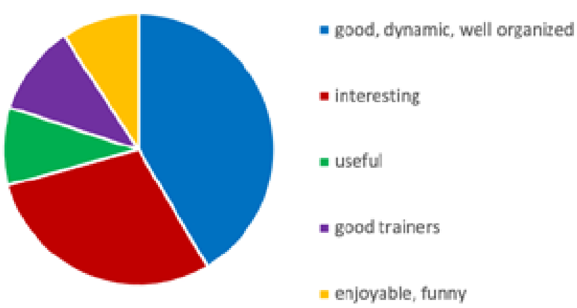

Figure 3: General appreciation of the workshop: sub-categories proportion.

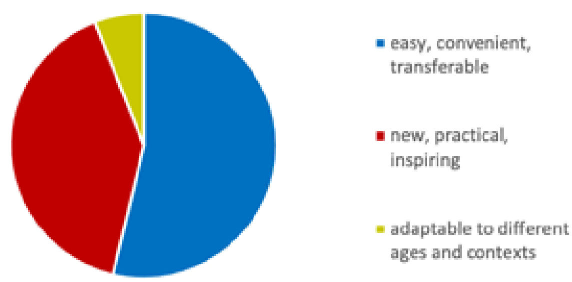

Figure 4: Comments on the practical knowledge: sub-categories proportion.

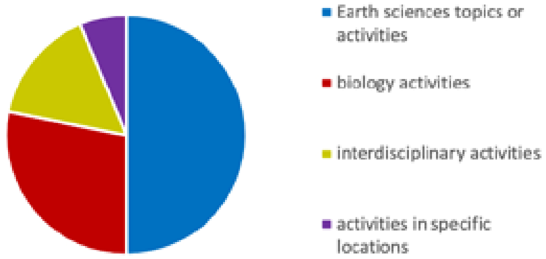

Figure 5: Specific requests for future workshop topics and subjects: proportion of sub-categories.

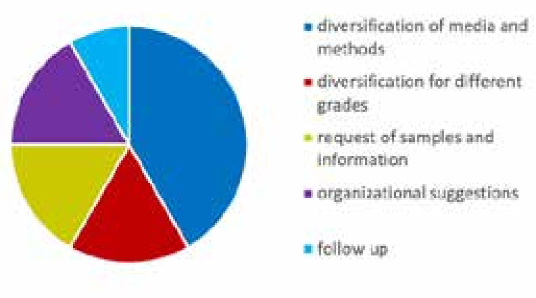

Figure 6: Methodological or organizational suggestions: proportion of sub-categories.

presented in a diverse, dynamic, rigorous and very pleasant way".

The category where the most answers were collected was "comments on the practical knowledge" provided by the workshop (***Figure 4***): more than half of the respondents commented on this point. In this category the most appreciated aspect of the training was the ease and transferability of hands-on activities (54% of the concepts in this sub-category), followed by the novelty, relevance and inspiration for use in the classroom (40% of the concepts in this sub-category). Finally, some teachers also praised the adaptability of the proposed activities to different age groups.

Comments of this category include example like these: *"Affordable activities. Easily implemented. interesting materials and tools", "Activities that integrate the programs of the curricular areas, activities to be developed at different levels", "Funny to be performed in the classes. Effective kinaesthetic experiences".*

Most comments on the theoretical and/or pedagogical knowledge evidenced participants' appreciation for the ideas, methods and knowledge achieved through the workshop, while others highlighted the motivational value of the activities for the students. Within the comments about the impact on the participants, many addressed the enrichment and significant learning opportunities, as well as the motivation and inspiration provided by the workshop. One teacher wrote *"I observed the rocks with other eyes"*, another *"You make people love Geology"*. Critical comments were few, and most of them complained about the time constraint, asking for longer workshops in order to carry out the activities with less pressure.

The second open question elicited suggestions for future workshops. In order of frequency among the responders, the identified categories were:

- specific requests about topics and subjects (51% of respondents),
- suggestions for more or longer training sessions like this (22%),
- methodological or organizational suggestions (20%),
- no suggestions (or general approval of the workshop, 19%),
- remarks on existing difficulties (3%).

In this category, too, different trends were further identified as sub-categories.

Most of the teachers' requests (***Figure 5***) addressed training on specific topics and activities within geology (rock recognition, geological charts, Earth history) and Earth sciences in general (atmosphere, global warming). Some of the attendees expressed interest in interdisciplinary activities or in activities in particular locations. Surprisingly, 30% of the requests were related to training and activities for biology teaching, which are not addressed by the geoscience-specific Field Officers.

Another interesting sub-category which emerged from the requests addressed organisation and methodology (***Figure 6***): some teachers proposed the use of media for dissemination, videos, field trips and practical labs.

Some suggestions concerned the diversification of activities for different school grades, others the need for samples (rocks) or references for materials providers. Some teachers also suggested running the workshops at the beginning of the school year or that they should be given a day's leave to attend the workshop. One comment suggested including a follow-up to check what use teachers have made of the information, activities and strategies covered by the workshop.

Most of the remaining suggestions asked for more training or longer workshops, or simply approved of the workshop they had attended: *"Go on with the dissemination of this methodology"*. Two suggestions addressed existing difficulties, due to the date of the workshop in the middle of the school year or to the constraints of the Spanish science syllabus.

Discussion

The analysis of workshop participant comments and suggestions in their questionnaire responses provided several elements inevitably absent from closed answers. However, it is notable that the responses to the closed questions were supported by those to the open questions and vice versa.

We found that the high level of appreciation for the general interest and the professional interest of the workshops given by the quantitative data was confirmed by "triangulation" with the high number of positive comments, especially in the categories "comments on the practical knowledge" (53%) and "general appreciation for the course and the trainers"(51%). Even taking into account a possible tendency to want to please the trainers, the appreciation expressed in the closed questions was strongly supported by the open-question responses.

Participants' critical remarks emerged in only 6% of the comments, and in more than half of the cases they expressed the need for more time or a deepening of the topics, as confirmed by the corresponding requests in the suggestion answers.

In comparison with the other studies on this kind of workshop performed in the United Kingdom with the use of a similar questionnaire (King & Thomas, 2012), our research yields higher mean scores in teachers' appreciation. A possible explanation could be the fact that in the countries of our sample the availability of these workshops is a novelty, while in the United Kingdom they have been run in large numbers across the country since 1999. It may also be because the majority of participants in the UK were trainee teachers, whilst the majority of participants in these workshops were practising teachers.

The recent UNESCO report on earth science education across the globe (UNESCO, 2019) found that the availability of teacher training courses in geosciences areas ranged between 33% (for primary and upper secondary schools) and 42% (for lower secondary schools) over 12 European countries, including the FOs' countries, evidencing the general need for professional development as a possible reason for the high appreciation found in our sample.

Also, the "suggestions for future workshops" confirm the data of the closed answers on the interest of the participants in attending future EGU FO training events. Teachers appear willing to attend this kind of professional development and gave evidence of their motivation by making specific and diverse proposals about workshops on geosciences and beyond. The suggestions about providing more/longer workshops or simply continuing this way (41%) further support this finding.

Conclusions

The results of this study, performed on a medium-sized international teacher sample, allow the drawing of some conclusions and recommendations:

- The outcome of EGU FO workshops, assessed as reactions of the participants expressed in their own words, appears very positive as a whole and in detail.
- EGU FO workshops seem to be valuable in filling the gap in the professional development support available to geoscience teachers across Europe and beyond.
- The EGU FO workshops can contribute to the improvement of geoscience education at school through the multiplying effect of teachers on large numbers of students.
- It would be advisable to monitor the real impact of EGU FO workshops on geoscience teaching through a follow-up involving the teachers attending the workshops, through later questionnaires and interviews.
- Finally, we ought to keep in mind that good quality geoscience education for all is a keystone for achieving UN Agenda 2030 Sustainable Development Goals, and is equally important in meeting the targets of the Sendai framework for Disaster Risk Reduction (2015-2030).

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Authors are grateful to the EGU and IUGS for funding the program. They also thank the EGU Committee on Education (CoE) and the IUGS Commission on Geoscience Education (COGE) for their strategic overview and support, and the FOs' supporters, whose collaboration was crucial to the success of the initiative.

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Digital transformation and geoscience education: New tools to learn, new skills to grow

Antoine Bouziat[1], Julien Schmitz[2], Rémy Deschamps[1] and Karine Labat[3]*

Digital transformation is a technological and societal trend currently reshaping many scientific and industrial fields. In this paper, we address the challenges and opportunities raised by this digital transformation for the specific topic of geoscience education. We discuss the value of new digital tools and methods for teaching geology, and highlight the digital skills the future generation of geologists will grow. We also underline that geoscience training can open exciting career paths for students and professionals from a computer science background. We illustrate these ideas with on-going practical projects at IFP Energies nouvelles, a French public institute for research and innovation in the energy industries, and IFP School, a specialised engineering school delivering several graduate degree programmes in applied geosciences.

La transition numérique est un phénomène technologique et sociétal qui bouleverse actuellement de nombreux secteurs scientifiques et industriels. Dans cet article, nous abordons les défis et les opportunités engendrés par cette transition numérique dans le domaine particulier des formations en sciences de la Terre. Nous analysons la valeur ajoutée de nouveaux outils et méthodes numériques pour l'enseignement de la géologie, et nous présentons les compétences numériques que la future génération de géologues devra développer. Nous soulignons également qu'une initiation aux géosciences peut ouvrir des opportunités de carrière stimulantes aux étudiants et professionnels issus du monde de l'informatique. Nous illustrons ces idées par des projets concrets en cours à IFP Energies nouvelles, un institut public français dédié à la recherche et l'innovation dans le domaine de l'énergie, et IFP School, une école d'ingénieurs spécialisée délivrant plusieurs diplômes supérieurs en géosciences appliquées.

La transición digital es un fenómeno tecnológico y social que actualmente está transformando muchos sectores científicos e industriales. En este artículo, discutimos los desafíos y oportunidades que genera esta transición digital en el campo particular de la formación en ciencias de la tierra. Analizamos el valor de las nuevas herramientas y métodos digitales para la enseñanza de la geología, y presentamos las competencias numéricas que la próxima generación de geólogos necesitará desarrollar. Por otra parte enfatizamos que una introducción a las geociencias puede abrir oportunidades de carrera estimulantes para estudiantes y profesionales del mundo de las tecnologías de la información. Estas ideas son ilustradas con proyectos concretos en curso tanto en el IFP Energies nouvelles, un instituto público francés dedicado a la investigación y la innovación en el campo de la energía, como en el IFP School, una escuela de ingeniería especializada que ofrece varios títulos superiores en geociencias aplicadas.

Everyone goes digital

The news has recently raised some attention on social networks: to replace a cancelled field trip in Oman, the students of the Petroleum Geoscience MSc programme at Imperial College in London will be offered an outcrop analysis course based on virtual reality and an introduction to machine learning techniques[1]. Beyond the field trip cancellation, the choice of the substitute material appears strikingly representative of a more global phenomenon, commonly referred as "digital transformation".

Digital transformation is a somehow fuzzy concept, for which various definitions have been proposed. However, most authors agree that digital transformation goes well beyond the use of the latest technologies and should rather be seen as a societal trend, which changes our habits and expectations as employees, customers and individuals (Reis *et al.* 2018). Consequently, all scientific and industrial fields are impacted and need to adjust, both to seize new opportunities and overcome potential threats.

Earth sciences and subsurface industries are not being left behind by the digital transformation swing; among all related activities, geoscience education is one that is especially affected. As geoscientists at IFP Energies nouvelles (IFPEN) or teachers at IFP School, we are privileged observers of and actors in the current technological and educational evolution. In this paper, we aim at sharing some insights and initiatives to further discuss how the geoscience education community can make the most of the digital transformation phenomenon. Could it be one of the keys to solve the paradox of growing public engagement in environmental and energy issues but declining enrolment in geoscience degree programmes?

Old rocks, but younger generations

The most classical approach to digital transformation in education is probably introducing devices such as smartphones and tablets in the classroom to increase student engagement. Indeed, much has been written on the learning styles of the younger generations. Students from the so-called Generations Y and Z notably favour autonomy in the learning process and quick direct access to information (*e.g.* Schofield and Honoré 2009). Meeting these demands can be challenging, and as another characteristic of these students is their comfort with technology, it is a logical temptation for professors to rely on it to renew their teaching methods. However, despite promising initiatives (*e.g.* Marçal

1 ***https://www.imperial.ac.uk/news/198915/geoscience-course-stops-running-oman-fieldtrip/*** (last accessed in August 2020)

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et al. 2014), the value of this approach still needed to be demonstrated for teaching geology, peculiarly in the field.

To appraise the assets of numerical devices in field-based teaching, IFP School launched a "mobile learning" experience in 2015. Geology students were provided with touchpads and a dedicated application was developed (***Figure 1***). While in the field, the students could use it to access various georeferenced data (such as thin section pictures, geological maps and surveys, aerial photographs, and even 3D numerical models), utility tools (such as GPS, a compass or cross-section design) and interactive multimedia material (such as videos or quizzes). Several positive effects were then noticed by the professors supervising the experience. The students more easily integrated different observation scales in their reasoning. They also better understood the links between outcrop analogues and subsurface exploration data. Besides, the application encouraged more teamwork and collaboration. Eventually, its use was extended to before and after the field trips, for instance in preparation and debriefing sessions. Similar conclusions were recently drawn from a comparable experience in Norway (Senger and Nordmo 2020).

Figure 1: IFP School students using a mobile learning application during a geological field trip in the Spanish Pyrenees in April 2017. Top left: access to reminders on the geological context. Top right: interactive quiz based on the geological map. Bottom left: landscape sketching. Bottom right: discussion with professors.

Figure 2: Common Digital Outcrop Modeling (DOM) techniques. Top left: convergent photogrammetry acquisition process. Top right: LIDAR acquisition device. Bottom: DOM of an eolian sandstone outcrop in Utah.

Virtual reality, but tangible benefits

If digital technologies can bring data from labs or desks to the field, they can also bring field data to the classrooms. When thinking about this objective, immersive virtual reality will quickly come in the reader's mind. However it is worth noting virtual geological field trips are not something new, and that the recent technological breakthroughs follow decades of improvement for Digital Outcrop Models (DOM).

DOMs are 3D virtual representations of outcrops with their actual textures and colours. They are usually created from a set of pictures taken from various angles using the convergent photogrammetry principle or a LIDAR (Light Detection and Ranging) acquisition device (***Figure 2***), leading to textured point clouds or triangular meshes. Several dedicated software packages have been developed to help with their geological interpretation, such as LIME (Buckley *et al.* 2019) or Virtual Reality Geological Studio (***https://www.vrgeoscience.com/***).

At IFPEN, DOM technologies were notably developed within the SmartAnalog™ project (***https://www.smartanalog.eu/***). Relying on a proprietary interpretation platform, this project aimed at running similar workflows on outcrop analogs as the ones run on actual petroleum reservoirs: horizon picking, facies interpretation and geostatistical modelling of petrophysical properties (Deschamps *et al.* 2015). Initially developed for better constraining subsurface models in an industrial context, this project also produced interesting educational support for teaching geology and was quickly integrated into IFP School classrooms.

On top of the DOM legacy, virtual geology has recently raised renewed interests globally, driven by the democratisation of immersive environments and growing concerns about physical field trips. Indeed, beyond the current pandemic crisis, opportunities for geological field trips are increasingly limited by their financial cost, carbon footprint, health-and-safety issues, and potentially exclusive nature. Meanwhile, though immersive virtual reality once necessitated a dedicated room or costly equipment, it has become more affordable, with fully independent mobile devices now commercialised below 500 euros.

The objective to integrate digital outcrop models within immersive virtual environments led to the development of several platforms, such as MOSIS (Multi Outcrop Sharing and Interpretation System, Rossa *et al.* 2019) and 3D Gaia (***https://www.imagedreality.com/***). Key features commonly highlighted are flexible displacements around the outcrop, multiple tools for interactive geological interpretation and integration of additional geoscience data in the environment, from field sample pictures up to reservoir models and synthetic seismic profiles.

A similar initiative was recently carried out at IFPEN, using a DOM model of turbiditic sandstones in the French Alps and the immersive JungleVR system (***https://junglevr.io/***). A specific effort was made to add geological data of various kinds in the environment, to be interactively visualised along with the outcrop. This included interpreted horizons, sedimentary logs, sample pictures, informative texts and educational videos (***Figure 3***). Early feedback underlined the value of the multi-data approach for educational purposes.

Eventually, will virtual reality signal the end of physical field trips? Not in our opinion. Analysing actual rocks, outcrops and landscapes should likely remain a key component of geological science. However, we see their virtualisation as a valuable complement, which fosters knowledge sharing, cross-disciplinary discussion and ful capitalisation on results. On this topic, digital technologies are far from threatening the existence of field activities. On the contrary, they considerably broaden the range of students and staff that can practice and understand them.

Artificial intelligence, but natural objects

Virtual reality is not the only emergent technology penetrating geoscience classrooms. Artificial intelligence also presents promising educational potential. Notably, computer vision, a subfield dedicated to automated image analysis, has boomed in the last decade, with applications ranging from facial recognition software to self-driving cars. As geology is intrinsically a science of image interpretation, it provides numerous cases where computer vision algorithms could assist students in their learning. For instance, approaches based on convolutional neural networks were successfully applied to classify field samples between lithology classes (Ran *et al.* 2019) and detect microfossils on core sections (Carvalho *et al.* 2020).

Concretely, how can geoscience education benefit from the current artificial intelligence momentum? Experience from another natural science gives some insights. Launched in 2009 by several French public institutions, the Pl@ntNet project produced a mobile application dedicated to the automated identification of vegetal species from field pictures (***https://plantnet.org/***). Available on the best known app stores, Pl@ntNet has gathered a community of 12 million users (150,000 daily), who increase their knowledge of botanic science through this medium.

At IFPEN, the success story of Pl@ntNet inspired us to start in 2019 a similar initiative for the identification of rock samples, the RockNet™ project. The idea is to provide students and geology enthusiasts with an application where they can take pictures of rock samples and obtain a proposal of lithofacies classification from computer vision algorithms. A first prototype application based on 12 lithology families is currently under testing. We imagine future versions could be used in geology classes, in the same vein as the RockCheck application (Valand *et al.* 2020).

Like any technology, the integration of artificial intelligence in geoscience education is not without risks. In our mind, the main pitfall to avoid is hiding the inherent complexity of geological objects and the irreducible part of subjectivity in interpretation. As the products of millions of years of multi-scale physical and chemical processes, similar geological objects can look extremely diverse and delineating classes cannot be done as easily as for plants.

It is worth noting the technology itself provides some safeguards. Most classification algorithms do not produce a unique answer, but attribute a probability to each possible one. This can be an interesting point to highlight the intrinsic uncertainty of interpretation processes (***Figure 4***, *top*). Moreover, a stimulating research path lies in the association of convolutional neural networks with decision trees. For instance, with this approach the networks are not trained to directly recognise the lithology on sample pictures, but only petrological features such as textures, structures or mineral species. Then these features are combined within a decision tree which mimics the naturalist methodology for rock identification (***Figure 4***, *bottom*). This technique was applied with promising early results (Bouziat *et al.* 2020) and offers some assets in an educational perspective.

More generally, teachers should put a particular emphasis on the critical assessment of the results from artificial intelligence. What they provide is a first-guess analysis, aiming at assisting the students but not at thinking on their behalf. With this mind set, artificial intelligence becomes a helpful ice-breaker which automates a first-level interpretation, which the student is then encouraged to discuss, amend and complete.

Figure 3: Exploration of the Annot sandstones (French Alps) in an immersive virtual reality platform. Top left: close-up view of the outcrop. Top right: display of geological information on a point of interest. Bottom: landscape view with display of interpreted horizons and a sedimentary log.

In addition, the ice-breaking aspect of automated interpretations is a powerful tool for science communication intended for the general public. For instance, outdoor enthusiasts could use a rock identification app to learn about the rocks and stones surrounding them, and get more insights on natural heritage and subsurface resources. Even the most urban folks can be interested in such democratisation of geological knowledge, as shown by the "London Pavement Geology" project (***http://londonpavementgeology.co.uk/***) or by the geological walk booklets available for several French city centres (***https://www.mnhn.fr/en/node/1375***).

Figure 4: Automated identification of lithofacies on field samples with artificial intelligence algorithms. Top: direct lithology classification. Each input picture displays the three most probable classes according to the neural network. The first two pictures are archetypal and the probabilities neatly favour a single class. However, the third picture is more ambiguous and the probabilities reflect the uncertainty that a human geologist would face. Bottom: lithology classification combining petrological feature recognition and a decision tree. Adapted from Bouziat et al. 2020.

Bridging the gap between geologists and data scientists

The impact of digital transformation on geoscience education does not only concern how we teach, but also what we teach. Earth sciences curricula have for long included subjects like geostatistics or signal processing. And, to a certain extent, geologists have always been some kind of data scientists, collecting data in the field and interpreting it with a combination of methods. However, we consider the need for geologists with a basic proficiency in computer sciences and mathematics to be likely to grow further in the near future. First, these disciplines closely interact with emerging technologies in geosciences, such as remote sensing or Geographic Information Systems. Besides, discussions in communities such as Software Underground (***https://softwareunderground.org/***) and publication logs in journals such as *Computers & Geosciences, Earth Science Informatics* or *Geoscientific Model Development* illustrate that the geoscience community increasingly uses Python for data processing, R for statistical analysis, or custom web services for sharing their results.

Fortunately for the students, there is no need to be an information technology expert to apply the most common techniques in computer and mathematical sciences. Indeed, these techniques have recently seen a tremendous increase in accessibility, notably through the rapid growth in community and open-source programming libraries. For instance, a decade ago, geologists wanting to train a neural network on a data set had to code one more or less from scratch in native Python language. Nowadays, they can rely on at least two stages of higher-level libraries, such as PyTorch (***https://pytorch.org/***) and Ignite (***https://pytorch.org/ignite/***). This considerably reduces the barrier for non-specialists and these geologists may be able to produce their first results with a few dozen lines, simply assembling code bricks already written and optimised by top-class experts.

Nevertheless, there is no point in running numerical methods if you cannot review and trust the results. That is why the increasing accessibility of digital technologies opens new opportunities for geology graduates. With the finest algorithms broadly available, much value lies in the ability to cast a critical glance at the results and analyse them with enough knowledge and subject matter expertise. Industrial companies and research organisations need young professionals who can run numerical models but can also spot potential biases in the input data, estimate uncertainty ranges in the parameters, and discuss the relevance of the model hypothesis for use in a specific case.

Logically, universities are adjusting their geoscience programmes to meet the changing needs. First, new courses are being added in existing programmes, like the machine learning course at Imperial College. At IFP School, Python programming has recently become part of the petroleum geoscience syllabus. Some institutions are even creating new programmes at the crossroads of computer and earth sciences. For instance, the Lassalle engineering school in Beauvais (France) just opened a major in "numerical geology". At the Lorraine University in Nancy (France) a similar major has existed at the school of geology since the 1990s, but students are now offered the chance to spend a semester in the school of information technologies beforehand.

While there are many advantages for aspiring geoscientists to learn some computer and mathematical science, the opposite seems also true. Geosciences involve 4D thinking, numerous data of diverse nature, scale and format and various models with multiple parameters of uncertain values. Thus they are an unexpectedly stimulating playground for students or professionals with a numerical background. Consequently, learning some basics of geology, even at a late stage of their training, can open some interesting paths for scientists with these profiles, notably in the subsurface resources industries. Some

Figure 5: Students from the Petroleum Data Management programme at IFP School acquiring GNSS measurements. They learned how to georeference geoscience data during a geological field trip in Forcalquier (France) in September 2020.

of these students enrol in the Petroleum Data Management programme at IFP School, dedicated to educating specialists in the geoscience data lifecycle. During this one-year programme, students and professionals initially trained in computer science join peers with more geoscience-related backgrounds and learn the essentials of geological science, notably through a week-long field trip (***Figure 5***). Most of them later take advantage of this rare blend of skills in industrial companies.

No reason to fear the wave, let's surf it!

Altogether, digital transformation appears to be a fabulous opportunity to teach, explain and promote earth sciences for students, professionals, recruiters and the society as a whole. It provides new innovative mediums to share geological knowledge and concepts with a broad range of profiles, including the general public. It also offers exciting career opportunities for those geologists ready to add a few numerical methods to their skills set, and to computer scientists ready to learn some geological rudiments.

The stakes at play are enormous. In a context of increased public interest in environmental and energy issues, it seems critical that young people see geology as an attractive, stimulating and rewarding scientific area, so they can develop at least a basic knowledge of our planet and its resources, which will fuel their development as mature citizens. As perfectly phrased in Wadsworth *et al.* (2020), *"our future depends on young people continuing to learn how the planet works"*. If the digital transformation wave can help in this objective, geoscience educators should not hesitate to surf it!

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Geosciences education at German universities

Ulrike Wolf-Brozio[1], Peter Merschel[2], Dominic Hildebrandt[3] and Ina Alt[4]*

Geoscientific education is offered by 31 German universities. Each year, about 4,000 first-semester students begin their bachelor's or master's studies and around 2,200 graduate with a bachelor's or master's degree. More than 90% of the bachelor's students continue with a master's course. Most graduates find employment in the applied sectors.
*Apart from understanding 'System Earth', modern geosciences programmes contain more and more socially relevant topics, leading to a broad and complex terminology and study program offer. In this context, the new 'GUIDE' portal by EFG and BDG (*Berufsverband Deutscher Geowissenschaftler*, German Professional Association for Geoscientists) allows (prospective) students to easily compare available courses and provides a quick overview of geosciences education in Europe.*

L'enseignement géoscientifique est proposé par 31 universités allemandes. Chaque année, environ 4 000 étudiants du premier semestre commencent leurs études de licence ou de maîtrise et environ 2 200 obtiennent un diplôme de licence ou de maîtrise. Plus de 90% des étudiants en licence poursuivent leur cursus en master. La plupart des diplômés trouvent un emploi dans les secteurs appliqués. Outre la compréhension du «Système Terre», les programmes de géosciences modernes contiennent de plus en plus de sujets socialement pertinents, conduisant à une offre de programmes d'études et de terminologie large et complexe. Dans ce contexte, le nouveau portail «GUIDE» d'EFG et de BDG (Berufsverband Deutscher Geowissenschaftler, Association professionnelle allemande des géoscientifiques) permet aux étudiants (potentiels) de comparer facilement les cours disponibles et offre un aperçu rapide de l'enseignement des géosciences en Europe.

La educación geocientífica es ofrecida por 31 universidades alemanas. Cada año, alrededor de 4.000 estudiantes del primer semestre inician sus estudios de licenciatura o maestría y alrededor de 2.200 se gradúan de dichas especialidades. Más del 90% de los estudiantes de licenciatura continúan con un curso de maestría. La mayoría de los egresados encuentran empleo en los sectores aplicados. Además de comprender el "Sistema Tierra", los programas de geociencias modernos contienen cada vez más temas de relevancia social, lo que conlleva una oferta de programas de estudios y terminología amplia y compleja. En este contexto, el nuevo portal "GUIDE" de EFG y BDG (Berufsverband Deutscher Geowissenschaftler, Asociación Profesional Alemana de Geocientíficos) permite a los potenciales estudiantes comparar fácilmente los cursos disponibles y proporciona una descripción general y rápida de la educación en geociencias en Europa.

From geology to geosciences and beyond

Education in Earth Sciences has a long tradition in Europe (Wagenbreth, 2015). Over time, classical geological disciplines were complimented by additional interdisciplinary sub-disciplines such as environmental geology or marine geology. New universities were established and thus, more than 30 higher education institutions in Germany came to offer study programmes such as like geology, palaeontology, geophysics and/or mineralogy. As part of a larger restructuring process at German universities in the 1990s, the four classical subjects were combined at many universities into a new subject, Geosciences, and so we understand geosciences as a subject which has emerged from these four basic disciplines.

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The two-tier system: Establishing the Bologna reform

Like everywhere in Europe, the old Diploma programmes were converted into bachelor's and master's degree programmes during the Bologna Reform at the beginning of the new millennium. All study programmes are modularized and equipped with ECTS credit points. According to the European standard, a German bachelor's programme usually has a standard duration of 3 academic years (or 6 semesters) and can be continued by a 4-semester (or two-year) master's programme. Another 3+ years are invested by students seeking a doctorate. Research institutions, public authorities and the geosciences faculties or institutes themselves offer attractive opportunities for a PhD position and further career steps into science. Most PhD students are employed at Universities or research institutions as research assistants with a 50-75% remuneration of research assistant positions.

Bachelor programmes in geosciences in Germany are commonly admission-free. Only a general university entrance qualification and sufficient knowledge of the German language is needed in order to be accepted. The master programmes, on the other hand, have very different and augmented high specialist admission require-

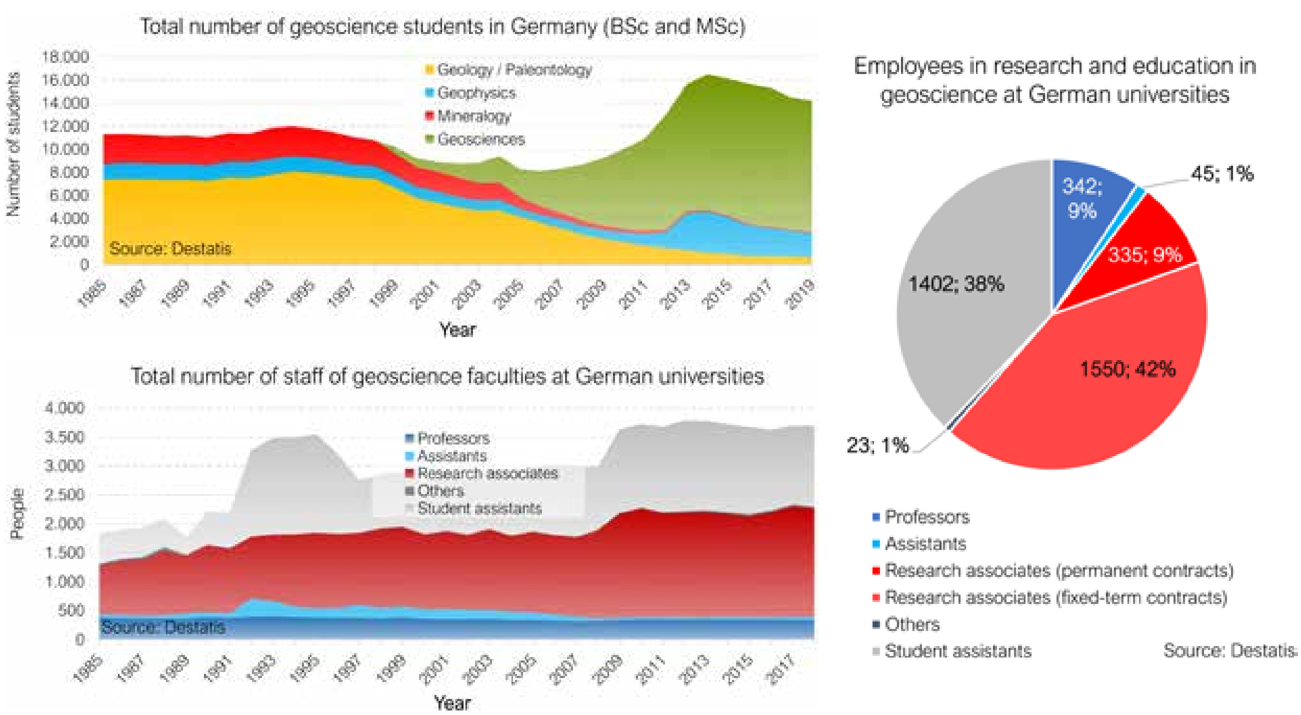

Figure 1: Students, teaching and research staff in geosciences in Germany (modified after Merschel, 2020).

ments. Of 75 master programmes geosciences faculties and institutes provide, 31 are offered with English as the language of instruction – increasing tendency. In contrast, only one bachelor programme is currently offered in English and a second one starts in 2021 (see ***Figure 3***, violet points).

In general, German universities do not charge tuition fees for European citizens – except at the few private universities. The structure, curriculum, and the infrastructure of all study programmes in Germany are accredited in 7-year intervals by accreditation agencies or within the evaluation processes of system accredited universities. This high-level quality assurance measure guarantees the quality in terms of studyability, study profile as well as employability and offers at the same time a competence-oriented control of German geoscientific study programmes among themselves.

Since the academic self-administration of the universities also requires participation of students, the student elect representatives who are organized in student councils. They are representing students in university policy bodies, helping with e.g. structural problems, and organizing freshmen introduction weeks. The umbrella organization of the student councils in geosciences is a not-for-profit association called "GeStEIN – Geoscientific Student Experience and Interests Network e. V.". Among other things, GeStEIN also develops proposals for the further development of geoscientific education. Furthermore, many universities host local student chapters organized in a Germany-wide network focusing on connecting German geoscientific companies with students.

Geoscientists at research institutions and universities and the German labour market in geosciences

Students with a bachelor's degree are considered to have achieved their first professional qualification and can enter the labour market. However, more than 90% of the undergraduate geoscientists continue in a master's programme to receive a higher graduate level before starting their professional career. Even though the situation in geoscientific research at universities and non-university institutions for entering a PhD position is good, only a very small percentage of the PhD graduates are able to pursue an academic career due to the lack of permanent positions in academia in Germany. The German Professional Association for Geoscientists (BDG) calculates that only 2–4% of geosciences students entering universities can later on count on employment in research and teaching. Of around 30,000 professional geoscientists in Germany, a little less than 10% are working at universities or research institutions, most of them (>80%) in non-permanent positions (***Figure 1***).

About 9% of the teaching and research staff in Geosciences are employed as professors - a share that has not significantly changed for decades. The share of research associates is currently just over 50%. In terms of numbers, it has stagnated over the last 10 years, as has the large number of student assistants and part-time workers, who tend to be involved in research rather than in the training of geosciences students. A comparison with the development of the student statistics in geosciences, as displayed in the upper bottom line graph in ***Figure 1***, clearly shows that the low remaining portion of lecturers were facing a strong increase of geosciences students between 2007 and 2014. At present, ~14,000 students are being supervised at geoscientific faculties and institutes by 342 professors and 1,900 research associates. 82% of the research associates are non-permanently employed (including qualification positions such as PhD students). Looking at the hierarchical structure of the universities hosting geosciences, we identified only eight geosciences faculties – i.e., equipped with all positions of academic self-administration. At all other universities, the geosciences are affiliated with the mathematics and natural science faculties or even with other faculties.

In 2019 nearly 1,000 bachelor's and 1,200 master's degree students graduated in geosciences (Source: Federal Statistical Office *Destatis*). These figures reflect the slight decline in the number of first-year bach-

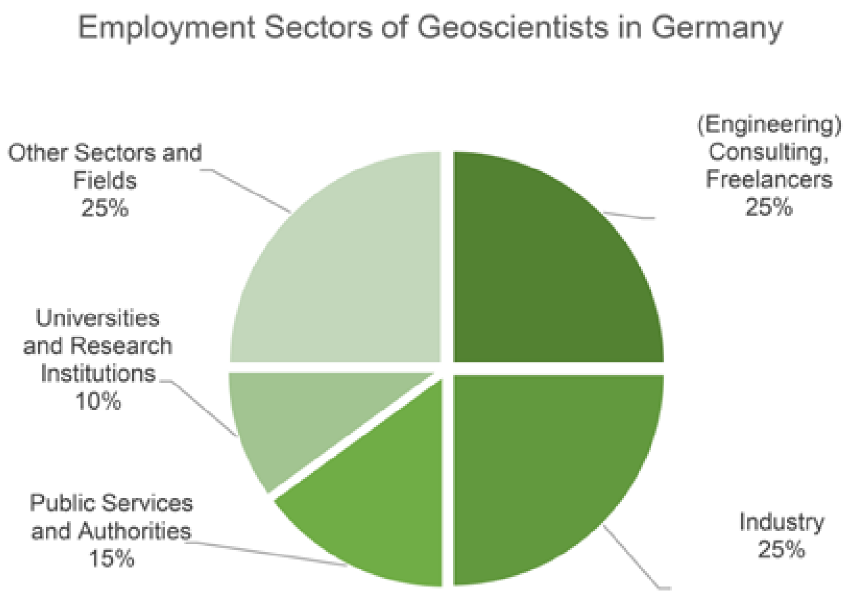

Figure 2: Approximate proportions of geoscientific employment in Germany (Merschel et al., 2020).

elor's students in 2016 and indicate as well a certain number of subject changers and international students entering geosciences for a master's degree. The gender proportion among the geosciences students (including PhD students) in Germany ranges between 40 to 45 % women. The majority of those seeking a job find employment in the applied professional fields of geosciences (Merschel *et.al.* (2020) (***Figure 2***). They are mostly employed in geo-consulting companies, in industry or work as freelancers (together 50%). The most-common sectors are engineering geology, hydrogeology, treatment of contaminated sites and deposits, raw materials and resources or the energy sector (Fahry-Seelig *et al.*, 2012). A further 15% of geoscientists are employed in governmental offices and authorities. The remaining 25% of those who once received a geoscientific education are now working in other professional areas that are either not related or only distantly related to geosciences. The current unemployment rate in geosciences in Germany is 4.7% (pre-Coronavirus pandemic).

Geosciences Faculties and Institutions

Today, the term geosciences is the most common at German universities. There are 22 bachelor's and 21 master's programmes named Geosciences or Applied Geosciences. In contrast, study programmes still called geology or geological sciences are just located at five universities (***Figure 3***, yellow points). Similarly, palaeontology is only offered as a master's program at one university (***Figure 3***, red point). Mineralogy no longer exists as a separate subject, but it still plays a significant role in study programmes dedicated to the materials science of natural solid-state materials. Geophysics is still represented as an individual bachelor' and/or master' programme at eight universities across Germany (***Figure 3***, green points).

Currently 31 geosciences faculties and/or institutes exist in Germany. The high number of universities in comparison with our European neighbours stems from historical reasons and is caused by the German federal system and is also related to the needs of the German labour market, which still demands a relatively high number of engineering specialists all over the country. In addition, many of the big German research associations like Leibniz, Senckenberg or Helmholtz also host geoscientific sections or departments whose staff is involved in both research and teaching. In areas with closely neighbouring geoscientific institutes, many universities have formed research alliances, some of which also cooperate in teaching, thus offering joint degree programmes or opening their courses to students from cooperating faculties. Examples are the ABC/J Geoverbund network between the universities of Aachen, Bonn, Cologne and the research institution Jülich, or the Munich Geocenter of the two universities LMU and TUM. A "role model" for study programmes with international cooperation partners and industry is the joint master's programme in Applied Geophysics offered by RWTH Aachen, ETH Zurich and TU Delft.

Geosciences curricula - similarities and specifics

One of the most important pillars in geoscientific training continues to be field work. Geological mapping and field exercises are still the main practical parts of German geosciences education, as required by the Tuning Project (2009). Apart from

Figure 3: Geosciences faculties and institutes at German universities (modified after Schlüter et al., no year). Colour code: in yellow - Geology; red - Palaeontology; green - Geophysics, violet - BSc in English.

GUIDE – a European portal to compare geoscientific study programmes

In order to provide students with a quick and comprehensive overview regarding the curriculum and specialisation areas in geosciences, the BDG initiated the GUIDE portal (***www.geoscience-studies.org***) in collaboration with the European Federation of Geologists (EFG). The GUIDE portal was rolled out in July 2020 and allows the comparison of study programmes in geosciences in Europe by listing all participating universities with their study contents in ECTS credits. GUIDE contains bachelor's as well as master's programmes at each study location, divided into the different specialisation areas such as e.g. sedimentology, petrology or hydrogeology. Users can choose the study locations and/or the specialisation areas they are interested in and can compare in a visually appealing way how many credit points (CPs) are offered in the respective study areas.

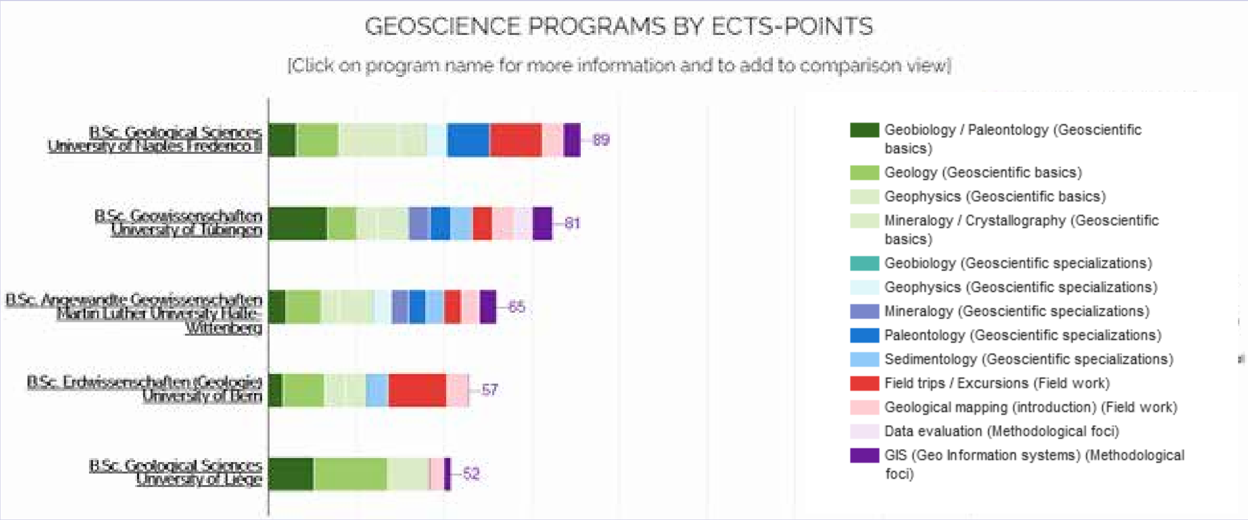

Figure 4: Screenshot GUIDE: Selection of bachelor's programmes with the most credits in specified subjects.

The information offered by GUIDE originates from study deans, programme coordinators and/or students of each participating institution. They enter the ECTS credits of their study programmes following the rule that each CP of a programme must appear, but only once, in one of the categories.

In recent years, a first version of the comparison portal within the geosciences education landscape of Germany enjoyed great demand. The good response and the unique proposition of this offer prompted the BDG to expand the portal to the European level. EFG joined this initiative, and GUIDE has also received support from the EFG Horizon2020 project 'International Network of Raw Materials Training Centers' (INTERMIN). GUIDE, a unique comparison portal for geoscientific study programmes in Europe, is available from summer 2020. Access for (prospective) students (and other interested parties) is free of charge, and so is the entry of study programmes. We urge universities across Europe to add their programmes to this database. For further information and for getting a university user account, please contact ***mail@geoscience-studies.org***.

understanding 'System Earth', the laboratory practice, analytical methods and more recently data management or geomathematics and modelling courses including software applications turn out to be important parts of the curricula. With a basic mandatory university education in mathematics, physics, chemistry and often biology within the bachelor programmes, German geoscientists have a good basis to quickly and competently familiarize themselves with a variety of scientific issues. The bachelor's as well as the master's degree is completed with a scientific thesis, which in most cases needs to be defended by the students, similar to a PhD thesis, leading the students to independent project management and a scientific workflow.

Direct insights into professional life are guaranteed by internships lasting between four and twelve weeks, which are part of the curriculum at most universities in Germany. Furthermore, many students take advantage of the opportunity of integrating a stay abroad into their studies, either as an internship or as a study exchange semester (e.g. via ERASMUS+ or any other international exchange programme).

While the geosciences curriculum of bachelor's programmes is supposed to be broad, the master's programmes offer the opportunity to specialise. The spectrum of specialisation ranges from e.g. applied geosciences to biogeosciences, climate system science, geophysics, georesources, geohazards, geoenergy, mineralogy and geomaterials, and marine geosciences. However, the geoscientific educational landscape in Germany continues to change (cf. Wefer, 2010). Bachelor's programmes such as Geosciences and Applied Geosciences are still the majority, but we are noticing a tendency towards more interdisciplinary programmes with adjacent scientific disciplines included. Environmental topics, climate, ecology and biogeosciences are gaining ground, as well as combined programmes with a special focus on management and sustainability. While this tendency is increasing the disciplinary diversity among geosciences graduates, it causes a loss in sharpness of their competence profiles, with negative impacts on their employability e.g. in the engineering sector, where other professions immediately fill these gaps.

Another consequence of the increasingly divers geosciences education landscape in Germany is that most prospective students (either after finishing their high-school education or after graduating with a bachelor's degree) face challenges obtaining a clear and holistic overview about the available study programmes in geosciences. It is impossible to become familiar with the quite different curricula of all geoscientific study programmes before making a decision. From the quality assessment surveys, we know that the students' decision on where to study is mainly based on where they live or would like to live (bachelor's) or the research profile of a particular geosciences faculty (master's). In consequence, many students do not make use of the extensive mobility options that arose from the Bologna Reform and may not always study within the programmes whose curricula suit their personal interest best.

Future challenges in German geosciences education

Geosciences education in Germany is excellent, diversified and well positioned – nevertheless future challenges lie ahead. In recent years, most universities offering bachelor programmes in geosciences have face a gradual decrease in entrants (***Fig. 1***). While small cohorts allow better targeted support for students, a continuously decreasing number of students can cause severe problems for small institutes in maintaining their offers. Combined with the retirement of teaching staff, this trend especially endangers the continued existence of teaching and research groups in the so-called 'small disciplines', e.g. crystallography, mineralogy and palaeontology.

Nevertheless, we welcome the development of geoscientific education towards a science that is becoming more and more oriented on socially relevant needs by opening up to other disciplines within Earth System Sciences. However, the entire breadth of geosciences education during the bachelor's programme that provides the required scientific and applied basis for further academic training will also be necessary in the future. Based on this broad education basis, the highly diverse master's programmes offer students the possibility to expand their scientific expertise further.

Although a rising number of graduates in geosciences are later confronted with and work on the most pressing societal issues such as global climate change, energy and raw material supply, as well as geo- and environmental risks (EFG, BDG, & GSL, 2015), most curricula do not yet include aspects of geoethics. Geoethics training, e.g. how geoscientific content should be communicated, would empower our alumni to work more effectively at the interface of future geoscientific and societal issues.

Even if the large number of graduates in geosciences compared to previous decades has been absorbed by the good economic situation over the last years, we must be concerned about the uncertain economic development connected with the COVID-19 pandemic. The balance between the number of graduates and the labour market demand needs to be maintained. In any case, additional efforts are necessary, e.g. to strengthen the role of geosciences in school education, which in turn can help to create greater visibility for geosciences.

Moreover, also a changing labour market requires us to adapt geosciences study programmes on a regular basis. We are currently witnessing how the field of hydrocarbon exploration is becoming less important as a potential employment sector, whereas other socially relevant areas are evolving, e.g. environmental geosciences, sustainable resource geology and other topics like carbon storage, nuclear waste management and the use of renewable energy resources. In addition, we must face up to the need to digitise our study and working lives. Modern study programmes are on the way to address these topics to ensure the training of qualified specialists capable to tackle future issues in geosciences.

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Out-of-classroom activities for geoscience education

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The aim of this paper is to suggest and present out-of-classroom educational activities that will enhance students' interest in geosciences. Direct experience with concrete materials and processes enables abstract concepts to be formed and aids comprehension, according to the literature. Furthermore, we suggest combining good structural and conceptual teaching of earth sciences with attractive interesting topics, i.e. making earth sciences something present and related to daily life. The goal of the present study is to create worksheets and methodological approaches for secondary schools teachers' use. The proposed activities will be based on student contact with geological services (agencies) through visits to their workplaces and interviews with geologists, as well as visits to museums and exhibitions.

Le but de cet article est de suggérer et de présenter des activités éducatives hors classe qui renforceront l'intérêt des élèves pour les géosciences. Selon la littérature, l'expérience directe avec des matériaux et des processus concrets permet de former des concepts abstraits et facilite la compréhension. De plus, nous suggérons de combiner un bon enseignement structurel et conceptuel des sciences de la terre avec des sujets intéressants et attrayants, c'est-à-dire faire des sciences de la terre quelque chose d'actuel et lié à la vie quotidienne. L'objectif de la présente étude est de créer des fiches de travail et des approches méthodologiques à l'usage des enseignants du secondaire. Les activités proposées seront basées sur le contact des étudiants avec les services géologiques (agences) à travers des visites de leurs lieux de travail et des entretiens avec des géologues, ainsi que des visites de musées et d'expositions.

El objetivo de este artículo es sugerir y presentar actividades educativas fuera del aula de clases que potenciarán el interés de los estudiantes por las geociencias. La experiencia directa con materiales y procesos concretos permite la formación de conceptos abstractos y ayuda en su comprensión, conforme a la literatura. Además, sugerimos combinar una buena enseñanza estructural y conceptual de las ciencias de la tierra con temas interesantes y atractivos, es decir, hacer de las ciencias de la tierra algo presente y relacionado con la vida cotidiana de los estudiantes. El objetivo del presente estudio es crear hojas de trabajo y enfoques metodológicos para uso de los profesores de secundaria. Las actividades propuestas se basarán en el contacto de los estudiantes con los servicios geológicos (agencias) a través de visitas a sus lugares de trabajo y entrevistas con geólogos, así como visitas a museos y exposiciones.

Introduction

In order to adequately understand the concepts of geology, it is necessary to refer to earlier times and at the same time to build scientific models that are not governed by the usual natural laws that a student has been taught. This process is probably of the greatest difficulty during teaching geosciences, which has made geology a relatively inaccessible and unfriendly science for the students of Greek schools, in combination with the strictly scientific written language and the large volume of concepts to be mastered (Makri, 2015).

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Interdisciplinary knowledge is required for the comprehension of Geosciences, leading the teachers to the need to adopt design and implementation of outdoor teaching strategies. In environmental research, it is accepted that a person who is aware and trained in environmental issues is able to develop an environmentally friendly attitude and mentality towards nature and the processes that occur in it. In times of environmental crisis and relentless transformation of the environment, through education geoscientists can lead the effort to prepare society for the changes to come and how to cope with them. Modern society demands citizens to rationally manage environmental resources, as well as the consequences of geological phenomena, by understanding the mechanism of their creation. It is extremely doubtful whether these issues can be approached without basic knowledge about terrain, water, weather, rocks, solid and liquid fuel extraction, earthquakes, landslides and mining activity. Geoscientists themselves have a significant responsibility for this situation, as they are often trapped only in the production and provision of scientific information. They should also be taking an active role in all aspects of the educational process. In the present work, two different ways are proposed to assist teachers in integrating geology into extracurricular activities.

There are various methodologies for preparing out-of-classroom activities, such as those suggested by Fedesco *et al.* (2020), who identified specific tips to help educators have a successful field-based learning experience. For their application in school it is desirable to consider the following:

1. Record in detail in a document the goals and expectations from the

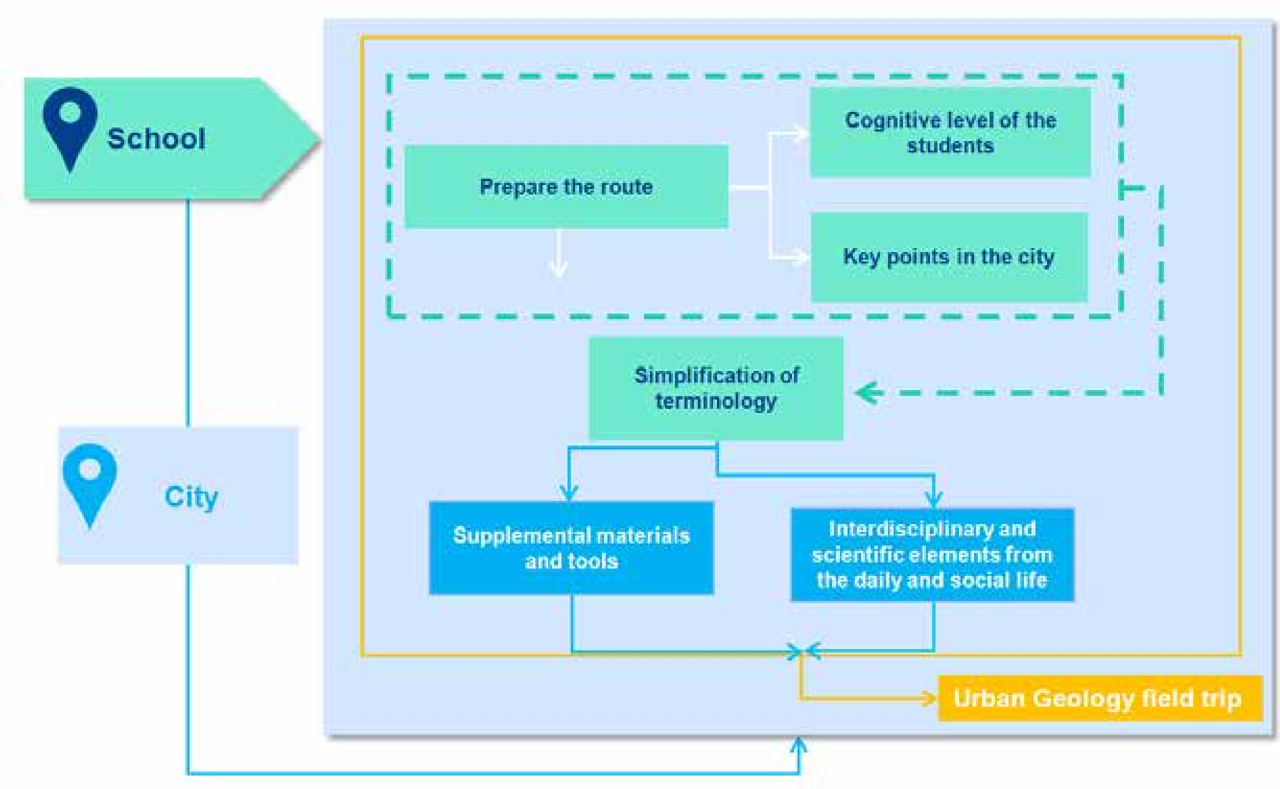

Figure 1: Methodology for the organisation of an urban geology field trip.

extracurricular activity.

2. Prepare an evaluation sheet for the students regarding the extracurricular activity they participated in.
3. Describe in detail the sections that the activity includes: a) duration, b) the staff of the visiting institution and c) special access and security requirements, if any.

Worksheet organisation 1: Urban Geology

As Bampton says, urban geology is 'the study of the inorganic components of cities and of Earth surface processes in their environs' (Bampton, 1999, p. 1). To understand the environment of a city, it is essential to consider the interplay between environmental and social components. Urban geology can be a key field of extracurricular activities, because it can answer questions such as: i) the field of work of geologists, ii) the professional field of geology applications in my city and iii) the importance of geology for my city.

For a successful urban geology activity, students should:

I. Observe basic geological structures;
II. Connect the learned knowledge with experiential experiences;
III. Discover geological phenomena in their daily life;
IV. Evaluate the impact of human activity on the urban environment.

The field of application of the activity is the city and all its elements. More specifically, one can observe and search for material in places such as:

- Floors and lined walls of apartment buildings and shops;
- Indoor-outdoor areas of public buildings (cultural buildings, administrative buildings, etc.);
- Indoor-outdoor areas of churches;
- Decorative and building mat*erials.*

When planning the activity, here are some important instructions and methodology that should be taken into account in order to have a positive result (***Figure 1***).

Step 1: First prepare the route by checking out different alternatives. This way you will be sure that you have covered all parts of interest in your city.

Step 2: Prepare the route based on the cognitive level of the students. It is important for the students to be able to identify some of the knowledge they already have in order to pique their interest.

Step 3: Strictly avoid scientific terms and simplify your terminology. The purpose of the activity is to make geosciences familiar, so the vocabulary should be familiar from the daily teaching at school.

Step 4: Use as many supplemental materials and tools as possible and necessary, such as maps, compass, magnifier, etc.

Step 5: Include interdisciplinary and scientific elements from the daily and social life of the city in the activity.

After taking these steps, check the safety measures and make sure that the route to the city that you have prepared meets the safety rules for your students.

The observations that an urban geology activity for students should include can be summarised as follows:

- Geological observations
  - Are there any rock formations along the way?
  - Is there anything remarkable about geomorphology?
  - How has geomorphology been affected by human activities?
- Observations on human structures
  - What material is used to build the monuments?
  - Can other elements be observed (tectonic, stratigraphic, paleontological, etc.) in structural or decorative stones?

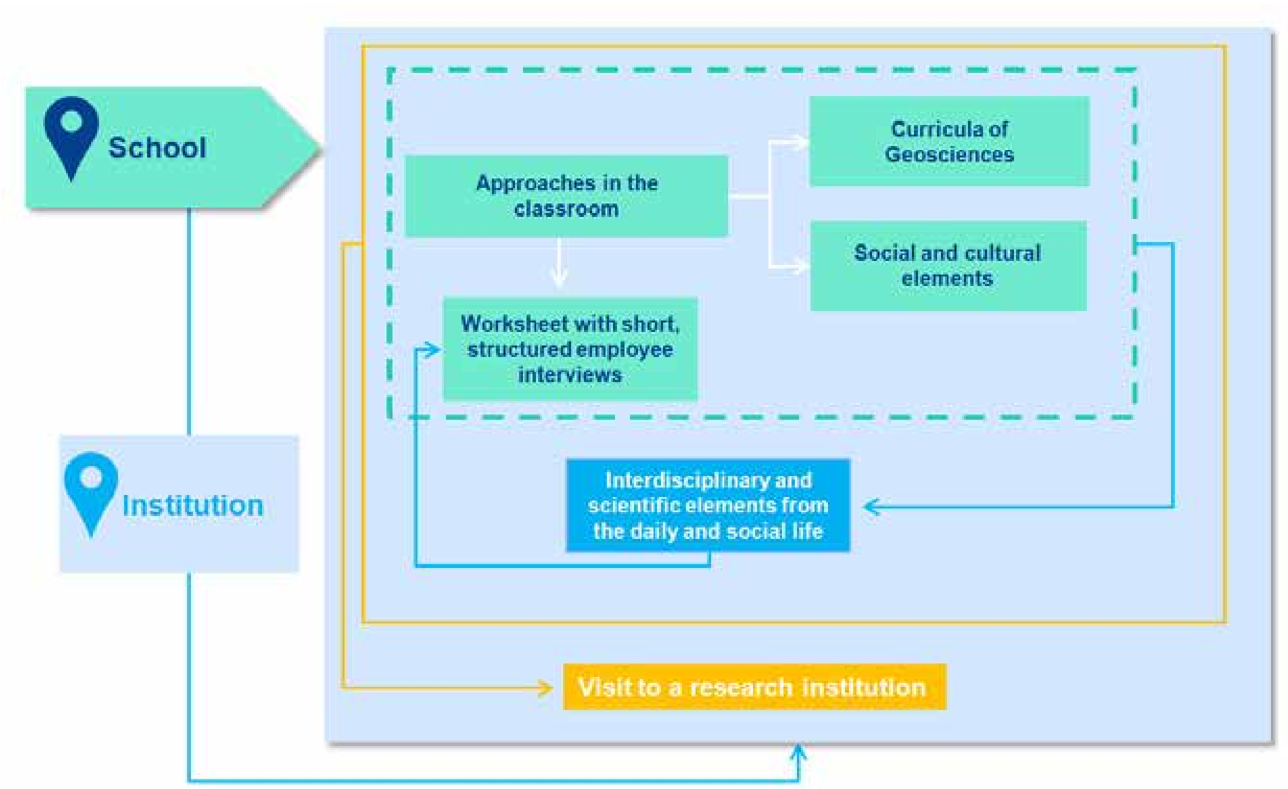

Figure 2: Methodology for the organisation of field site visits.

- Historical significance of geology
  - How did local geology affect the structure and development of the city?

Typical and notable examples of urban activities for students are mentioned in the seminar entitled "Field Geosciences Teaching Module: Cities and Exomuseums" of the GEOschools Project (Fermeli *et al.*, 2014).

Planning field trips is the most critical step for most teachers. (Kean & Enochs, 2001).

Worksheet organisation 2: Visit to a research institution

According to modern pedagogical approaches, science should not only impart to students basic scientific knowledge but should also prepare citizens to make informed decisions in society (Mansour, 2009). New educational approaches of teaching, such as exploratory learning, where students are actively involved in the learning process, attract the interest of students and contribute to the acquisition and cultivation of important skills (European Commission, 2007). Research institutes and institutions as well as initiatives linking students to the scientific way of thinking can play an important role in general education, providing students and teachers with new opportunities to develop important skills that will make them active citizens of the twenty-first century and competitive within any work and social group.

The main goal of the proposed action is to introduce students to the research mindset so that they can understand and relate to the principles of science they learn in the curriculum. At the same time, through the research process, students will be made aware of the effects of geological phenomena in everyday life. Students have the opportunity to enter the role of researcher and therefore to apply the stages of a scientific method. The aim is for students to develop critical thinking and problem-solving skills so that they can formulate solutions scientifically and identify patterns and methodologies that they can apply to other problem-solving through collaboration with their classmates.

Specifically, the activity will put the student in a situation to:

- Identify a phenomenon (e.g. a natural hazard);
- Observe natural phenomena and interpret them scientifically (e.g. seismological observations, paleontological findings, climatic and meteorological data);
- Perform experimental exercises;
- Process data and come to conclusions;
- Judge the consequences of natural phenomena using with scientific criteria.

When planning the activity, the organiser should consider important instructions and methodology. Information should be acquired, such as whether the institution accepts student visits and how the safety rules are met, and visits to dangerous sites such as construction sites and mines should be avoided. The methodology for the organisation of field site visits to institutions is presented as follows (***Figure 2***):

Step 1: Choose an institution that is close to the school. The aim is that students could get in touch not only with the research and the profession of geologist, but also with a professional structure of their area.

Step 2: The subject of the institution should have been introduced in the classroom. It is recommended that there is a class briefing on the role of the organisation you will be visiting.

Step 3: Contact the person in charge of the organisation beforehand. Prepare them for your students' level of knowledge and needs.

Step 4: Create a worksheet with short, structured employee interviews. The aim is for students to gather as much information as possible about the subject matter.

Step 5: Connect the activity with social and cultural elements of the area in which it is located.

Suitable bodies for the organisation of extracurricular activities could be the national geological survey, energy supply companies, observatories, seismological laboratories, etc.

In the era of the COVID-19 pandemic, extracurricular activities can be an alternative approach for educational practice, as an outdoor activity. It is noted that the Ministry of Education and Religious Affairs in Greece recommends outdoor activities during the COVID-19 pandemic. At the same time, it can be an opportunity to connect geosciences with society and everyday life. The above methodology and objectives can be used for the organisation and selection of extracurricular activities.

Conclusions

In the present article, two proposals for the integration of extracurricular activities for the Geosciences are presented. Practical work stimulates interest in geology and allows students to actively participate in gaining new information, having a direct effect on establishing links between what they learn and the reality of the outside world (Gomes *et al.*, 2016). The goal was to provide teachers with an instant-use guide in the classroom. The activities will help the students to be in direct contact with the subject of geosciences and at the same time to avoid the daily teaching in the classroom, which is not recommended due to the COVID-19 pandemic. They can also contribute to the increased interest of students in the profession of geology, as they will come into direct contact with the subject and career opportunities in it. Finally, extracurricular activities in urban geology and visits to research centres and institutions are a unique opportunity to connect geosciences with society and everyday life.

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Geoscience education through environmental ICT storytelling in primary education across Europe

N. Evelpidou, D. Pontikou, A. Komi, G. Saitis, K. Giannikopoulou, M-A. Gatou and A. Petropoulos*

Raising awareness for sustainable development and environmental consciousness is an alternative teaching approach of geosciences in primary education. Through our methodology this is achieved by strengthening teachers' profile to effectively coach students to work on several environmental issues. By creating a teacher's guideline handbook, in accordance with the educational targets and regulations of EU countries, teachers acquire a fresh perspective on teaching environmental sciences. They also gain scientific knowledge in five educational topics through the implementation of five mini-projects. An e-book enriched with the pupils' digitalised environmental stories was designed to attract students and motivate them to engage environmental issues. The final product acts as a triggering factor for the much-needed environmental awareness of pupils around Europe.

La sensibilisation au développement durable et à la conscience environnementale est une approche alternative d'enseignement des géosciences dans l'enseignement primaire. Grâce à notre méthodologie, cet objectif est atteint en renforçant le profil des enseignants pour inciter efficacement les étudiants à travailler sur plusieurs questions environnementales. En créant un guide pédagogique, conformément aux objectifs pédagogiques et aux réglementations des pays de l'UE, les enseignants acquièrent une perspective à jour sur l'enseignement des sciences de l'environnement. Ils acquièrent également des connaissances scientifiques sur cinq thèmes pédagogiques grâce à la mise en œuvre de cinq mini-projets. Un livre électronique enrichi des histoires environnementales numérisées des élèves a été conçu pour attirer les étudiants et les motiver à s'engager sur les questions environnementales. Le produit final agit comme un déclencheur de la sensibilisation environnementale indispensable aux élèves de toute l'Europe.

Concienciar sobre el desarrollo sostenible y la conciencia ambiental es un enfoque de enseñanza alternativo de las geociencias durante la educación primaria. A través de nuestra metodología, esto se logra fortaleciendo el perfil de los docentes para capacitar de manera efectiva a los estudiantes para trabajar en varios temas ambientales. Al crear un manual de directrices para profesores, conforme a con los objetivos educativos y las normativas de los países de la UE, los profesores adquieren una nueva perspectiva sobre la enseñanza de las ciencias ambientales. También adquieren conocimientos científicos en cinco temas educativos a través de la implementación de cinco mini-proyectos. Se diseñó un libro electrónico (e-book) enriquecido con las historias ambientales de los alumnos para atraer a los estudiantes y motivarlos a involucrarse en cuestiones ambientales. El producto final actúa como un factor desencadenante de la tan necesaria conciencia medio ambiental de los alumnos de toda Europa.

Introduction

Since the beginning of the 21st century, the vision for sustainable development has undoubtedly laid its foundations in education. A natural consequence has been the integration of the concept of sustainability into the national curriculum of most European countries. Studying the 17 sustainable development goals (SDGs) reveals the strong links tying geosciences and natural environment with sustainability (energy, climate change, biodiversity, geophysical hazards, hydrogeology, etc.) (Gill, 2016). Taking this under consideration, educating students on issues related to the environment and geosciences is deemed more necessary now than ever before.

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Training on the subject of Education for Sustainable Development (ESD) has been absent from the curriculum in primary education (Ham & Sewing, 1988) and remains so even today (Kadji-Beltran *et al.*, 2013). Furthermore, it is observed that teachers misunderstand environmental issues, or lack accurate knowledge on them (Francek, 2013). As a result, teachers have difficulties, do not feel confident, and even avoid the implementation of similar programmes (Ham & Sewing, 1988). According to Kadji-Beltran *et al.* (2013), the way in which teachers will approach the learning process is just as important as the content of teaching. For all of these reasons, teachers' education in natural environment and geosciences is a vital priority (Ham & Sewing, 1988; Kadji-Beltran *et al.*, 2013).

Through the Erasmus+ KA201 project "Environmental Stories for Sustainable Development - EnvStories" our goal is strengthening teachers' profile so that they can effectively coach students to deal with several environmental-geosciences issues. The first step into achieving this goal was the design of the teacher's guideline handbook. The handbook includes methodological tools and teaching approaches proposed for the implementation of ESD programmes, as well as the scientific background for five environmental topics, accompanied by five proposed projects to be implemented. The second step was the implementation of a one-week training school. Teachers and students participated in organised training activities to gain real-world experience and raise their environmental awareness.

In the modern world, in order for anyone to keep up with the technological advancements and the ever-evolving digital tools, basic knowledge and ability to handle technology and its applications is a mandatory minimum skill (Lim & Oakley, 2013). The benefits of utilising Information and Communications Technologies (ICT) in primary education have been studied thoroughly and are generally acknowledged (Lim & Oakley, 2013).

By utilising ICT in the educational process, students are provided with access in a variety of different sources of information and educational material (Smeets, 2005). ICT also appear to act as a motivation factor for learning, especially for less capable students (Venezky & Mulkeen, 2002). Additionally, ICT can contribute to the better understanding of complex concepts and processes with the use of explanatory multimedia material and simulation software, it can facilitate collective work among the students, and it can act as a tool for them to test their own knowledge (Smeets, 2005). There is also the possibility of easily providing personalised educational material which can be proved extremely useful, particularly in special education. Finally, ICT seems to serve effectively active learning theories that support "experiential learning" instead of a "teaching" method. In such a case the role of the teacher is to merely guide the pupils and provide them with the proper tools that will enable them to learn on their own. The concept of innovative use of ICT has become prominent in educational practices during the last years. It refers to the creative and unconventional use of whatever ICT equipment is available in order to supplement the learning experience in the classroom or outside of it (as e-learning or extra-curricular activities) (Venezky & Mulkeen, 2002).

Within the framework of the EnvStories project 20 e-books were developed by the pupils through the EnvStories online platform. Fueled by the offered training material and the guidance of their teachers, the students created interactive stories related to prominent environmental problems with their respective solutions. These stories are presented in the e-books.

Methodology

Handbook

Educational purpose

Within the framework of the EnvStories project, an experiential approach was chosen for the five environmental topics included in the teachers' handbook. This approach results from the combined application of the Howard Gardner's theory of multiple intelligences (MI) in the educational process and of the Kolb's learning theory (***Figure 1, Table 1***). According to the MI theory, all people have at least 7 different types of intelligence equally important, but not equally developed (***Table 2***). People learn by utilising these different types of intelligence (Gardner & Hatch, 1989; Griggs, *et al.*, 2009).

According to McFarlane (2011), the MI theory is based not only on acceptance, but also on understanding the value of diversity, making this one of the most effective teaching methodologies of the 21st century. The teacher, under the assumption that a different learning style is appropriate for each student, has the opportunity to prepare his/her teaching in a way that equal oppor-

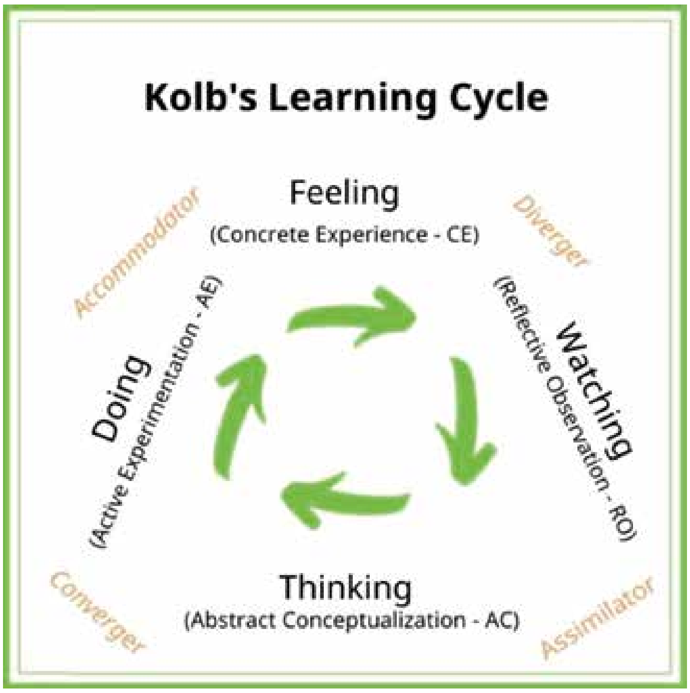

Figure 1 Kolb's learning theory.

Table 1: Types of people, characteristics and learning tools, according to the four stages of Kolb's experiential learning cycle.

Types of people	***Characteristics***	***Learning Tools***
Accommodator (doing and feeling - CE/AE)	• *They rely on intuition rather than logic.* • *They emphasise exploration through experience.* • *They are spontaneously involved in new experiences.*	• *"Hands on" activities* • *Role games* • *Team games* • *Labs*
Diverger (feeling and watching - CE/RO)	• *They collect information and process it carefully.* • *They express opinions only when they are certain of their correctness.* • *They choose observation from action.* • *There are many brainstorming ideas when solving problems.*	• *Projects* • *Reading* • *Use of audiovisual interactive media*
Assimilator (watching and thinking - AC/RO)	• *They have developed reasoning ability.* • *They develop a unified theory for the experience.* • *They analyse a wealth of information to support their theory.*	• *Use of audiovisual interactive media* • *Brainstorming* • *Projects - Research*
Converger (doing and thinking - AC/AE)	• *They emphasise the facts and use the experiment to draw conclusions.* • *Strong at finding solutions to problems.*	• *Projects* • *Simulating experiments* • *"Hands on" activities* • *Case studies* • *Use of audiovisual interactive media*

Table 2: The different types of intelligence according to Gardner, their characteristics and teaching tools.

Types of intelligence	Characteristics	Learning Tools
Linguistic	• *Ability to use oral and written language correctly.* • *Proper use of language.* • *Good memory.*	• *Writing and narrating* • *Commenting on events* • *Speeches* • *Debate*
Logical -Mathematical	• *Ability to solve mathematical calculations.* • *Solving logical problems.*	• *Experiments* • *Puzzle games* • *Creating charts* • *Categorisation of concepts*
Bodily - Kinesthetic	• *Ability to use body as a means to convey meaning.* • *Kinetic skills.* • *Kinesis synchronisation.* • *Physical memory.*	• *Sports* • *Dance* • *Theatrical games* • *Dramatisation* • *Sculpture*
Musical	• *Musical sensitivity.* • *Ability to recognise and synthesise musical patterns.* • *Rhythm recognition.*	• *Use of musical instruments* • *Singing* • *Musical toys*
Spatial	• *Ability of spatial representations.* • *Good orientation.* • *Visual memory.*	• *Charts and maps* • *Art - Drawing* • *Visual representation of concepts* • *Sculpture*
Interpersonal	• *Ability to recognise and understand the intentions and desires of other people.*	• *Collaborative activities* • *Discussion* • *Theatrical games* • *Dramatisation*
Intrapersonal	• *Ability to understand himself.* • *Identification of his weaknesses and strengths.*	• *Self-awareness and self-concentration exercises* • *Projects* • *Individual tasks*
Naturalist	• *Ability to connect with the natural environment and protect it.* • *Love and interest for the different forms of life on the planet.*	• *Actions - field trips* • *Projects* • *Labs* • *Arts*

tunities to students are provided, resulting in school success (Griggs *et al.*, 2009; Pritchard, 2009). Students who are taught to approach the learning process more efficiently, discovering their strengths at the same time, enjoy similar benefits (Griggs *et al.*, 2009).

The utilisation of MI theory in our programme resulted in the development of the term "EnvironmentART education". This term includes all art forms (visual arts, movement, literature, photography and theatre-music-video). With this term, it is suggested that forms of art may be used by the teacher himself/herself as a tool for the presentation of each topic. It is also proposed that they can constitute a powerful tool for the students, as forms of art may act as the vehicle for new ways for approach, expression and presentation of any environmental topic.

The teacher's guide, apart from the pedagogical approach, includes all the scientific background necessary for the full understanding of the five topics under study. Additionally, considering the 17 goals of sustainable development as well as the goals of the curriculum of the participating countries, 5 projects were designed with the respective worksheets. These projects are available to be used by any primary school teacher who wishes to implement an ESD programme at their school.

Scientific purpose

The main aim of our novel teaching approach of geosciences in primary education is to cultivate the spirit of environmental consciousness and sustainable development among children of young age. This approach will lead to environmentally conscious citizens who will handle the environment with respect, not contributing to its constant degradation. Through consulting this handbook and implementing it into the teaching process, teachers will acquire a proper background – both educational and scientific – in five modern environmental topics that they are very likely to encounter in their countries. More specifically, the examined topics are (a) waste management and recycling, (b) natural environment, (c) health and environment, (d) geophysical hazards and (e) natural resources.

In the scientific part of the developed handbook, the aim was to simplify and highlight basic terms that describe each topic, as well as to point out their main effects in human societies and the ecosystems. Basic environmental problems were also presented, alongside with respective response measures, utilising diagrams, colourful pictures and text boxes. The first topic analysed in the handbook is that of "waste management and recycling", which describes the waste management hierarchy and modern waste management techniques, such as recycling, composting, development of landfills and combustion with energy recovery. Secondly, within the framework of the topic "natural environment", terms such as atmosphere, hydrosphere, geosphere, biosphere, flora and fauna are presented and explained. In addition, the water cycle and biodiversity and its preventive measurements are examined. The third topic addressed in the handbook is that of "health and environment". In this chapter air, soil pollution and water pollution are described and important factors contributing to them are listed, in order for the teachers to gain a broader view of the different pollution categories and the various measures that, if applied by the young generation, will lead in the long run to the mitigation of phenomena such as the greenhouse effect and ozone layer weakening. The fourth chapter, "geophysical hazards", includes earthquakes (mechanism, pre- and post-earthquake phenomena and things people must do during and after an earthquake), volcanoes (formation and location, main parts and types), floods (possible causes, effects, things people have to do in case of a flood and preventive measurements), wildfires (types, causes and preventive measurements), landslides (causes, impacts and preventive measurements) and coastal erosion (causes, location of its occurrence and preventive measurements). Lastly, within the framework of the topic "natural resources", the term of natural resources depletion is highlighted and explained, as well as water management practices and soil degradation preventive measures, as human societies rely heavily both on water and territorial resources to develop. The difference between renewable and non-renewable energy sources is also explained, and finally, alternative forms of energy are presented (nuclear and hydrogen combustion).

Figure 2: Outdoor activities.

Figure 3: EnvironmentART activities.

Training activities

Interactive activities play a significant part in the proposed teaching approach, especially those that take place outdoors. Through those activities, pupils are trained to become more familiar with the geo-environment and geosciences. This way environmental education becomes more meaningful and memorable, enhanced by real-world experiences, rather than being limited by the simple attendance of an instructional programme inside a classroom. In accordance with our methodology, a one-week educational training school was organised in Athens, Greece. All participants – pupils and teachers – had the opportunity to search for ideas and solutions regarding the five environmental issues explored in the teacher's handbook. Various activities were carried out in places of environmental and cultural importance, where the "learning by doing" method was applied. The organised activities are part of the teaching methodology and teachers are encouraged to apply this approach to other environmental subjects.

During outdoor activities, pupils had the time to explore and observe in order to focus on the issues that might be a point of concern for them or the environment (***Figure 2***). Part of the outdoors activities was the demonstration of issues related to educational objectives such as geology, physical geography, the water cycle, recycling and waste disposal, fossil fuels as non-renewable energy sources and even astronomy in a creative educational way that provides an opportunity for learning in a more entertaining approach. Furthermore, pupils were assigned by the training school instructors to work in groups of 5 to complete learning activities, share ideas and discuss their experiences during the field trip. The multimedia material (images, videos, sounds) gathered by the pupils and their teachers were used for their digital stories (e-books). Pupils were instructed to express their experiences from the training school through any of the art forms (***Figure 3***) Their imagination and creativity led the pupils to fulfil the assignment in the forms of song writing, paintings and photographs, always supported by their teachers.

EnvStories platform and e-book

During the EnvStories project, 20 different e-books were developed by students, presenting interactive stories related to environmental problems with effective solutions. Teachers assisted pupils to develop these stories using the project's handbook and an online platform for the co-creation of interactive stories (in the form of e-books). Pupils worked collaboratively using the platform in order to produce stories that communicate complex concepts to others, structuring information and data in meaningful and useful ways (storytelling) (***Figure 4***).

The content of the e-books is specifically defined and relevant to the training topics developed during the project and provides substantial information to pupils. Digital material relevant to the environmental problems and possible solutions was designed and offered for free through the platform to support students' work. Each school was assigned different subjects relevant to local problems. Through activities carried out in places of environmental interest, the participants had the opportunity to make realistic proposals in their stories (e-books) for the protection and conservation of those areas, which could be possible if implemented by many citizens. In this regard, the conservation of each area's environment as well as the promotion of the natural and cultural heritage will let us move towards sustainable development of each region in terms of environment, economy and society. The pupils' stories in the form of interactive e-books and the

Figure 4: EnvStories e-book creation.

teacher's guide will become publicly available at the end of the project.

Results and discussion

The need for an open-minded approach and flexibility in the way of teaching that arises from the use of the MI theory are main demands in education (McFarlane, 2011). In addition, the multitude of ways to approach students through the MI theory constitutes a new challenge for many teachers (Griggs, *et al.*, 2009). The application of these new methods resulted in the successful coverage of a larger percentage of the objectives of the curriculum. This was achieved also by students who could not follow the traditional teaching. Students discovered more about their potential and their limitations as performance anxiety receded. They better understood the value of diversity and learned to work together for a common cause. Reflecting on their experiences, they cultivated their critical ability, perceived the human-environment relationship from a new angle, and acquired a willingness to take an active part in resolving environmental issues.

During the training school, pupils were requested to fill in evaluation sheets, one for each day of the training school. The purpose of this evaluation was to identify how activities that took place during the training school affected the pupils. Most of the participants pointed to the main characteristics of each activity from which they gained additional knowledge and experience by doing the indicted activities. Pupils got involved in numerous activities, learning each day something new and useful, not only for the purposes of the project but for their everyday life, as they were educated on general science issues. It was an indisputable fact that through the activities, pupils raised their will to learn more about what triggered the most their curiosity. Finally, the experiential approach of the training school motivated the pupils to participate actively not only on their own, but also in groups, in order to collaborate and share experiences and their cultural background.

Pupils used their imagination to create realistic proposals in their stories (e-books) for the protection and conservation of those areas that have the potential to be implemented by many citizens. Finally, the e-books constitute a powerful tool which serves as an inspiration to even more pupils about learning for the sustainable environment.

Acknowledgement

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Student enrolment in geology from a systemic earth science education perspective: an Italian case study

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The knowledge of our planet should represent a common background for active and responsible citizenship and should be provided by the school. Although earth science is present in all Italian school curricula, most teachers do not have a strong geological background and that affects earth science education. On the other hand, the number of students that enrol in geology as an academic major has significantly decreased in the last 20 years. In this paper we suggest that the teaching should be suggested to geology students as a career possibility, so to improve the quality of the geological education in school and also on the enrolment in geology courses.

La connaissance de notre planète doit représenter un fond commun pour une citoyenneté active et responsable et doit être apportée par l'école. Bien que les sciences de la terre soient présentes dans tous les programmes scolaires italiens, la plupart des enseignants n'ont pas une solide formation géologique et cela affecte l'enseignement des sciences de la terre. D'autre part, le nombre d'étudiants qui s'inscrivent en géologie en tant que discipline académique a considérablement diminué au cours des 20 dernières années. Dans cet article, nous suggérons que l'enseignement soit proposé aux étudiants en géologie comme une possibilité de carrière, afin d'augmenter la qualité de l'enseignement géologique à l'école ainsi que l'inscription aux cours de géologie.

El conocimiento de nuestro planeta debe representar una base común para una ciudadanía activa y responsable el cual debe ser proporcionado por las escuelas. Aunque las ciencias de la tierra están presentes en todos los planes de estudios de las escuelas italianas, la mayoría de los profesores no tienen una sólida formación geológica y eso afecta la educación en ciencias de la tierra. En otro orden de ideas, el número de estudiantes matriculados en cursos de geología como especialidad académica ha disminuido significativamente en los últimos 20 años. En este artículo recomendamos que se sugiera la docencia a los estudiantes de geología como una alternativa de carrera, para mejorar la calidad de la educación geológica en la escuela y también en la matrícula en los cursos de geología.

Introduction

At the end of high school few students decide to pursue a career in geoscience, and sometimes the low enrolment puts the existence of geology courses at risk. This is the situation in Italy and it is not a unique situation. And this is just the tip of the iceberg of a struggling structural situation related to earth science education system. Here we define the earth science education system as the ensemble of actors (schools and university students and professors), the teaching-learning process, and school and university curricula, as well as the interactions among them.

In the last decades many authors have emphasised the importance of earth science literacy for society. Mayer (1995) indicated the need to integrate the science curricula within the frame of the earth system, rather than following a strictly disciplinary approach, and concluded that earth science teachers should be leaders of this paradigmatic change. The philosopher Morin (1999) stresses the importance of earth science for the education of future citizens. Despite the recognised significance of that area of knowledge, the status and relevance of earth science are quite low, as proved by several international surveys (King, 2013; Greco & Almberg, 2016; Gorfinkiel & Frick, 2019). Orion (2017) defines this situation as a disturbing gap.

In this article, using secondary data that are publicly available on governmental websites, we analyse the Italian earth science education system with the aim to put forward some suggestions for the improvement of the actual situation. Italy is a country largely exposed to seismic, volcanic, and hydrogeological hazards; moreover, geoscience are represented, even if for a few dozen hours a year of teaching time, in all the national curricula of natural sciences. Both these features could be strengths in order to improve earth science literacy. In this context, the agreement between the National Association of Natural Sciences Teachers (ANISN) and the Italian Geological Society (SGI), to improve earth science teaching is welcomed.

After a short description of the earth science curricula in Italian primary and secondary school, we focus on geology higher education, as we identify it as the core where it is possible to make changes that could generate positive feedback on the whole earth science education system.

Earth science in school

The Italian school system is organised into 5 years of primary school (usually children start school at 6 years old), followed by 3 years of middle school and 5 years of high school.

Natural sciences – and earth science within them – are taught in all levels of Italian school, from the primary to high school. According to the most recent

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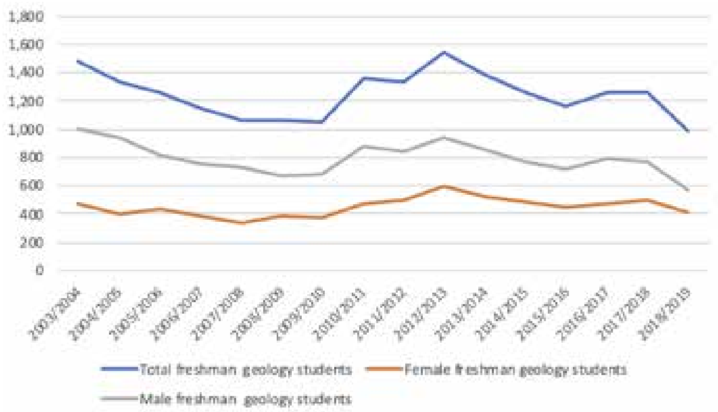

Figure 1: Total number of geologist freshmen, female and male geologist freshmen between 2003 and 2018.

National Indications of the Italian Ministry of Education (*Ministero dell'Istruzione, Università e Ricerca*, hereafter MIUR), in the first years of primary school the children are expected to observe the characteristics of soil and water and to interpret the natural transformations of the environment, including the cyclic changes due to astronomic movements (MIUR, 2012). Usually primary teachers are graduates of a 5-year pedagogical studies programme in higher education, with a deep background in pedagogy and general knowledge in all the disciplines, as a single teacher takes care of the whole spectrum of contents.

At the end of middle school, students should be able to explain astronomical mechanisms such as eclipses, the alternation of day and night and the sequence of seasons, to recognize the main rock types, to describe the internal structure of Earth and its movements – plate tectonics – and to identify volcanic, seismic and hydrogeological risks of the area they live in. In middle school, teachers are specialised in different subjects and one teacher takes care of math and science; math and science teachers may have very different academic science backgrounds, such as mathematics, physics, chemistry, agriculture, biology (in most cases), natural sciences and even geology.

Primary and middle school follow the same curriculum for all pupils, whereas at the end of middle school the students have to choose the kind of high school: lyceum (which prepares specifically for university), technical institutes (which prepare technicians for industry, commerce, tourism) and vocational institutes (which prepare skilled workers in specialised fields). Just to give an idea of the students' choices, in the 2019/2020 school year, around 55.4% of students enrolled in lyceum (among them 15.6% in sciences lyceum and 8.4% in applied sciences lyceum), 31% in technical schools and 13.6% in vocational schools (MIUR, 2019a). As a whole, in the 2019/2020 school year the total of 2,626,226 high school students was distributed as follows: 49.8% in lyceum (sciences 366,280, applied sciences 188,467), 31.5% in technical schools, and 18.7% in vocational schools. The comparison between the two distributions shows that the number of enrolled students in lyceum is significantly growing (MIUR, 2019b).

In high school, earth science topics are taught together with biology and, in lyceum, also with chemistry, within the Natural Sciences subject. All of the high school curricula include at least two hours per week of natural sciences in the first two years. The science-oriented high school (sciences and applied sciences lyceum) includes even more earth science contents. At the end of high school, students should have encountered the earth science topics which are shown in ***Table 1*** for the different high schools and the students' age, according to the 'Guidelines' (MIUR, 2010a, 2010b).

A study carried out by Realdon *et al.* (2016) shows that the time that teachers devote to earth science teaching gradually decreases over the five years of the upper secondary schools, to leave more space for chemistry and biology. For example, teachers often choose to anticipate the earth science topics of the 5th year (***Table 1***) in the 3rd year, to leave just biology and biochemistry in the last school year, which ends with the national final examination. This is probably due to the fact that the vast majority of natural science teachers are biologists, followed by natural scientists, and then other fields of science, including geologists in a few cases. This situation undermines the relevance of earth science in school and the teaching-learning processes, especially in the use of practical and field-based educational activities, which are one of the pillars of earth science education.

Earth science in higher education

Following the Bologna Process, higher education was reorganised into two cycles: the Bachelor Degree (1st cycle of three years) and the Master's Degree (2nd cycle, two years). In a few cases (e.g. for the degree courses in medicine) single-cycle master's degrees exist, lasting 5 or 6 years. Access to university requires a high school diploma for both 1st-cycle and single-cycle master's degrees, and the bachelor's degree for the 2nd cycle master's degree.

In the first cycle students will gain an adequate mastery of general scientific methods and topics and the acquisition of specific professional knowledge. In the second cycle, advanced level training is offered in

Table 1: Earth science topics in the science courses for the different Italian high schools and years, as suggested by the Italian Ministry 'Guidelines' (MIUR 2010a, 2010b).

High School	Lyceum	Technical Institute	Vocational Institute
First two years (age 14 and 15)	*- astronomical geography - geomorphology - hydrosphere - atmosphere*	*- astronomical geography - hydrosphere - atmosphere - rocks and minerals - volcanoes - earthquakes*	*- astronomical geography - hydrosphere - atmosphere - rocks and minerals - volcanoes - earthquakes*
Third year (age 16)	*- minerals and rocks - volcanoes - earthquakes - orogenetic processes*		
Fourth year (age 17)	*- No earth science contents*		
Fifth year (age 18)	*- meteorological phenomena - plate tectonics - relationships among hydrosphere, geosphere and atmosphere - biogeochemical cycles*		

order to perform highly qualified activities in specific areas.

In the following, we focus on the three-year course "Geological Science" (previously also called "Earth Science") because here we have the interface between high school and higher education. In Italy there are 28 universities that offer a first-cycle course in geological science[1]. The data provided hereafter refer to these universities, are freely available on the MIUR website[2] and cover the period 2003-2019.

Between 2003 and 2019 the number of students enrolled in the first year of the geology courses ranges from a minimum of 986 students in the academic year 2018/2019 to a maximum of 1,541 in 2012/2013 (in ***Figure 1*** the data are reported separately for the total freshmen geology students, female and male freshmen geology students). The peak of geology freshmen in 2012/2013 is evident not only in absolute terms, but also in percentage, taking into account that it corresponds to a period when overall enrolment in higher education was relatively low (***Figures 2 and 3***).

On a qualitative basis, it is noteworthy that the peak of enrolment in geology courses corresponds both to relevant seismic activity in Italy (earthquakes of Aquila, 2009, and Emilia, 2012) and to intense outreach activities on earth science linked to the International Year of Planet Earth (2008) and to the selection of students for the International Earth Science Olympiad (IESO) through the national Olympiad. In fact, the national selections for IESO give the opportunity to school students to become deeply engaged in earth science learning and to discover their interest in subjects that could be addressed in a geology course. Italy hosted the IESO in 2011. In the same period sessions on earth science education research became an established presence in geology scientific conferences.

Among students enrolled in the first year of the geology course there is a percentage of students that move from other courses; this percentage seems to have decreased in the considered period to reach the present value of 18%, which is lower than the mean of 23% of the overall three-year courses.

The gender ratio between females and males is quite imbalanced (nearly 1:3; ***Figure 4***), with the percentage of female students enrolled in geology courses having increased from a low of 30% in 2004/2005 to 42% in 2018/2019, mainly due to the decrease in enrolled male students. The percentage of female students varies quite a lot across the country, with the highest proportions of female students being in the islands (47%) and southern region (46%), whereas in the northern and central regions the percentage is 42% and 35%, respectively.

When we look at the type of school where geology freshmen come from, we discover that in the academic year 2018/2019 almost two thirds came from lyceum schools (61%), one third from technical schools (30%), few of them from vocational school (7%) and pedagogic school (2%). These percentages remain almost constant in the whole considered interval, with a slight positive trend for lyceum compared to technical schools. The number of students that choose geology coming from lyceum is below the corresponding value in other science courses (80% in biology, 83% in physics, 72% in chemistry, 78% in math).

At the end of high school, all Italian students are assessed in a national exam. If we look at the evaluation that the geology students gain in that examination, and we separate data for males from females, an interesting pattern appears (***Figure 5***). There is a significant difference in the percentage of females and males in each class of assessment, and females are predominant in the class of high assessment. As a whole, the majority of students have a low class assessment (***Figure 6***) and just 11% are in the top two class scores. Civil and environmental engineering, biology, and physics courses look much more effective in attracting high school students with the best assessments (***Figure 7***).

1 ***https://www.universitaly.it/index.php/cerca-corsi/universita***. The Geological Science course is identified by the code L-34, the Earth Science Course with the code 16.
2 ***https://anagrafe.miur.it/index.php***, data dowloaded on September 2020.

Figure 2: Total number of freshmen by academic year.

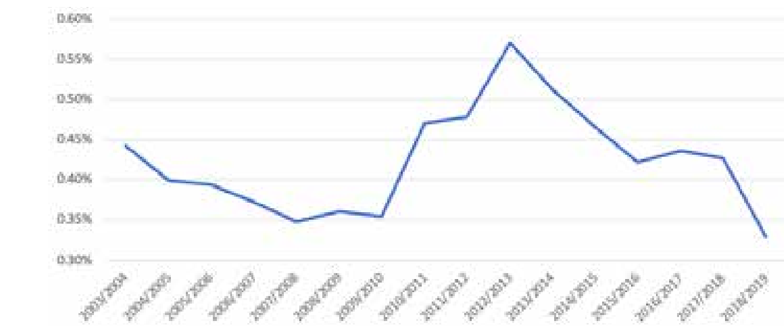

Figure 3: Percentage of geologist freshmen of the total freshmen in Italy.

Figure 4: Changes in the percentage of female freshmen in the considered period for geology courses in Italy.

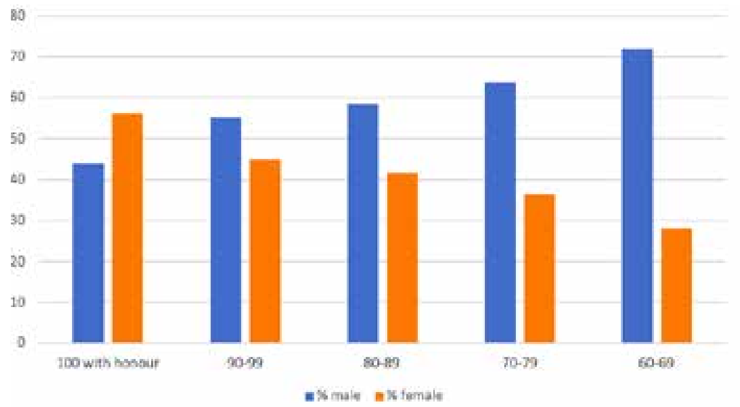

Figure 5: Distribution of male and female geology students by classes of assessment in the academic year 2018/2019.

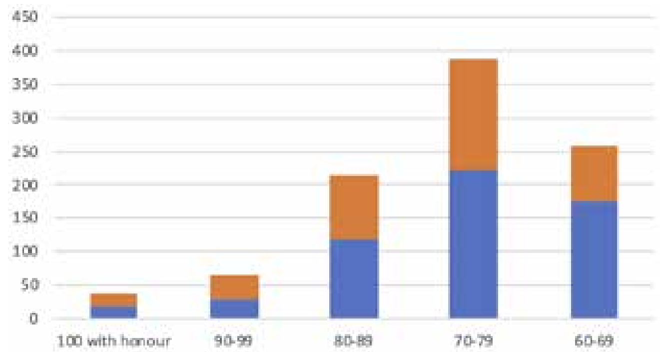

Figure 6: Distribution of geology freshmen by classes of assessment in the academic year 2018/2019.

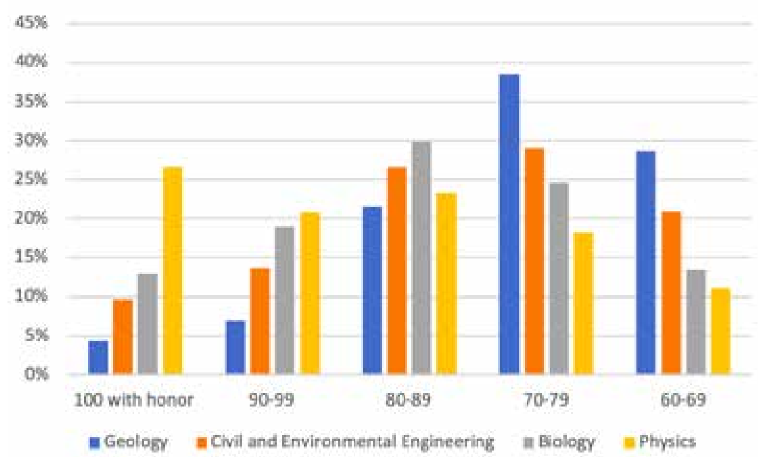

Figure 7: Entry grade distribution comparison among some scientific degree courses in the academic year 2018/2019.

Post-university formation

After a three-year degree, students can continue their studies with an additional two-year master's course such as geophysics (national academic course code: LM-85) or geological science (national academic course code: LM-86).

In the Italian academic system it is possible to integrate the master's programmes to take classes that will allow students to qualify for teaching at school. However, this is not a common choice of geology students. It is well-documented that – in Italy as well as in all of southern Europe – geoscience is generally taught by teachers without a strong geological background. In contrast, in northern Europe earth science contents, if any, are taught in a geography discipline by geographers (Greco & Almberg, 2016; King, 2013; Realdon *et al.*, 2016). In fact, the majority of the academic degrees leading to teaching earth science in middle and high schools do not involve a specific academic background in earth science. In particular, the majority of natural sciences teachers are biologists, a quite predictable output considering that the number of students enrolled in biology is almost nine times higher than the students enrolled in geology. This represents positive feedback that amplifies the gap.

Only in recent years have aspiring teachers been required to complement their training in areas of knowledge not covered in their academic career. This means, for example, that an aspiring teacher with a chemistry major will have to acquire credits in biology and earth science to be eligible for selection.

The importance of science teachers in determining the career choices of their students emerged in a survey that involved more than 700 geology students (Greco & Gualtieri, 2010). Among the motivations to choose the geology course, the degree of their teachers in geology or natural sciences represents an important factor. It is also important to note that in the same survey many geology students reported that they choose geology but they were also tempted by biology or natural sciences. From this data it seems that having more geologists as science teachers in high school could make a difference in motivating students' choice.

Conclusions

The Italian earth science education system presents several critical issues that affect the possibility of gaining significant literacy in earth science to the advantage of the whole society:

- there is a need to improve the high school curricula with better integration and organisation of earth science content;
- there are few school teachers with an earth science background;
- there are few school students who choose geology as a career;
- there are few geology students who invest the time and resources to get the education credits needed to become teachers.

We would like to focus on the last aspect because it is the one where the geological community, including geoscientists and professional geologists, could have more direct influence:

1. Including teaching as a possible career for a geologist is basically a cultural choice. Humans are social beings and geology students do not escape the influence of the community where they grow up. The way

the established geoscientists and professional geologists comment on teaching as a profession affects the perspectives and decisions of geology students.
2. Encouraging the geology students to obtain the academic credits that will allow them to teach at school will increase the spectrum of their job opportunities. In order to work as professionals, a geologist must be registered in the *Consiglio Nazionale dei Geologi* (CNG), which represents the category of their expertise, guarantees the quality of the service provided and offers continuous training. As of 11 September 2020 almost twelve thousand (11,835) geologists were included in the CNG. Of those, 1,751 are public employers, including all of the geologists that are working as school teachers (data from the secretary of the CNG). As a matter of fact, teaching is already one of the possible professional activities for a geologist.
3. Last but not least, education credits deal with communication and reasoning skills, which could benefit any professional geologist/geoscientist.

Of course, besides this challenging effort, the whole geoscience community should collaborate with school teachers to improve the quality of earth science teaching and learning. Different experiences, both at national and international level, highlight how the sharing of good practices or tools, possibly at low cost or for common use, can be the first step in the promotion of the more exciting, more engaging and therefore more effective teaching of earth science.

The new magazine of the SGI, 'GeologicaMente' (which can be translated as 'Geologically' or, with a play on words, 'Geological Mind'), dedicates a large space to the teaching of earth science. We hope that descriptions of laboratory, practical and field activities will be soon included, with strong cooperation among science teachers, geoscientists and professional geologists.

Our aim should be the sharing of good practices, but also increasing knowledge and training in this important scientific field, which also includes, unavoidably, attention to the environment, sensitivity to natural hazards and a culture that looks to the objectives of Agenda 2030 for sustainable development.

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Geoscience education using virtual worlds

Eleonora Paris, Annalisa Boniello and Michelina Occhioni*

Virtual Worlds are immersive environments enabling situated and constructivist learning, where the learner is inside a computer-simulated environment. Here, activities and experiences can take place using different didactic approaches, engaging the students and enhancing the learning process. This paper describes design and experimental results of three-dimensional immersive virtual environments dedicated to geosciences teaching at school for 12–19-year-old students. The aim of the project was to test the educational effectiveness of the virtual worlds to foster knowledge acquisition and increase students' interest in geosciences. A 3D virtual environment dedicated to geoscience topics was developed where students and science teachers were invited to visit paths on volcanoes, earthquakes, rocks, water and other themes relevant for the school curriculum, in a highly interactive mode, useful to engage digital-native students. Results revealed the high potential for this approach in geoscience education. The virtual environment was especially useful during the COVID-19 lockdown, when it was impossible to carry out laboratory classes and field trips.

Les mondes virtuels sont des environnements immersifs permettant un apprentissage en situation et un apprentissage constructiviste, où l'apprenant se trouve dans un environnement virtuel simulé par ordinateur. Dans cet environnement, des activités et des expériences ont lieu en utilisant différentes approches didactiques, engageant les étudiants et améliorant le processus d'apprentissage. Cet article décrit la conception et les résultats expérimentaux d'environnements virtuels immersifs tridimensionnels dédiés à l'enseignement des géosciences à l'école pour des élèves de 12 à 19 ans. L'objectif du projet était de tester l'efficacité pédagogique des mondes virtuels pour favoriser l'acquisition de connaissances et accroître l'intérêt des étudiants pour les géosciences. Un environnement 3D virtuel dédié aux géosciences a été développé pour les étudiants et les professeurs de sciences. Ils ont été invités à explorer de façon hautement interactive les volcans, les tremblements de terre, les roches, l'eau et d'autres thèmes pertinents par rapport au programme scolaire. Cette méthode a permis de captiver les étudiants de l'ère du numérique. Les résultats ont révélé le potentiel élevé de cette approche dans l'enseignement des géosciences. L'environnement virtuel a été particulièrement utile pendant la période de confinement lié au COVID-19, lorsqu'il était impossible de mener des cours de laboratoire et des visites de terrain.

Los mundos virtuales son entornos inmersivos que permiten el aprendizaje constructivista y situado, donde el alumno se encuentra dentro de un entorno simulado por computadora. Aquí, las actividades y experiencias pueden tener lugar utilizando diferentes enfoques didácticos, involucrando a los estudiantes y mejorando el proceso de aprendizaje. Este artículo describe el diseño y los resultados experimentales de entornos virtuales inmersivos tridimensionales dedicados a la enseñanza de las geociencias en la escuela para estudiantes de 12 a 19 años. El objetivo del proyecto era probar la eficacia educativa de los mundos virtuales para fomentar la adquisición de conocimientos y aumentar el interés de los estudiantes por las geociencias. Se desarrolló un entorno virtual en 3D dedicado a temas de geociencias donde se invitó a estudiantes y profesores de ciencias a visitar senderos sobre volcanes, terremotos, rocas, agua y otros temas relevantes para el plan de estudios de la escuela, en un modo altamente interactivo, útil para involucrar a los estudiantes nativos digitales. Los resultados revelaron el alto potencial de este enfoque en la educación en geociencias. El entorno virtual fue especialmente útil durante el encierro del COVID-19, cuando era imposible realizar clases de laboratorio y viajes de campo.

Introduction

During the COVID-19 lockdown, the need of online instruments to ensure teaching continuity became evident, due to the difficulty for the teachers to personally interact with the students and the cancellation of lab activities and field trips. This situation made geoscience teaching/learning more difficult, reducing as a consequence the interest in geoscience learning among the students, who were not able to enjoy the practical part of the lessons. The use of videos, the most common aid to showing Geoscience phenomena, can only partially overcome this difficulty, because of the lack of interaction, personal engagement or situated learning. Universities and geosciences scientific societies started to collect useful tools and information on virtual outcrops or virtual databases of minerals/rocks/fossils, making them available to all (e.g. ***http://www.minsocam.org/msa/Teaching_Resources.html*** and references within; ***https://serc.carleton.edu/NAGTWorkshops/GeoEd_Progress.html***; ***https://www.egu.eu/education/resources/***. These materials, although very useful, can be still difficult to use when teaching young students. The geoscience topics presented by the Earth Learning Ideas project represent a valuable aid in teaching geoscience at school (***https://www.earthlearningidea.com/***) even to younger students, although distance learning is still a problem to be solved when labs are necessary.

Gaming, on the other end, allows interaction and immersion, and serious gaming, applied already in many fields other than education (scientific exploration, health care, emergency management, city planning, engineering, defense, politics) has been proved to be an effective means to overcome the students' lack of interest or learning difficulties, as well as becoming a widespread teaching approach. In this context, virtual worlds represent an effective tool, which can be successfully applied to Geoscience learning.

Virtual worlds (VW) are 3D computer-simulated environments accessed by the user in form of an avatar (the digital rep-

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resentation of the user), using the web browser or a graphical user interface (viewer) (Schroeder, 2008). VWs have the characteristics of being persistent (running whether the user is logged in or not) and accessible by a massive number of users at the same time, so they are also called MUVEs (Multi User Virtual Environments). The users/avatars are directly responsible for all that is created in the virtual world environment (differently from videogames, where the developers of the game create a fixed environment). Another important difference between virtual worlds and videogames is the absence of a game master deciding rules and missions. The users move and act freely in VWs.

VW are considered constructivist platforms (Wilson, 1996; Jonassen & Carr, 2000). In fact, from a technical point of view they offer diversified tools to foster collaborative work and situated learning (see glossary). With the mediation of the avatar, the user really has the impression

GLOSSARY

Avatar

A digital representation of the user in a digital environment.

Collaborative learning

Collaborative learning is the educational approach of using groups to enhance learning through working together. Groups of two or more learners work together to solve problems, complete tasks, or learn new concepts.

Constructivism

Constructivist views of learning in science suggest that learners can only make sense of new situations in terms of their existing understanding. Prior knowledge is used by learners to interpret observations; meaning is constructed by individuals in a process of adding to or modifying their existing ideas.

IBL (Inquiry based learning)

Inquiry Based Learning (IBL) is a term used to encompass a variety of instructional methods, all of which centre around learning through the inquiry process or, more generally, learning by doing.

MUVE

Multi-User Virtual Environments (MUVEs) are environments that have been digitally created to allow users to interact with each other and the digital environment through the use of avatars.

Opensimulator

Opensimulator (***www.opensimulator.org***) is an open- source server platform for 3D virtual worlds, born in 2007. It can be considered the open source counterpart of Second life. In fact, they are very similar, so the user can access both the worlds with the same viewer. Today Opensimulator has developed several new features and extensions that are suitable and useful for teaching purposes, like for instance the possibility to run the program in one's own server, complete user access control and better customisation.

Recursive learning

In this model of learning the educational path is divided in steps, where students are continually 're-engaged' in every step using challenges and proposing activities to reinforce learning.

Screencast

A screencast is a digital video recording of the computer screen and usually includes audio narration.

Serious game

The word 'serious game' was born in recent years to mark games with educational purposes.

Situated learning

According to Jean Lave, the originator of the Situated Learning Theory, learning is unintentional and situated within authentic activity, context and culture. Knowledge needs to be presented in authentic contexts, settings and situations that would normally involve that knowledge. Social interaction and collaboration are essential components of situated learning.

Teleport

In a virtual world .teleporting is an action to instantly move the avatar from one zone to another in the world.

Videogames

A videogame is a game which we play thanks to an audiovisual apparatus and that can be based on a story.

Virtual worlds

"A virtual world is a spatially based depiction of a persistent virtual environment, which can be experienced by numerous participants at once, who are represented within the space by avatars" (Bell, 2008).

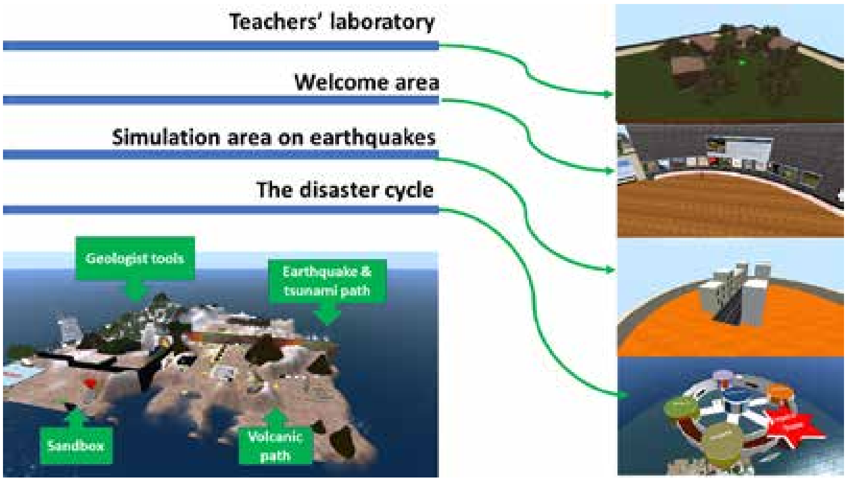

Figure 1: The Unicamearth virtual island, showing the superposition of layers with the learning paths and activity areas. The avatars can move freely on the layers and go from one layer to the other. The paths can be used as proposed or can be implemented by teachers/students to integrate the contents or to approach a different topic.

of living and acting in the world, interacting with objects and other avatars, sharing ideas and resources, accessing websites and reading documents, participating in proposed experiments or creating their own. The avatars can build interactive objects and scenarios, using a tool embedded in the viewer, and can model the terrains to obtain rivers, lakes, mountains or beaches, making them changing with time. They can travel within the terrains to explore rocks or outcrops, use instruments and tools like a hammer, magnifying lens or compass, or use geological and topographical maps. The avatar can walk, run, fly or sit, communicate by text chat or voice and use non-verbal communication like facial expression. In addition, the avatar can be customised and used as an actor in a movie (screencast video) to produce, for example, project presentations or illustrate an experiment. These characteristics allow the students to actively participate in knowledge acquisition, becoming protagonists engaged in what they are doing/learning. Being stimulated in attention to the object of the lesson, learner interest increases, allowing even difficult or abstract topics to be treated while learning at their own pace.

One of the platforms that meets all the features listed above is the open-source Opensimulator, which is a constructivist platform very suitable for teaching purposes. Because of these specific features of VW, researchers were quick to recognise the potential of Opensimulator for educational purposes (Allison & Miller, 2012), especially using inquiry-based learning methodologies, which emphasise the role of pupils in the learning process: students are encouraged to explore materials, ask questions, and share ideas rather than having the teacher transmitting information and knowledge.

Use of VW in Geoscience education

A research project in Geoscience Education using virtual worlds has been carried out at University of Camerino (Italy) in the last years, in the frame of a PhD program dedicated to Geoscience Education (Boniello and Paris, 2016; Boniello *et al.*, 2017). The aim of this project was to evaluate the effectiveness of virtual world technology for geoscience education, using topics suitable for middle and high school students (the 12–19 age range in the Italian school system), designing and developing learning paths suitable for younger or older students (12–15 and 16-19 years old), using different levels of difficulty. In the following some paths are listed:

- **Palaeoisland** – the fossils island - what is a fossil? How did they live? Where can they be found? Learn about the dinosaur Antonio (*Tethyshadros insularis*), how it was discovered, and visit the museum where it is located now (younger students, with links to zoology);
- **Volcanoes** – to learn characteristics and differences of volcanoes in the world and where they can be found. Enter inside a volcano and learn how it works: (older students, with interdisciplinary links to chemistry);
- **A trip to the volcanic area of the Campi Flegrei (Italy)** – to learn about the high volcanic risk in the area near Naples, the gas emissions in the caldera, earthquakes in a volcanic area (younger students, with elements of civil protection);
- **Earthquakes and Tsunamis** – to investigate how they form, are measured and studied. Study of seismic waves and seismographs can be performed through lab work. The seismic areas in Italy (older students, with interdisciplinary links to physics);
- **Darwin's trip** – to learn about Darwin's discoveries, following him in some steps of his trip, from atoll formation to the earthquake in Concepción (younger students, with interdisciplinary links to history and biology).

The learning paths are present both at the ground level of the island and at different heights on layers suspended in the air (***Figure 1***). The teacher can concentrate the activities on a single path or let the stu-

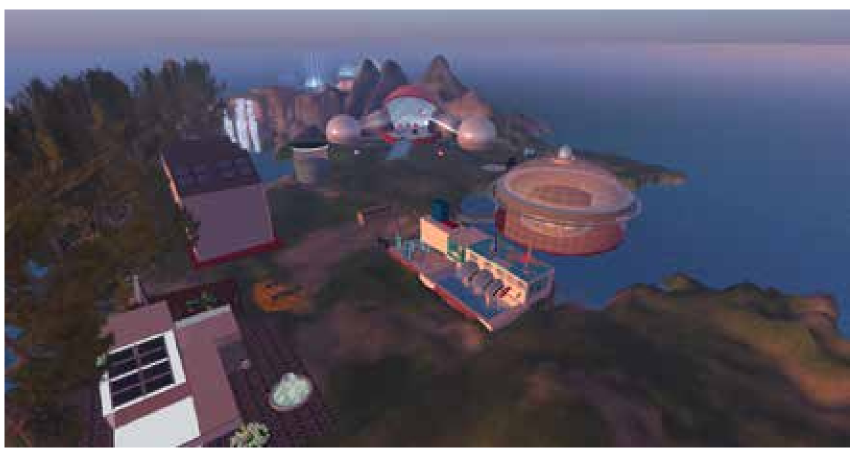

Figure 2: Waterland Island (in the Techland virtual world), is focused on water, from physical-chemical properties to its consumption and use for energy production. The students can enter the island and find information, documents and videos, links to websites, as well as homework and tests.

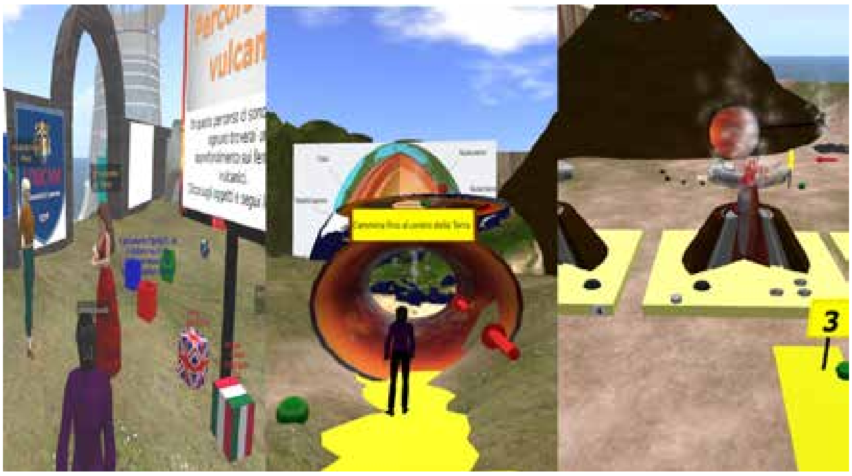

Figure 3: Steps of the volcanoes path, where the students can walk inside a volcano or observe different types of eruptions in a 4D mode. They can also travel to the centre of the Earth.

dents explore more than one, in separate moments and even by themselves. The learning path can be used as an introduction to a geo-topic or as a practical activity to carry out after the lessons or as a separate project. In all cases, the student can benefit from a different teaching approach which can helps carry out observations of phenomena in 3D or events in 4D or study geomaterials transmitted by a technology close to their liking. Therefore, when the study of geosciences could be considered annoying or trivial, the interest can be triggered using a gaming approach, which stimulates the curiosity of proceeding along the path, acquiring knowledge to pass the tests, in order to reach the end.

Project UnicamEarth – A virtual experiment with Geosciences

In the Unicamearth Island the starting point is the 'welcome area', an informative zone where users choose the path or the area where they want to go by clicking on a map panel and "teleporting" to it. There is also a laboratory where teachers can do the training to familiarise themselves with the VW, create new paths and share knowledge and skills with other teachers. In the sandbox users can learn to build objects and program them. The description of the paths and the VW tutorial are freely accessible online (***http://d7.unicam.it/unicamearthisland/***).

Paths on water and the water cycle can be also found in "Techland" (Occhioni, 2017), where an entire island is devoted to water in all its aspects (chemistry, world resources, water footprint, domestic and industrial consumption, wastewater management) as well as to the water cycle. This island (***Figure 2***) is the product of a collaborative project completely planned and accomplished by 11–14-year-old students, testifying the abilities of young students to deal with the VW and to focus on a topic when they are fully engaged.

In Unicamearth Island, each educational path can be experienced by school students in sessions of about 60 minutes, and the paths were also translated into English to allow older students to use the island as a content-based foreign-language lesson, to learn English as well as geosciences. For testing the activities, questionnaires (pre- and post-activity, evaluated by a Likert scale and multiple choice) have been used to determine: (a) the engagement and immersion of the students in the activity, (b) the acquisition of knowledge about geoscience topics, (c) the acquisition of digital skills and soft skills, and (d) the evaluations/suggestions/criticism from the teachers participating in the testing, which are useful to improve the activity. The teachers previously introduced to the use of VW and the content of the island have also been interviewed to obtain as much information as possible. During the activity, the teacher always acted as an external observer, to check the activity of each student and report any problem or difficulty.

Volcanoes path

The path on volcanoes, for example, is an informative and explorative serious game divided into seven areas of investigation, taking about one hour to complete. Teachers can choose the path or just leave the students free to explore. Students can use a 'guided sheet', with information useful to perform the activities. The design of the virtual environment has the aim to engage and reengage students in every step, following the principles of recursive learning (Pivec *et al.*, 2004). Students learn by exploring the environment, reading and interpreting texts, searching for information and data, exploring three-dimensional volcanoes models, observing and studying igneous rocks with documents and images they find along the path. For example, when they learn about the distribution of volcanoes on the Earth they can then also visit the earthquake path, or investigate magmas and volcanic eruptions, with simulation of different styles of eruptions and classification of volcanoes (***Figure 3***). They find and compare pictures and videos of recent eruptions, pictures and maps of old eruptions, simulations of various kinds of eruptions, learn about Vesuvius and the Latin historian Pliny the Old, who died during the eruption. They can investigate magma composition, role of gases, viscosity, explo-

Figure 4: The path of volcanic area of Campi Flegrei, near Vesuvius (Napoli, Italy), where the students learn about the gas emitted in the caldera and the phenomenon of bradyseism. A schematic virtual representation of the Macellum, a Roman building in Pozzuoli, which shows the variations of the sea level on the columns, helps visualise the results of the bradyseism affecting the area.

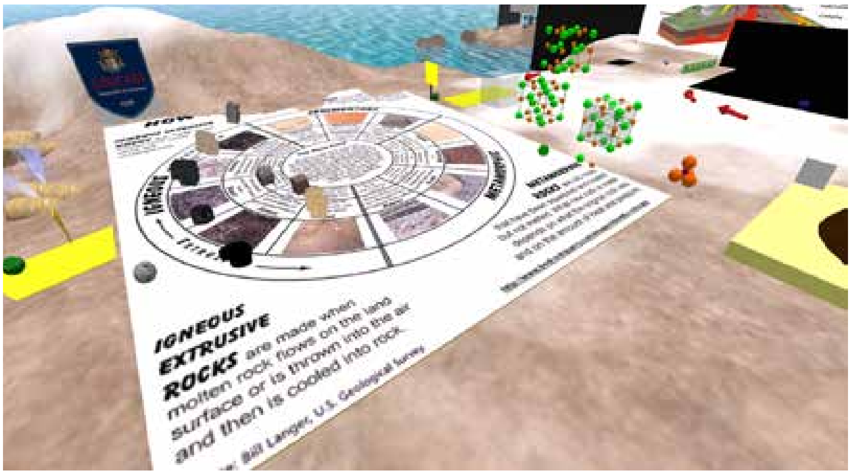

Figure 5: Learning about igneous rocks and the minerals they contain. It is possible to see their characteristics, rotate the rock samples in every direction, use a magnifying lens and look inside the structure of minerals.

sive behaviours and volcanic products.

A visit to the centre of the Earth offers many points of discussion and interaction with the earthquakes path. They can visit the Campi Flegrei area (***Figure 4***) and investigate seismic hazard and risks in highly populated areas and learn about bradyseism. In this path they also find an activity on rock classification, which is a topic usually carried out in the lab with hand samples or in the field. Here they can choose a rock sample, rotate it, check the minerals it contains, use a magnifying lens and look inside the structure of minerals, making the study more attractive than only reading from a book (***Figure 5***).

A problem-solving activity and a questionnaire are always present at the end of the path, helping the teachers to verify the acquisition of knowledge. Here, a final activity on volcanoes is proposed, variable with students' age (build a volcano, find a picture of a volcano whose shape is similar to yours, check out the rocks produced by a volcano, look at important eruptions in the Earth history…). This can represent also a follow-up of the path, to be continued at home as homework or at school as a link to continue working on the topic.

Earthquakes path

This path can be experienced by students at various levels, and is composed of topics regarding earthquakes, all related one to the other. Students can follow the yellow ways in the paths, full of images, animation, interactive objects, videos and simulations, or they can freely explore the area, which is divided into the following topics:

1. earthquakes and tsunamis (definitions and examples, effects of earthquakes, tsunamis and their effects);
2. earthquake distribution on Earth (investigating correlation with volcanoes, plate tectonics) with possibility to connect to the volcanoes path;
3. seismic waves and seismographs, with a lab activity and interdisciplinary links to physics, and extra activities for the older students about seismic waves in the Earth (link to the trip to the centre of the Earth). Also, there is a prompt for high school students to start a class project about seismic hazards and the seismic risk of the area they live in.
4. Richter and Mercalli scales: how they work and what they mean.
5. If there is an earthquake, how do you protect yourself? Here the student can simulate the safety behaviour in the classroom during an earthquake. Clicking on objects, they can choose an action and immediately verify if it is the correct one (e.g. stay inside under your desk or run outside?). This activity is particularly dedicated to younger students.

This path offers options to more in-depth analysis. It gives in fact the possibility to discuss about catastrophic earthquakes and their effects on population, as well as to make other multidisciplinary connections with current events, safety, seismic engineering, civil protection rules and behaviour and other social aspects. Students can start a project in the path, implementing it with their own documents or presentations. Older students can also access the Disaster Cycle path, to learn about the various steps of disaster management. This path has been developed to introduce students to the work of civil protection officers and professionals, dealing with geological hazard and risks. It allows them to learn how the Italian civil protection system is structured and works in the case of an emergency. The path has been tested by university students in geology programmes.

Virtual Geoscience Education: What could be learned so far?

The testing of the effectiveness of the paths has been carried out on 520 students from middle and high schools and 83 teachers. Teachers' observations on their own students during the activities, as well as interviews with the teachers aimed at inves-

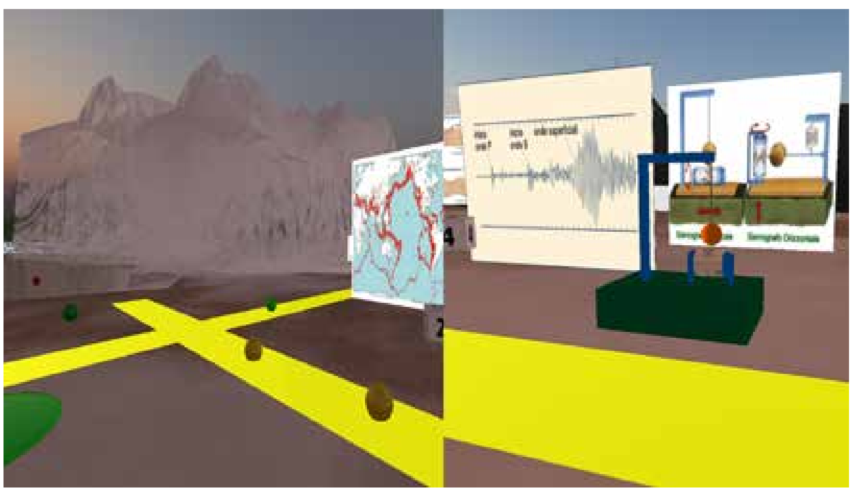

Figure 6: The earthquakes path, showing a tsunami representation, with information on how they form and why. A lab activity shows a seismograph and how it works, allowing observations to be discussed with the teacher or classmates or to be further investigated using the available information and the interdisciplinary links with physics.

tigating behaviours and attitudes, revealed that students were enthusiastic and very focused during the learning units. This was expected, but a further result was that the virtual world experience helped reduce the divide between students –as digital natives – and teachers, favouring better inclusion in the learning process, even of those less prone to study geosciences. Regarding knowledge acquisition, the evaluation of questionnaires administered to the students and similar to normal school tests demonstrated that the results obtained by the students using the VW were 23% higher than those of the control group. The simulation of a scientific context, which allowed the situated learning experience, positively affected students' motivation to learn, as noted also in biology studies (e.g. Clark, 2009).

In teaching geoscience at school, several concepts and Earth processes occurring in geological timescales are often difficult for young students to grasp or conceptualise. A virtual world can help them to visualise and follow phenomena in 3D or 4D modes, or to simulate environments otherwise not accessible (such as a magmatic chamber or a volcano). The reconstruction of Darwin's trip, where the student/avatar is Darwin himself immersed in a role-play game and storytelling, triggers curiosity and fascination with adventure. It offers the students the chance to identify with the actor of the discoveries, a young Darwin, giving them the feeling of being a geoscientist at work.

Older students and young adults feel perfectly at ease in the VW environments they use also for social entertainment. VW are not seen as poor drafts of reality, but just as something completely different, a tool to use as they play a videogame. VWs are already used for instruction, e.g. in teaching safety rules, and could find useful applications in training in the use of instruments or analytical techniques. One potential application of VW is in building up virtual fieldtrips by assembling maps and satellite images, organising virtual outcrops made of videos and 3D scans, uploading presentations and documents. An environment can be created where a student can use the compass and a lens or a virtual microscope to look at rocks in thin section and microfossils. Many universities have already been forced to organise similar activities to partially overcome the difficulties introduced by the COVID-19 in education, but VWs offer also a wide possibility for interaction between instructors and students during "field or lab work", as well as actual evaluation of tests and individual projects.

Conclusions

Virtual worlds can be extremely powerful instruments for geoscience education, engaging the students' attention in geoscience topics, providing also a valuable alternative laboratory and field activities or integrated into traditional teaching, while favouring acquisition of both knowledge and soft skills. During the COVID-19 lockdown period, VW allowed the teachers to actually carry out practical activities, confirming the positive outcomes obtained in the previous experimentations of the VW paths. The students, who missed the social aspects of school, were able to interact positively with classmates in individual or team activities.

Nothing will ever substitute an enthusiastic teacher in the lab or in the field, sharing passion for discovering Earth systems! However, since the use of technology is intrinsic in the life and habits of young students, who appreciate new trends and novelties, the use of virtual learning environments is also reasonable, if they can favour better communication of geosciences.

Acknowledgements

The authors would like to thank the schools and teachers taking part in the experimentation of the VW activities, but also those who continue to use the paths, giving useful feedback. The members of the UnicamEarth group of Geoscience education at University of Camerino are acknowledged for the collaboration.

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The Science and Education Network for Sustainability in Estrela UNESCO Global Geopark

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The Estrela UNESCO Global Geopark is a territory where sustainable development is sought in an integrated way, based on its geological heritage, marked by the landforms left by the last glaciation, its biodiversity and its culture, which reflects the secular adaptation of its communities to this mountain. In this perspective, the Science and Education Network for Sustainability was implemented in 2019, based on an articulated set of interdisciplinary working groups with close links to higher education institutions and the Portuguese scientific and technological system, with emphasis on entities that carry out research in mountain regions. As such, the Science and Education Network for Sustainability of the Estrela Geopark can play an essential role in the promotion of development and territorial cohesion, leveraging new educational approaches and, by doing so, reinforcing the important role of education for geosciences in Portugal, in Europe and the World.

Le Estrela Géoparc Mondial de l'UNESCO, constitue un territoire où le développement durable est recherché de manière intégrée, basé sur son patrimoine géologique, sa biodiversité et sa culture, reflet de l'adaptation séculaire de ses communautés à cette montagne, dans laquelle sont observées des marques importantes de la dernière glaciation. Dans cette perspective, le Réseau des sciences et de l'éducation pour la durabilité (RCES) a été mis en place en 2019, sur la base d'un ensemble articulé de grappes interdisciplinaires ayant des liens étroits avec les établissements d'enseignement supérieur et le système scientifique et technologique portugais, en mettant l'accent sur les entités qui mènent des recherches dans les régions de montagne. Dans cette perspective, le réseau scientifique et éducatif pour la durabilité du géoparc d'Estrela peut jouer un rôle essentiel dans la promotion du développement et de la cohésion territoriale, en tirant parti de nouvelles approches éducatives, renforçant ainsi le rôle important de l'éducation aux géosciences au Portugal, mais aussi en Europe et dans le monde.

El Estrela Geoparque Mundial de la UNESCO, constituye un territorio donde se busca el desarrollo sostenible de manera integrada, basado en su patrimonio geológico, su biodiversidad y su cultura, reflejo de la adaptación secular de sus comunidades a esta montaña, en la que se observan importantes huellas de la última glaciación. En esta perspectiva, en 2019 se puso en marcha la Red de Ciencia y Educación para la Sostenibilidad (RCES), basada en un conjunto articulado de agrupaciones interdisciplinarias con estrechos vínculos con las instituciones de enseñanza superior y el sistema científico y tecnológico portugués, haciendo hincapié en las entidades que realizan investigaciones en las regiones montañosas. En esta perspectiva, la Red de Ciencia y Educación para la Sostenibilidad del Geoparque Estrela puede desempeñar un papel fundamental en la promoción del desarrollo y la cohesión territorial, aprovechando los nuevos enfoques educativos, reforzando así la importante función de la educación en materia de geociencias en Portugal, pero también en Europa y en el mundo.

Framework

The UNESCO Global Geoparks are territories of science, education, culture and communication, but science has not always played a prominent role in these classified territories. One of the goals of the Estrela UNESCO Global Geopark (UGGp) is to put science and research effectively at the service of populations. The actions carried out since 2016 and the planned activities for the future reveal the importance that science has for this territory. Thus, a concerted, cohesive and coherent strategy with a medium- and long-term vision towards sustainability has been prepared, based on the fulfilment of the SDG (Sustainable Development Goals of UN's 2030 Agenda), including ambitious commitments to stimulate the region economically in the short term and to help the agents of the territory in the definition of a medium-to-long term trajectory.

Thinking about science or research is still today a distant idea for many, reduced to the image of a research centre, a university, or a laboratory. However, science is increasingly a strategy that opens up to society, incorporated in our daily lives, becoming more accessible and democratic. Since its foundation, UNESCO has sought to achieve development and peace through scientific knowledge, placing it at the service of all, on the assumption of contributing to the resolution of the real problems of societies, making them more informed and trained, and thus better prepared to achieve development.

In the second decade of this century, UNESCO formalised the creation of UNESCO Global Geoparks, defining them as territories where education, culture and

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science converge to build a more sustainable future (UNESCO, 2015). So, why have the 161 geoparks worldwide been selected as territories of science? The answer to this question lies in two points. Firstly, geoparks are territories with a unique geology, which because of their value, are considered a common legacy for communities, i.e. as heritage. In this context, one of the ways to perpetuate their value and contribute to their preservation is through the knowledge that one has of these resources, using science to help us understand the shapes and landscapes that we see. The affirmation of geoparks as living laboratories effectively brings science closer to people, making them actors of knowledge, grounding new visions that foster citizen science or open science.

Estrela UNESCO Global Geopark

The Estrela UNESCO Global Geopark was recognised in 2020. It is made up of nine municipalities, with a total area of about 2216 km^2, whose identity is directly linked to Serra da Estrela, the highest mountain range in mainland Portugal. It has a long geological history, which is reflected in its great geodiversity, ranging from deeply deformed rocks of more than 600 million years to the important landforms left by ancient glaciers during the last ice age. The Estrela Geopark seeks to work in an integrated way on sustainable development, based on its geological heritage, its extraordinary biodiversity and its culture, a reflection of the centuries-old adaptation of communities to this mountain, with education being one of its strategic priorities. Therefore, this work seeks to demonstrate the importance of education and science in the valorisation of heritage and the relevant role of the Estrela Geopark in their promotion as a strategy for Geoconservation and dissemination of scientific knowledge, since only what is truly known can be preserved and valued.

The Estrela Geopark (***Figure 1***) is a territory with a remarkable heritage that with its relevance, uniqueness and meaning constitutes a common legacy that must be safeguarded and valued (Gomes *et al.*, 2019). Its geological history extends for millions of years, beginning more than 650 Ma, when the territory was at the bottom of an ancient ocean, culminating with the uplift of the current mountain and the highlight of Estrela´s geological heritage, the landforms left by the last glaciation, with special relevance to its position in southwest Europe.

Its heritage values, in particular its geological heritage, are enhanced by its geographical position, at the crossroads of different biogeographical zones, in addition to the strong link between communities and the mountain, where human occupation of over a thousand years has given rise to a mosaic of ecosystems and natural and semi-natural landscapes with a rich cultural heritage. For these reasons, the UNESCO seal proves to be a great tool to foster the preservation, promotion and valorisation of this heritage in a holistic way.

The strategy outlined for science is focused on research in specific disciplinary areas, sometimes transversal, that can promote a structural transformation, namely in the area of training and capacity building of the territory, contributing to help a variety of stakeholders obtain the appropriate training to act and work in a world in transition, including decision-makers and the public administration, teachers and students, professionals in the area of tourism, catering and hospitality, among many others, obtain the appropriate training to act and work in a world in transition. The strategic plan developed relies on applied science with a general and interdisciplinary approach, where access to resources can be facilitated, thus enhancing quality education and lifelong training, stimulating job creation at regional level, while taking advantage of the opportunities arising from its unique heritage (geological, biological and cultural). It can, for example, promote the territory as a health destination by promoting fluvial beaches and thermal waters; find innovations that contribute to a more circular economy and to the improvement of the living conditions of communities; also, it can promote work on the adaptation and mitigation of climate change in the territory.

It is a pre-requisite that UNESCO Global Geoparks must develop educational activities for all ages to spread awareness on geological heritage and its links to other aspects of natural, cultural and intangible heritage. Geoparks establish partnerships with schools, universities and research centres, focusing on research collaborations, to offer educational programmes for schools and education, both formal and informal, for adults, such as providing training courses for teachers and local people (Álvarez, 2020).

The Estrela UGGp promotes the Sustainable Development Goals, in particular Goal 4 – ensure inclusive and equitable quality education and promote lifelong learning education for all – because it actively educates their local communities and their visitors of all ages. According to UNESCO (2017), Global Geoparks are "outdoor classrooms and incubators for sustainable development, sustainable lifestyles, appreciation of cultural diversity and the promotion of peace".

The importance of education in the dissemination of scientific knowledge, especially in the field of geosciences, show how the Estrela territory can be an authentic living laboratory where didactic experiences are developed (Fernandes *et al.*, 2018).

Estrela UGGp Science and Education Network for Sustainability

The Estrela UGGp uses its extraordinary natural heritage to promote multidisciplinary educational programmes, transforming the Estrela mountain range into a big

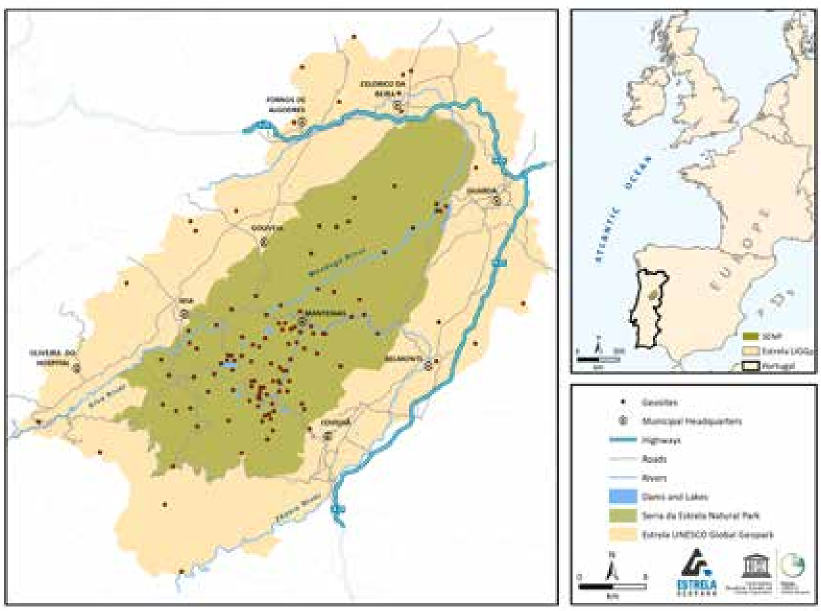

Figure 1: Estrela Geopark map and location.

classroom, where students and teachers can learn about geodiversity, biodiversity, and culture, promoting the conservation and valorisation of its heritage through education. In fact, the goal of the Estrela UGGp Science strategy is to transform the territory into a "living laboratory" for the achievement of sustainability and its promotion among communities, the country, and the world (Fernandes *et al.*, 2018).

Taking into account these objectives, the Science and Education Network for Sustainability (RCES) was implemented (***Figure 2***), aimed at supporting and promoting applied research to the Estrela territory. The network is based on an articulated set of interdisciplinary working groups spread throughout the territory with close links to higher education institutions and the national scientific and technological system, with emphasis on entities that carry out research in mountain regions. It will also serve as a catalyst for the new generation of scientists that will benefit from the more than 2,200 km^2 of the Estrela UGGp as an open laboratory. In this context, RCES will support all areas of scientific research, including natural, social, human and sports sciences. The activities defined in the framework of Estrela Geopark Strategic Plan for Science are focused on the following areas: Geology and Geomorphology, Landscape, Culture and Heritage, Climate and Climate Change, Biodiversity and Ecology, Environment and Natural Resources, Spatial Planning and Risks, and Tourism, Leisure and Sustainable Development.

This network promotes five science and education Working Groups on Territory: Climate and Climate Change; Water Resources; Biodiversity and Mountain Ecology; Tourism and Sustainability; Geodiversity and Geoconservation. The working groups aim to create structures to promote science, education and scientific knowledge in a collaborative way, based on the establishment of medium and long-term strategic partnerships between different actors of the territory and institutions that develop research in the different areas. Its main objectives are cooperation in identifying challenges, creating projects, sharing resources and infrastructures and mobility and/or exchange of qualified human resources between network members and research & development agencies, with the objective of sharing and disseminating knowledge. This network is not a closed structure and can be extended to other disciplines and other working groups in different areas.

The Estrela Geopark constitutes the most emblematic mountain range in mainland

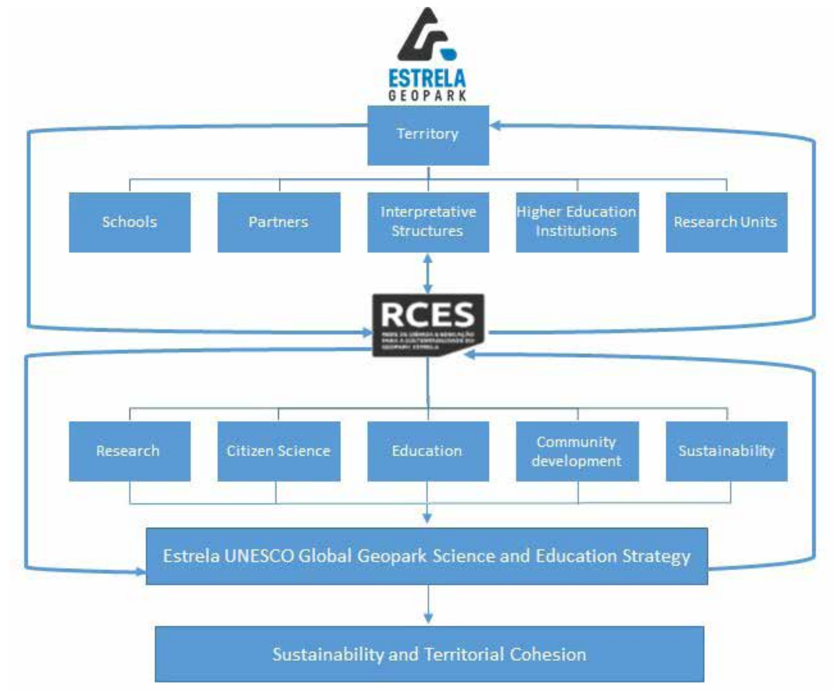

Figure 2: Estrela UNESCO Global Geopark Science and Education Strategy.

Portugal, with evident local climatic contrasts controlled by differences in altitude and topography and their interaction with atmospheric flows. The climatic importance of Estrela is also felt on a regional scale, causing important asymmetries in the distribution of precipitation and temperatures, with consequences for the ecosystems and human occupation of the territory. The climatic character of Estrela also makes it one of the most important resources for water in the country, used for human consumption, industry and energy generation. This is also the only place in Portugal with significant snowfall, with an ecological, socio-economic and cultural impact. The climate history of the Estrela has left indelible marks on the landscape, particularly in the coldest periods of the Quaternary, marked by an extensive ice plateau and glacial valleys. In a context of rapid climate change and accelerated changes in land use, driven by unbalanced regional and national socio-economic dynamics, the Working Group on Territory, Climate and Climate Change aims to foster basic and applied scientific research, linking it to regional development and education for sustainability.

The Working Group focused on Water Resources will play an essential role in the development of research lines related to water resources and thermal waters. The objective of this working group is to develop some measures that will promote a harmonious local and regional development of this low-density territory. It is not enough to have well-equipped and qualified thermal resorts, it is fundamental to work in a network to attract new audiences, invest more in the sector, establish partnerships, encourage greater promotion/dissemination and organise activities that can energise and promote the territory. On the other hand, the water resources of Estrela are a valuable asset of this territory, so greater knowledge of them will allow greater capacity for innovation, preservation and valorisation. The region of Serra de Estrela, in the context of the Portuguese landscape, is excellent in terms of water resources. It is one of the regions with the highest precipitation, either in the form of rain or snow. This characteristic leads to a territory with great richness in surface water, with a large number of natural lakes, many of them converted into dams. It is also in this region that the largest Portuguese rivers are born, such as the Mondego and the Zêzere rivers. As a consequence, the region of Serra da Estrela is also a territory of excellence for abundant and high-quality groundwater. There are significant aquifers that have been used to supply local populations for millennia, leading to their eventual settlement. Thermal and/or mineral-rich groundwater is also found, which in some cases has led to the creation of spas and bottling industries, which are relevant to both local and national economy.

The Science and Education Working Group in Biodiversity and Mountain Ecology will play an essential role in the development of research projects in ecosystems and agroecosystems of the Estrela villages, aiming at the recompilation, classification and production of knowledge that will serve to promote the conservation and sustainability of this territory, as well as the enrichment of science. The Serra da Estrela is located in the westernmost part of the Iberian Central System, in the transition area between temperate and Mediterranean climates, a location particularly vulnerable to global warming. The Estrela ecosystems are closely linked to human action as well as to forest management or moving herds to pasture in the Alpine-like ecosystems. These ecosystems, located in the upper part of the mountain, are an important reserve of biodiversity with a significant number of endemic species and offer a unique opportunity to study the effect of climate change on the functioning of ecosystems. The conservation of these ecosystems requires education and environmental awareness, which currently play a fundamental role in the development of sustainable strategies.

The establishment of a Working Group on Tourism and Sustainability aims to consolidate studies on culture, leisure and tourism in its relationship with the territory, the latter assuming a role in the relationship between different resources and tourism products. Taking into account that tourism is one of the pillars of UNESCO Geoparks, actions were selected that aim to boost tourism in the Estrela territory, strengthen partnerships and contribute to the continuity of the Estrela's identity by creating a strong tourism brand based on heritage and culture, leading to an increase in the number of tourists and their average stays and helping decrease tourist seasonality. In fact, tourism assumes increased importance as an inducer of development in the territories where it occurs. However, it must be promoted as a sustainable phenomenon, valuing local potential as a differentiating resource capable of generating motivation and tourist attractiveness.

The Working Group focused on Geodiversity and Geoconservation will play an important role in promoting geodiversity in modern civilisation, in prospecting for and exploiting raw materials, as well as specific actions of geoconservation, safeguarding and enhancing the outstanding elements of the geological, geomorphological and landscape heritage. In addition to these intervention areas, special attention will be given to networking among UNESCO Global Geoparks. Thus, this will be an important part of the dissemination of geosciences, namely in geoconservation strategies, valorisation of geological heritage and interpretation of landscape.

Final Remarks

The Estrela UNESCO Global Geopark, one of the 15 new territories classified in 2020, is seeking to give special emphasis to the actual reality of populations, affirming itself as a true territory of science, a place that must promote and achieve a main objective - sustainable development. In this sense, long before its classification, the Estrela Geopark has clearly committed itself to science and scientific knowledge, relating it to education and turning the territory into a real laboratory. In fact, the Estrela mountain range presents unique characteristics for studies in several scientific areas. However, the science produced in these areas must be done with the participation of the populations (citizen science), using research to tackle problems and making the results available in an open and accessible way. Proof of this is the work carried out on forest fires, climate change, geological heritage and geoconservation, among many other studies. These results are presented at the International Conference on Managing Mediterranean Mountains and Geoheritage (3MG), organised every two years in the territory of the Estrela UGGp.

Due to our awareness of the value of science and its importance, the Science and Education Network for Sustainability was implemented. Its main goal is to promote the knowledge of Estrela in various areas. The next four years are a challenge for this territory and for this UNESCO Geopark, to place science as a foundation for the development of Serra da Estrela in Portugal, involving its populations and creating knowledge networks.

To sum up, all of these initiatives in the field of science, promotion of culture and territorial development are part of the everyday life of the Estrela UNESCO Global Geopark and must take a holistic and promotional approach to sustainable development. In this context, each year until 2030 will be dedicated to one of the SDG, through an action plan in the areas of citizen science and education, raising awareness, promoting and defining strategies to achieve the recommended development goals adapted to the reality of this territory. This is intended to alert people to or solve concrete problems of this geographical region through multiple actions aimed at community participation.

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Integrating new tactics for mineral exploration and Social License to Operate into geoscientists' training and life-long learning: Lessons learned through the INFACT Project

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Effective transfer of knowledge gained through international research and development projects (i.e. FP7, H2020 etc.) to either university curricula or to vocational training often fails. For this reason, the INFACT project, financed through the H2020 programme, paid special attention to knowledge transfer in the disciplines of mineral exploration and mining. A key objective of INFACT objective was to provide knowledge transfer opportunities for master's and PhD students, young scientists, the community, wider society, policy makers and exploration practitioners in the areas of mineral exploration and Social License to Operate. This was achieved through integrating education initiatives with a variety of stakeholders into INFACT's tasks, to enable a longer-lasting impact. Emphasis was put on activities that included formal education as well as lifelong learning for wider society and professional development through passive (informative) and active training. The topics addressed focused on the raw materials value chain, upstream primary exploration activities, the sustainability aspects of exploration tools, and social acceptance of mining and exploration best practices. In addition, education initiatives provided a mechanism to disseminate information regarding the INFACT project and its progress via tailored messages for respective key stakeholders.

Le transfert efficace des connaissances acquises grâce à des projets internationaux de recherche et de développement (c'est-à-dire FP7, H2020, etc.) vers les programmes universitaires ou vers la formation professionnelle échoue souvent. Pour cette raison, le projet INFACT, financé par le programme H2020, a accordé une attention particulière au transfert de connaissances dans les disciplines de l'exploration et de l'exploitation minière. Un objectif clé de l'objectif d'INFACT était de fournir des opportunités de transfert de connaissances aux étudiants de maîtrise et de doctorat, aux jeunes scientifiques, à la communauté, à la société au sens large, aux décideurs et aux praticiens de l'exploration dans les domaines de l'exploration minière et de la licence sociale d'exploitation. Cet objectif a été atteint en intégrant des initiatives d'éducation avec une variété de parties prenantes dans les tâches d'INFACT, afin de permettre un impact plus durable. L'accent a été mis sur les activités qui incluent l'éducation formelle ainsi que l'apprentissage tout au long de la vie pour la société au sens large et le développement professionnel grâce à une formation passive (informative) et active. Les sujets abordés ont porté sur la chaîne de valeur des matières premières, les activités d'exploration primaire en amont, les aspects de durabilité des outils d'exploration et l'acceptation sociale des meilleures pratiques minières et d'exploration. En outre, les initiatives d'éducation ont fourni un mécanisme pour diffuser des informations concernant le projet INFACT et ses progrès par le biais de messages personnalisés destinés aux principales parties prenantes respectives.

La transferencia efectiva de conocimientos adquiridos a través de proyectos internacionales de investigación y desarrollo (por ejemplo, FP7, H2020, etc.) a los planes de estudios universitarios o a la formación profesional a menudo fracasa. Por esta razón, el proyecto INFACT, financiado a través del programa H2020, prestó especial atención a la transferencia de conocimiento en las disciplinas de exploración y minería de minerales. Un objetivo clave del proyecto INFACT era brindar oportunidades de transferencia de conocimientos a estudiantes de maestría y doctorado, jóvenes científicos, la comunidad, la sociedad en general, los responsables políticos y los profesionales de la exploración en las áreas de exploración minera y Licencia Social para Operar. Esto se logró mediante la integración de iniciativas educativas con una variedad de partes interesadas en las tareas de INFACT, para permitir un impacto más duradero. Se hizo énfasis en actividades que incluían la educación formal, así como el aprendizaje permanente para la sociedad en general y el desarrollo profesional a través de la formación pasiva (informativa) y activa. Los temas abordados se centraron en la cadena de valor y comerzialización de las materias primas, las actividades de exploración primaria upstream (aguas arriba), los aspectos de sostenibilidad de las herramientas de exploración y la aceptación social de las mejores prácticas de minería y exploración. Adicionalmente, las iniciativas de educación proporcionaron un mecanismo para difundir información sobre el proyecto INFACT y su progreso a través de mensajes personalizados para los respectivos inversionistas.

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Introduction

Sustainable economic growth and energy transition processes are and will be based on intensive mining (and recycling) activities. The challenges that these processes bring can be classified into three broad categories: (1) rapid demand growth caused by the rising global population as well as the increased material needs for climate change policies and UN sustainable development goals; (2) constraints on supply arising from inadequate investment in exploration and new capacity, growing community resistance to mining, governance problems in many host countries, long gestation periods for new mines, growing government regulations to protect the environment and for other reasons, and declining amounts of identified mineral resources; and (3) the inability of recycling and secondary production to contribute greatly to mineral commodity supply until the mid-21st century (Tilton *et al.*, 2018).

Exploration discovery of raw material resources requires perpetual innovations that change the geological targets of exploration, the physical places that are reached, or the way they are explored for. Despite Europe's rich history of mining and residual mineral wealth, current conditions within the EU present social, environmental, political, legislative, cost, technical and physical obstacles to raw material exploration. To overcome this innovation, dialogue and reforms are needed. Experiences (Proctor and MacCallum, 2019) and recent studies (Mitchell, 2020) indicate such an approach can build public trust and can invigorate and equip the exploration industry, thus unlocking unrealised potential in new and mature areas.

The INFACT project (***https://www.infact-project.eu/***) sought to develop exploration techniques more acceptable to society and at the same time test two-way communication with stakeholders during the exploration process (MacCallum, 2016; Proctor and MacCallum, 2019; Mackenzie *et al.*, 2020). At its outset, INFACT reviewed all existing publicly available best practices for exploration, with a view to building on these. As its legacy, INFACT aims to integrate all promising outcomes from its work on both these aspects and all promising new practices learned into education and life-long learning for geoscientists. This integration work started early in the INFACT project and will continue after its completion. Identified stakeholders for INFACT include the affected communities, exploration practitioners, wider society and policymakers at a national and EU level.

INFACT established realistic benchmarks conditions at each of three test sites against which to assess requirements and outcomes and to ensure meaningful quality technical and social testing.

All three test sites – Sakatti (Finland), Geyer (Germany) and Minas de Ríotinto and Cobre las Cruces (Spain) – were subsequently redefined as permanent European Reference Sites (ERS) to enable ongoing benchmarking and related endeavours, in support of recommendations for EU exploration policy reform.

This paper focuses on the knowledge transfer achieved through stakeholder engagement and various education activities, as well as lessons learned from these activities across the INFACT project.

The approach and strategies used

Engagement of appropriate stakeholders during all INFACT activities maximised the adoption and implementation of its results. The higher education, life-long learning and wider society education initiatives that were integrated and that are presented in this paper form the foundation for a long-lasting impact of the INFACT project. A number of communication mechanisms were applied in leveraging the performance and impact of networking, dissemination and education objectives of the INFACT. These included:

- clustering, linking and transferring the knowledge and know-how to other stakeholders, EU projects and research and industry consortia,
- dissemination to various target groups, and
- traditional educational activities designed for students (in higher education), experts (lifelong learning) and the public.

The clustering with, linking to, and knowledge and know-how transfer to other Horizon 2020 projects included attending meetings of other projects (i.e. MIREU project workshop on Social License to Operate – SLO), or organising joint meetings, organising joint data acquisition campaigns at the three reference sites and writing joint papers on exploration in Europe (with the PACIFIC, MIREU and Smart Exploration projects).

Dissemination to various target groups involved the use of social media (i.e. LinkedIn, Instagram, FaceBook, YouTube, Twitter), printing of brochures, leaflets, posters etc., issuing regular e-Newsletters (3-4 times annually), and actively participating at relevant international conferences.

Much is possible for education activities designed for students, experts (also called professionals or practitioners) and the public, but content must be both focused and relevant to each group, whether covering technical matters or environmental, social and governance (ESG) aspects.

Stakeholder engagement

The engagement with stakeholders was an integral part of INFACT, as no matter how technically revolutionary, advanced and/or novel the developed techniques are, without public acceptance such a technique is merely a tool that cannot be applied. Consequently, understanding the public perception, its attitude and acceptance of or antipathy towards the exploration tools, method and processes plays an essential role in shaping the future of any exploration campaign. To address these issues, INFACT included the following activities (ATC *et al.*, 2019)

- Investigating the knowledge, perception and opinion of the public about exploration and mining and typical exploration work;
- Analysing the media coverage and media responses to exploration techniques;
- Undertaking active and innovative engagement of stakeholders at all three reference sites and with expert stakeholders laterally and vertically across society in order to obtain relevant information for the future development of the exploration processes;
- Mitigating and testing for field operation risks associated with Health, Safety, Environment & Community during work at each reference site; and
- Optimising the effectiveness of stakeholder engagement activities by effectively employing the established INFACT network.

The above-mentioned activities, which were developed and regularly benchmarked and evaluated during the INFACT project at the three reference sites, helped to improve the environmental, social and governance protocols/approaches for the exploration campaigns. Based on the outcomes, the knowledge gained was disseminated mainly via short courses (or workshops) for graduate students, academic publications, presentations in virtual conferences and on-line courses on environmental, social and governance aspects, focused on experts from the exploration industry.

Discovery Roadmap and its support in developing long-term solutions

Developing proper, understandable and realistic recommendations associated with policy reforms, plans for improved availability of quality exploration data, and education gaps related to civil society, the state and industry were the goals of the INFACT, summarised in the document titled the "Discovery Roadmap". These were aimed at the highest decision-making levels in order for INFACT findings to inform both legislative and formal development (SRK, 2019).

Focussing on both extent and quality of existing protocols and services, a series of detailed reviews and gap analysis were carried out on existing policies, environmental and social conditions, and technical capabilities related to mineral exploration and mining. In order to change and ameliorate the "status quo", a series of recommendations was provided for improving the technical, environmental, social and governance aspects of mineral exploration in Europe.

One of the key findings was that for Europe to be able to source and extract the critical raw materials required for a "greener" society, in addition to promoting less invasive search techniques, both environmental and social concerns and considerations needed to be given greater parity. Use of the term "NIMBYism" (Not in my backyard) was seen as offensive by large sectors of society, who felt overlooked and undervalued by current policies and practices related to mining.

While the EU has an impressive range of regulations and frameworks to protect the natural environment, social protections are less rigorous, with many EU states relying on national planning laws and only one EU convention – 1998 the Aarhus Convention, which makes provision for the right of everyone to receive environmental information that is held by public authorities.

One of the key outcomes from INFACT, in addition to recommending greater social protections and considerations within the minerals sector, has been to integrate issues such as social performance and Social Licence to Operate principles into all geoscience education at all levels.

Innovative technologies in mineral exploration

Mineral exploration and the successful exploitation of resulting discoveries, besides facing technical (i.e. prospectivity, exploration interest and exploitation possibilities) and social challenges (i.e. economic conditions, social and environmental acceptance, and legislative aspects), has historically also been hampered by shortages of skilled geoscientists (i.e. TBR's Skills and Labour Market Team, 2012; European Migration Network, 2015; Australian Mining, 2018; Mining People International, 2018; The West Australian. 2018). This is compounded by the rapidly changing skills needed to apply technological innovations in modern exploration and mining operations.

At the same time, the current curricula in applied geophysics at many European universities are developed taking into account mainly the needs of the hydrocarbon industry, with focus upon control source seismics, while the number of specialised courses in potential fields, electric and electromagnetic methods are limited. As a result, graduates are not familiar with the modern equipment for data acquisition or methods of non-seismic data processing and interpretation that are routinely used in mineral exploration and mining. Another problem is limited access of university teachers to digital materials from recent mineral exploration campaigns owned by private companies. In parallel, geoscience student numbers are declining in undergraduate and post- graduate levels as mining is perceived to be a "dirty" industry. All of these factors limit the availability of European graduates suitably trained to find ready employment with companies involved in exploration.

In cooperation with the PACIFIC project, also funded from Horizon 2020, the INFACT team organised a four-day course called "Winter School on Sustainable Mineral Exploration" in Huelva, Spain. This course, held in March 2020, was developed as an interactive workshop on social, environmental, and technical aspects of sustainable mineral exploration. The curriculum of the course followed the sequence of a modern grassroots exploration campaign to introduce concepts like best practices, stakeholder engagement and non-invasive exploration techniques. The technical content covered common airborne exploration methods with an emphasis on innovative geophysics, including hyperspectral imaging, UAV magnetics, and low-frequency airborne electromagnetics.

The workshop targeted European master's and PhD students and post-doctoral researchers. In all, 40 participants attended in person and 13 followed parts of the programme remotely, due to the Covid-19 outbreak.

Impact creation including outreach and dissemination

A special part of INFACT was devoted to impact creation; this includes outreach and dissemination activities. It also focused on higher education, life-long learning and wider society awareness raising. The impact activities were related to exploration campaign activities, the sustainability aspects of exploration tools and exploration best practices in both technical and social areas.

Within the INFACT project strong emphasis was placed on the instant inclusion of the project's results in the areas of technical and geological, and social science research into the higher education at the graduate level via:

i. Upgrading several courses with recent developments in non-invasive geophysical techniques for mineral exploration for MSc students of geophysics at Oulu Mining School (OMS);
ii. Including students in short field courses on exploration techniques (MSc students of geophysics at Freiberg University); and
iii. Giving several lectures and online courses on the social aspects of mineral exploration in Europe were given:
    a. *Communication, dialogue and public consultation* for MSc students of Leuphana University of Lüneburg, Germany;
    b. *Public engagement in mining and mineral exploration: case study INFACT* for MSc students at Stuttgart University, Germany;
    c. *Environmental and social aspects in mining* for MSc students in Geology and Environmental Management of Mining Resources at the International University of Andalusia, Spain.

And in addition, two education events were held for two local high schools in Andalusia, Spain.

At the postgraduate level the "immediate" inclusion of the results was achieved with i) the inclusion of a PhD student into the INFACT's tasks in the field of geophysics; ii) full-time employment of a postdoctoral researcher in geology; iii) direct knowledge transfer via internal workshops, field campaigns and research for the students involved.

The aims were twofold, firstly to immediately transfer the know-how to the students and secondly to test and shape the courses to develop an ideal knowledge transfer path.

Life-long learning (LLL) activities were focussed on addressing the experts in technical and social fields of exploration in early and mid-stages of their career. A Life-Long Learning Mining Value Chain programme at Oulu Mining School includes three courses (Introduction to Mining, Mining Geophysics, and Ore Geology and Society) that draw their content and know-how directly from INFACT results.

Another mode of life-long learning was performed through the international collaboration on airborne geophysics that enabled

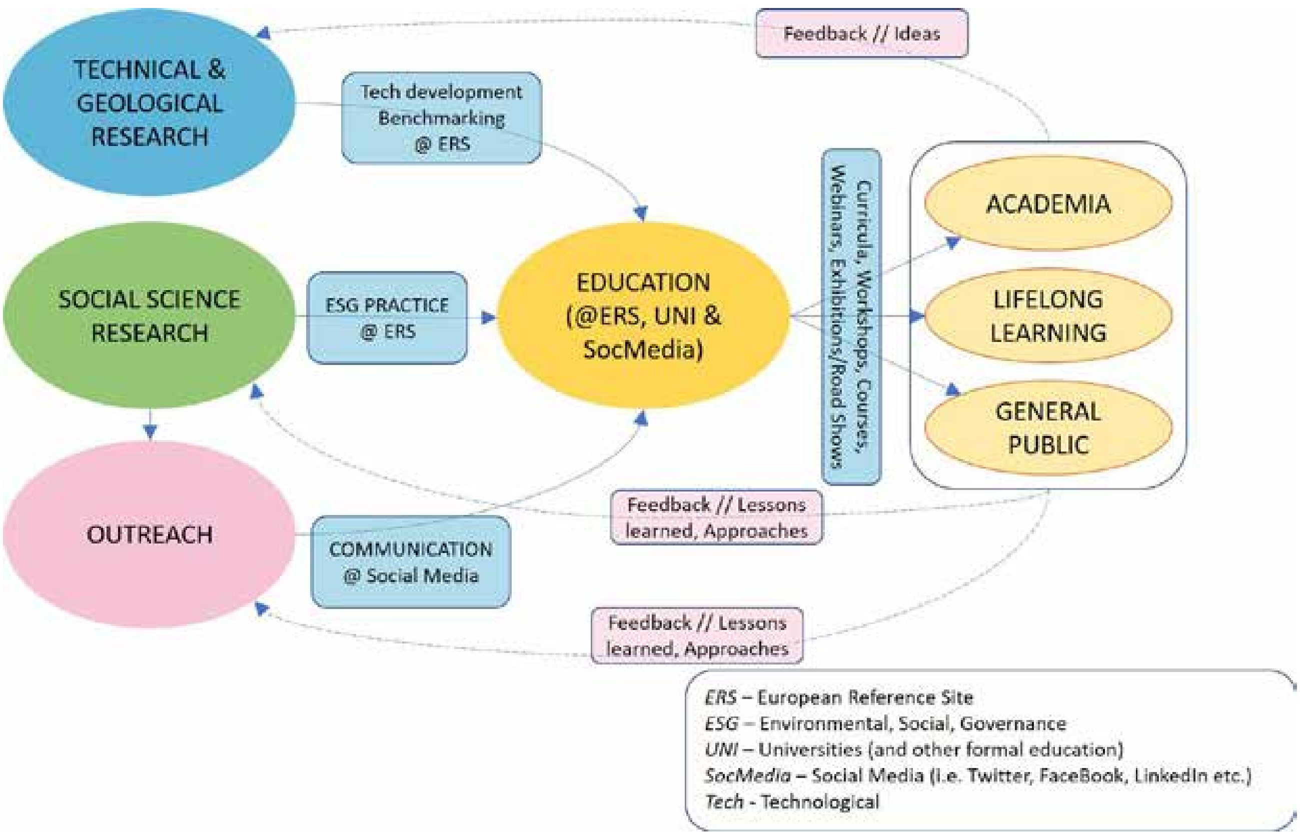

Figure 1: Consortium–stakeholders learning loop, as adopted in the INFACT project.

state-of-the-art knowledge transfer with one of the partners (Helmholtz Institute Freiberg for Resource Technology), hosting Canadian experts for a week of research and collaboration on integration and advanced processing of airborne geophysical data, including specific geophysical data generated within the INFACT project over the reference sites in Finland and Germany.

The clustering activities performed with other "sister" projects are listed in the previous section.

Experts from the field of geoscience were regularly informed on the INFACT's development and any interesting results through the weekly news compilation (EFGeoWeek), monthly newsletter (GeoNews) and through the social media campaigns. Also, a course on the novel approaches in the Social License to Operate and Environmental, Social and Governance domains is being prepared in a form of an on-line training/ lecture for Competent Persons in the exploration industry.

Transfer of knowledge performed within the INFACT project

Types of activities have been presented above. This section provides an overview of the quantity of activity. Firstly, it must be noted that the numbers of outreach events is not final, as during the preparation of this paper the INFACT project was close to its end, not all activities had been collated for the last six months of the project. Within the first 30 months, a huge number of activities and/or events were performed, targeting different audiences: the general public, experts, policy- and decision-makers, primary and secondary school pupils, and stakeholders in wider fields (NGO, environmentalists, local groups etc). All activities had the purpose to include, integrate, educate and inform. Roughly 800 events were performed by INFACT project partners and more than 500 by linked third parties.

Project partners estimate that the events organised by the INFACT consortium in the period between November 2017 and April 2020 reached an audience of more than 20,000 through public presentations, more than 600 through workshops and up to 50,000 through newsletters. Considering the educational events, 15 undergraduates and 60 postgraduates attended and two PhD students gained practical experience. In addition, approximately 150 experts attended life-long-learning events.

Lessons learned

From the very beginning of INFACT the "educational" component was designed in a circular mode, as a "consortium–stakeholders learning loop" in order to optimise the knowledge and know-how transfer to the various stakeholders. In addition, the benefits of the feedback received from these groups helped the INFACT consortium shape, adapt and enhance all content developed within the INFACT project – from new exploration search techniques to concepts, knowledge and processes. ***Figure 1*** shows the educational loop that INFACT adopted.

Conclusions

During the INFACT Project several challenges of future mineral exploration were addressed –novel geophysical techniques and novel environmental, social and governance approaches. The lessons learned were successfully integrated into various types of training courses in the three countries with the reference sites and form a good basis for strengthening the expertise of geoscientists that work (or will work) in the raw mineral exploration industry on a daily basis.

The chosen approach of a learning loop (a two-way learning process) proved to bring benefits to both the end-users/stakeholders and to the INFACT project partners, resulting in an optimal use of the project's resources. At the same time, it brought useful and applicable results to the exploration and mining sector in Europe (and beyond), to local communities where the exploration and mining activities are ongoing or could be developed in the future, and to the wider European public, which more and more will depend on domestic raw mineral supply.

In this aspect it is essential that geoscience education is tightly linked to the actual developments in the sector, drawing directly and instantly from progress, from newly-acquired know-how and from the in-situ lessons learned. It is only by enabling this that trust between the community and industry can be built and tightened.

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On all fours: report about a future geologist with a physical disability, or how to overcome the 'fit professional' stereotype

Nuria Guirado-Romero[*1]

The report describes a student's experience of having a physical disability and studying geology at a Spanish university, and discusses the adaptations carried out by this institution of higher education during the period 2016-2019. The discussion focuses on a bachelor's degree apparently founded on expectations of physical fitness, with all its gradations and possible intermediate nuances. Comparisons with other national and international universities are provided to ensure the inclusion of functional diversity, drawing a comparison with the experiences provided and framing them within the principles given by the new 'Geoeduethics.' Finally, possible solutions are provided in order to address the historical lack of inclusion in the geological sciences, which allow us to understand that being a geologist is much more than being an experienced climber.

Le rapport décrit l'expérience d'un étudiant en géologie présentant un handicap physique dans une université espagnole et les adaptations réalisées par cette institution supérieure pendant la période 2016-2019. Le débat est centré sur un diplôme de licence apparemment basé sur des attentes d'aptitudes physiques, sous toutes ses formes et nuances. Les comparaisons avec d'autres universités nationales et internationales sont fournies pour assurer l'inclusion d'une diversité fonctionnelle. Les expériences présentées sont ainsi comparées et structurées selon les nouveaux principes de « Geo-edu-ethics ». Finalement, de possibles solutions sont avancées pour combler le manque historique d'inclusion sociale dans les géosciences, nous permettant de comprendre qu'être géologue est bien plus qu'être un grimpeur expérimenté.

El informe describe la experiencia de un estudiante de geología con discapacidad física en una universidad española y analiza las medidas realizadas por esta institución de educación superior durante el período 2016-2019. La discusión gira en torno a un grado universitario en el cual, aparentemente, se esperan unas aptitudes físicas con todos sus matices y posibles medidas intermedias. Se proporcionan comparaciones con otras universidades nacionales e internacionales para asegurar la inclusión de la diversidad funcional, haciendo una comparación con las experiencias brindadas y enmarcándolas dentro de los principios dados por la nueva 'Geoeduética'. Finalmente, se proporcionan posibles soluciones con el fin de abordar la histórica falta de inclusión en las ciencias geológicas, lo que nos permite entender que ser geólogo es mucho más que ser un escalador experimentado.

Introduction

Sergio (not his real name) was born in 1996 with a spinal cord injury (myelomeningocele) which affected his fifth lumbar and first sacral vertebrae, with irreversible clubfoot and mild hydrocephalus. He underwent emergency surgery to close the open vertebrae and a peritoneal bypass valve was inserted. He began to take his first steps at 20 months. His feet are affected by a chronic neurological condition, that is, they will become echinovars (also known as clubfoot) again. Future considerations are amputation and subsequent prosthesis placement. Now, he uses orthopaedic shoes and inserts; he sometimes has trouble balancing on two feet and walks more slowly than average.

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This is his medical background. His personal story is something else; it is the story of a young man shaped by much more frequent and intense contact with nature than his reduced mobility would seem to allow. He had and has an aptitude for understanding geological environments. He has discovered them while walking at his own pace with those feet and a trekking stick.

Academic History

Sergio (not his real name) chose to study in the bachelor's programme in Geology at the Faculty of Sciences at a major university in southern Spain but was not, from the very beginning, welcomed or fully accepted by the Faculty. During the first year and on his first field trip to the Hoyazo fossil atoll (Níjar, Almería, Spain), his family voluntarily contacted the responsible professor to inform him of his degree of disability. The answer, sincere and friendly, was "don't worry", "thank you for notifying me". While on signing up it was specified that three of the places available for this degree course were reserved for people with disabilities, it turned out that they were unaware there were any students with problems of reduced mobility). Sergio gained the impression that the purpose of the excursion was to remove those students who did not have a true vocation and who would not finish the walk...a kind of preliminary natural selection to keep the fittest.

From then on, a series of events followed, with the clear aim of undermining Sergio's interest in the degree programme. The Degree Coordinator directly suggested to him to leave, saying "you are not going to make it."

There were, however, professors who offered to use their own cars to take him to the places of interest without having to do all the unnecessary mileage that was demanded of them as mere physical training: "geologists do not go on trails but cross-country" was one of the most repeated slogans in this type of practice. This stubbornness not only had repercussions on this student but also others who showed other physical limitations such as mild heart disease or obesity. His classmates did not understand the insistence on taking the most complicated, risky and difficult paths, either. They all arrived at the same interpretation: the idea was to select those students who truly wished to become geologists, no matter how or at what price. Physical resilience was, apparently, the most precious quality for screening among students.

The Vice Degree Coordinator for the course spoke with the family and argued that Sergio could not take part in the field trip because they did not have the means to carry out adaptations, nor permits to use cars from different departments, they could not change their campsites...they couldn't do anything, in fact, since they had not been offered a suitable budget from the university. With a clear lack of ethics, they further argued that they had checked the academic previous record of this student in high school: it was not very good. However, they neglected to mention the highest mark in his university entrance exam: an A+ in Earth Sciences. An improper environment was being built to slow the academic growth of this student. He was literally driven to sadness and lost motivation. These circumstances did not help him overcome the images that others held of him, which were already prejudiced by his physical disability. They definitively undermined the psychological state of Sergio.

Two academic years later, the Student Orientation Service of the university finally decided to implement measures to adapt the practical lessons in the countryside. The use of wooden platforms was the only measure offered during the first year, with the purpose of easing access on the beaches without having to sink into the sand, so that walking would be safer and less difficult. This measure shocked the Degree Coordinator, being totally impossible to carry out and making no sense in the field. The Student Orientation Service also decided to implement extra measures (though some members of the body did not agree with the decision): Sergio would be accompanied to each field camp by an assistant, and they would bring a car made available for such an occasion. However, he would never be with the rest of the group of students because it limited, affected and harmed them. The family kept contacting the university and this time they made contact with the Vice Rector for Inclusion and Diversity of the university. The Vice Rector explained that there were adjustments in this degree for students with mental illness and ADHD but not for students with reduced mobility. In the enrolment process, however, there was a series of places reserved for students with disabilities (without specifying which one they admitted and which not). When the family pointed this out, the response was that the law required them to include that. However, they said, it makes sense for someone with a physical disability to understand that they cannot perform these studies.

Field camps began. The student went with his "sherpas", as he ironically called them – they were there to take his backpack during breaks (but not while hiking), while the student settled on the ground and began to take notes and carry out tests. One of these experiences was a pleasure for the senses for Sergio – the professor not only taught him in depth but also naturally shared the route, talked about experiences and showed memorable style and eloquence.

However, in the second camp his dignity was literally attacked ("You will never be a geologist and if you succeed, you will not be as valid as the others because you have used a non-equivalent training itinerary"). He was exposed to extraordinarily disruptive conditions. During a storm and heavy rainfall, most of the professors decided to go back to town with their assigned students. Sergio could see how his classmates were being driven to town while his assigned professor made him walk in order to continue the visit. By this point, it was clear for the student this professor was harshly trying to convince him he was not capable of meeting the demands of the field class.

In addition, when in the classroom, Sergio had to be examined on what he had learnt and seen in the field, he was given the route that the rest of the group had followed. He got up to leave and another teacher asked him why he had not done anything: "because it is not the route that I did." "Sit down, please, the exams do not have to be the same, they have to be fair" (though the professor who went with him to the camp was present, he mentioned nothing at all and simply left the room). This story can now come to an end: the student did not want to take the last exam that he had left of a subject, for which he had already passed two parts. He was tired of this psychological stress, where his potential capacities were constantly undermined by reminding him that he would never be a geologist like the others. He was unwilling to see the teacher who had daily practiced this demeaning behaviour. In short, they had managed to defeat him but not convince him that he was unsuited to be a geologist.

Sergio will continue trying to complete his degree when he has evidence that the prevailing assumption in Spanish universities that asserts that most traditional field environments are inaccessible for students with reduced mobility problems has been revoked. He contacted the degree coordinators of two other universities in Spain and found that they had not made any adaptations for this "prototype" of student either because, they said, no case had been presented or, if the case had been, they would have had tried to persuade the person that it was not the career for him. They only made these adaptations when they designed social outreach activities in the geological sciences involving people with sensory disabilities, entitled "Geology for All."

Sergio will keep trying when he perceives that the institutional policies do not intend to differentiate him from the other students – and more so, from the rest of society – by what he can or cannot do.

Disability and higher education in geological sciences: a brief history

Higher education in Geological Sciences is very different in some countries compared to others. The subject of field education and the barriers it presents for students with mobility issues (Stokes *et al.*, 2019) have been discussed in considerable depth by different universities, particularly in the

United Kingdom and the United States of America.

When looking at images of field work presented in advertising brochures of various universities to try to motivate and increase interest in geological sciences, pictures of young male and healthy people who overcome difficulties of the terrain predominate (Wilson, 2014).

Regarding this lack of conceptual diversity about who can and cannot be a geologist, there was a recent (2020) virtual meeting in which the former president of The Geological Society, Nick Rogers, pointed to the decline in numbers of registered students enrolling in geoscience courses. He also highlighted the lack of criticism of this lack of diversity: "Our science is suffering from a great image problem and as a community, we have not done enough to promote what we offer" (Bullough, 2020, p. 26). Iain Stewart argued in this virtual meeting that geology needs a reboot. “Geoscientists think in a unique and important way: it is not just a historical science but also a derivative and interpretive science. We steal from everywhere and we merge it!” (Bullough, 2020, p. 27). It seems that fusion has its limits and geology as a science is disabling itself, for now, by failing to accept something as natural as biological diversity.

However, in the last decade new procedures have emerged to improve this situation. Publications and programs associated with the American Institute of Geosciences, the US National Institute of Sciences, the Foundation and the International Association for the Diversity of Geosciences (IAGD), as well as technical sessions and conferences with representatives from a diverse society, are promoting this change. Their objectives are improving awareness, and increasing the rates of graduates of different genders and ethnicities, even though people with physical disabilities are still underrepresented (Atchison & Libarkin, 2013).

To assist in this enormous task, geoscientific educational institutions should understand the different models of disability. Medical models of disability assume that people with disabilities are subjects to be treated and cured. By comparison, social models shift by focusing on the failure of society to accept disabled people for who they are and to provide adequate facilities for them. The emphasis thus moves from pity or sympathy to generic barriers to participation in mainstream activities.

Fieldwork is essential for teaching and learning in Geology and fulfils a number of pedagogical functions. However, it has the potential to exclude students with disabilities in different ways (Hall *et al.,* 2002). Despite this, and the numerous attempts by educational staff to include students with disabilities, there have been no substantial studies that have attempted to include the opinions of disabled students and thus explore their experiences in field work (Hall & Healey, 2005).

Departments have been left to develop inclusive curricula with little insight or pedagogical training. The ideas that professors and departments of geology in the United States have regarding the accessibility of field activities has been collected in a study that compiles information about those departmental practices that try to be inclusive (Carabajal, 2017). Nothing less and nothing more is needed than reform in educational practice for all educational communities (schools, universities, ministries, NGOs) around the world.

Geological science teachers have little guidance or support in reconciling adaptation with field geology learning objectives. They tend to think that those service personnel who accompany people with disabilities act as guardians. The net effect of this idea is to reduce the professors’ empathy and thus their ability to include students with disabilities in field settings. Recommendations for instructors include taking campus disability service providers on field trips, opening and maintaining communication with them, and designing pedagogically sound field trips that align as closely as possible with universal design principles. This field practice should be described under a case-by-case approach, focusing on students and the educational process, rather than institutional compliance. Finally, geoscience teachers should conceptualise disability service providers as providers of accessibility services (Feig *et al.*, 2019).

Not only are there physical barriers to these practices but there are also attitude barriers. One of the most effective ways to encourage students with physical disabilities to pursue the study and professional practice of geological science is to change the attitudes and behaviour of teachers (Locke, 2005).

A qualitative investigation (Stokes *et al.*, 2019) states that multisensory engagement, consideration for pace and time, flexibility of access and delivery, and a focus on shared tasks are essential for effective pedagogical design in field practices with students with disabilities. Furthermore, fieldwork can support the social processes necessary for students with disabilities to be fully integrated into learning communities, while promoting individual development by providing the opportunity to develop and practice personal skills.

Searching for Solutions

Due to the emphasis on field research at the undergraduate level, people with mobility issues face limited opportunities to progress in geosciences. A strategy to overcome this is to apply adaptive technologies, such as virtual field trips (VFT) and also to apply the principles of the novel concept geoeduethics (Promduangsri *et al.*, 2019), among which one principle that stands out as essential is mutual respect for all interactions between student and professor, student and student, and professor and professor.

Disability issues "cannot remain closed within a student services arena but must become part of the mainstream learning and teaching debate" (Adams and Brown, 2002, p. 7). In this statement there will always be an opportunity, not just a challenge.

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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.

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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

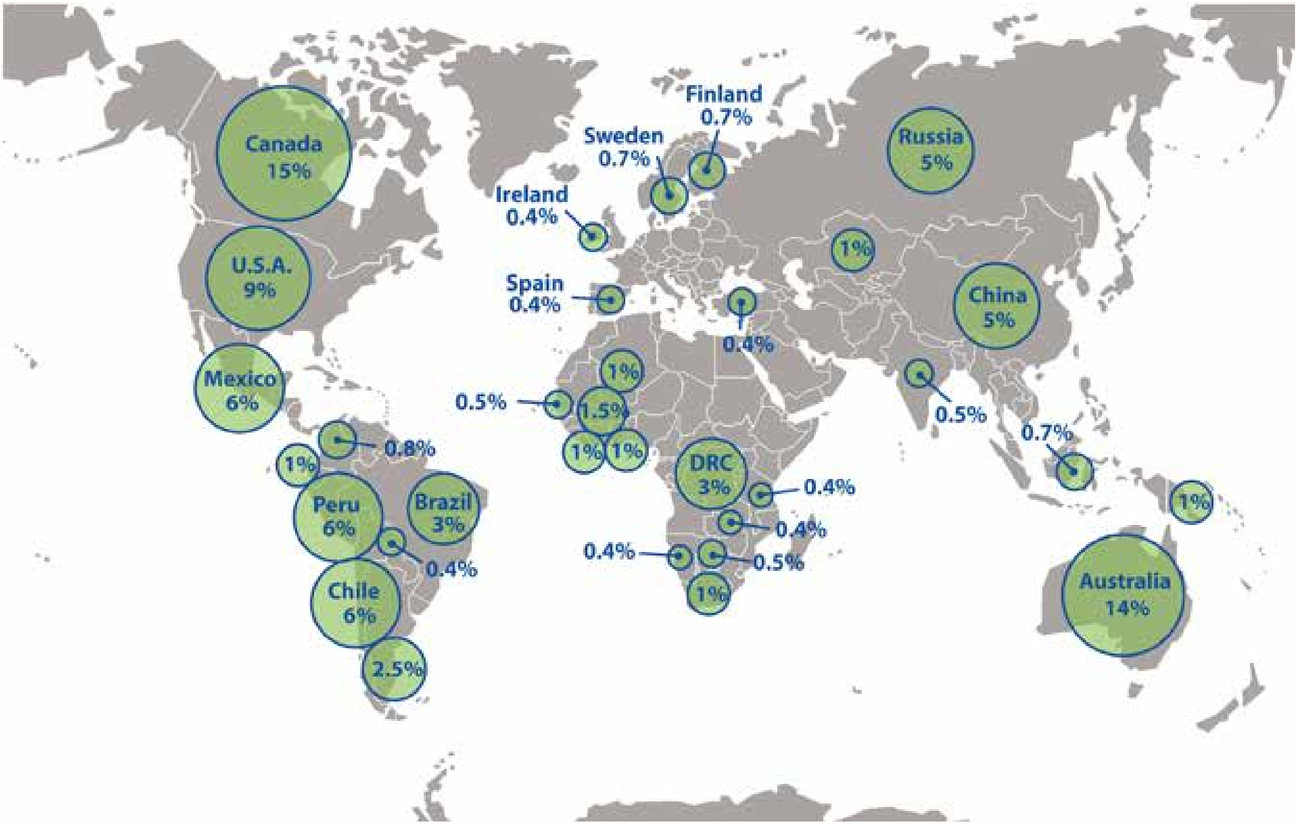

Figure 1: Global allocation of exploration costs in 2019 (excluding iron ore). Modified from Statistics of the Swedish Mining Industry (SGU, 2019).

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

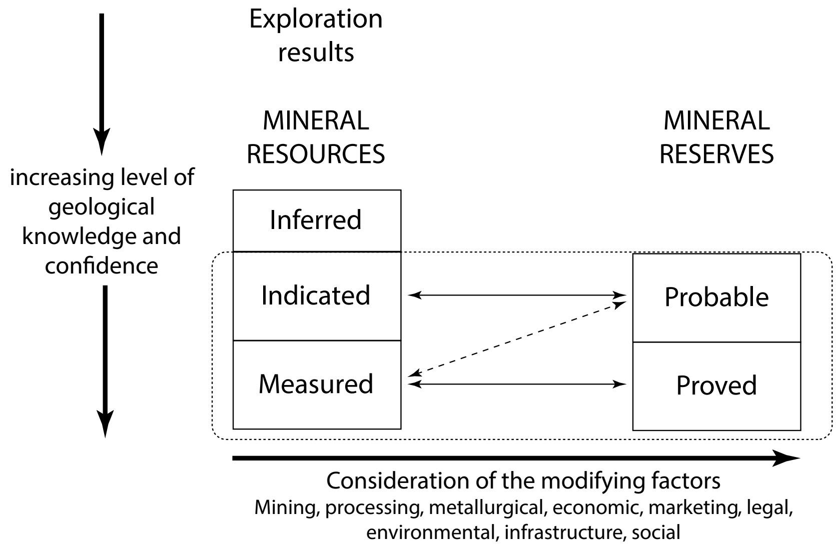

Figure 2: Diagram depicting the difference between mineral resources and mineral reserves according to the Joint Ore Reserves Committee (JORC, 2012). Conversion to mineral reserves requires consideration of all the modifying factors and solutions to any identified issues which would render mining sub-economic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

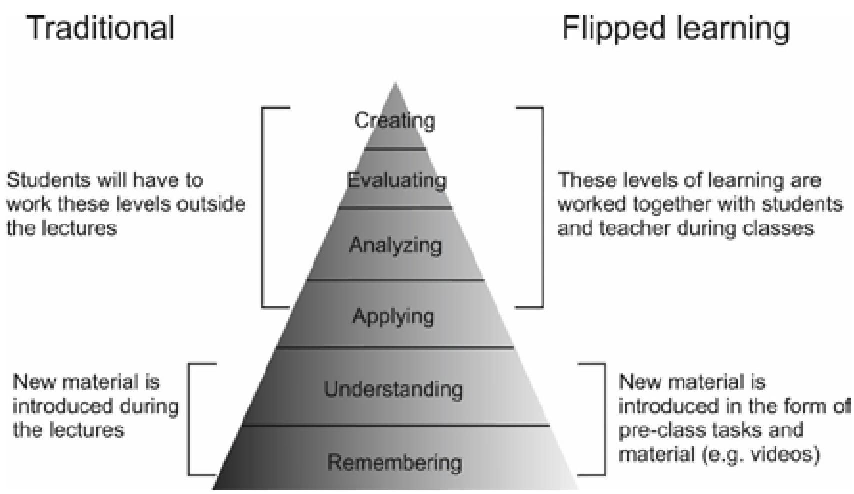

Figure 4: Bloom´s taxonomy (Bloom, 1956) related to the traditional lecture based teaching and the flipped learning method. Modified after Ouda and Ahmed (2016).

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***).

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.

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.

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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. *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.* *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.* *d. An appreciation of a multi-disciplinary approach to mining and exploration, including an understanding of operational, logistical and health and safety aspects.*	*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.* *f. The ability to foster a more inclusive workforce environment and to develop a practical understanding of diversity and community relationships in the workplace.* *g. The ability to recognise challenges and requirements in the mining industry and to proactively develop or provide solutions to these challenges.*

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

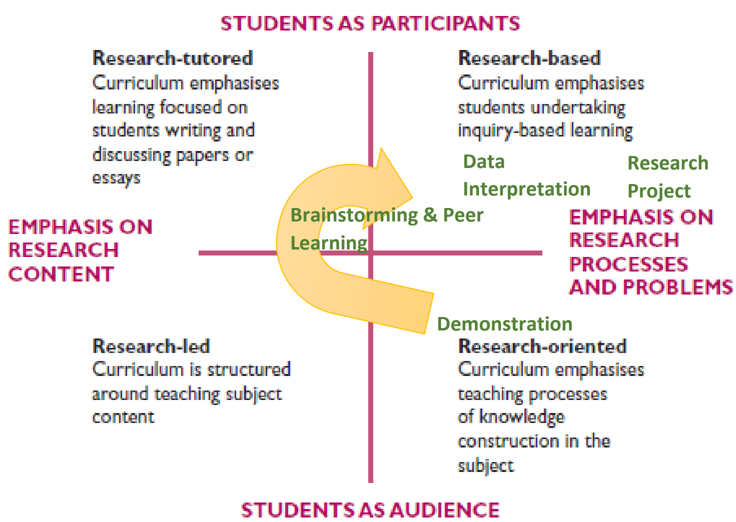

Figure 2: Curriculum design and the 'research-teaching nexus' after Healy (2005), modified from Jenkins et al. (2007). See main text for further information on the teaching activities (green) developed in this illustration.

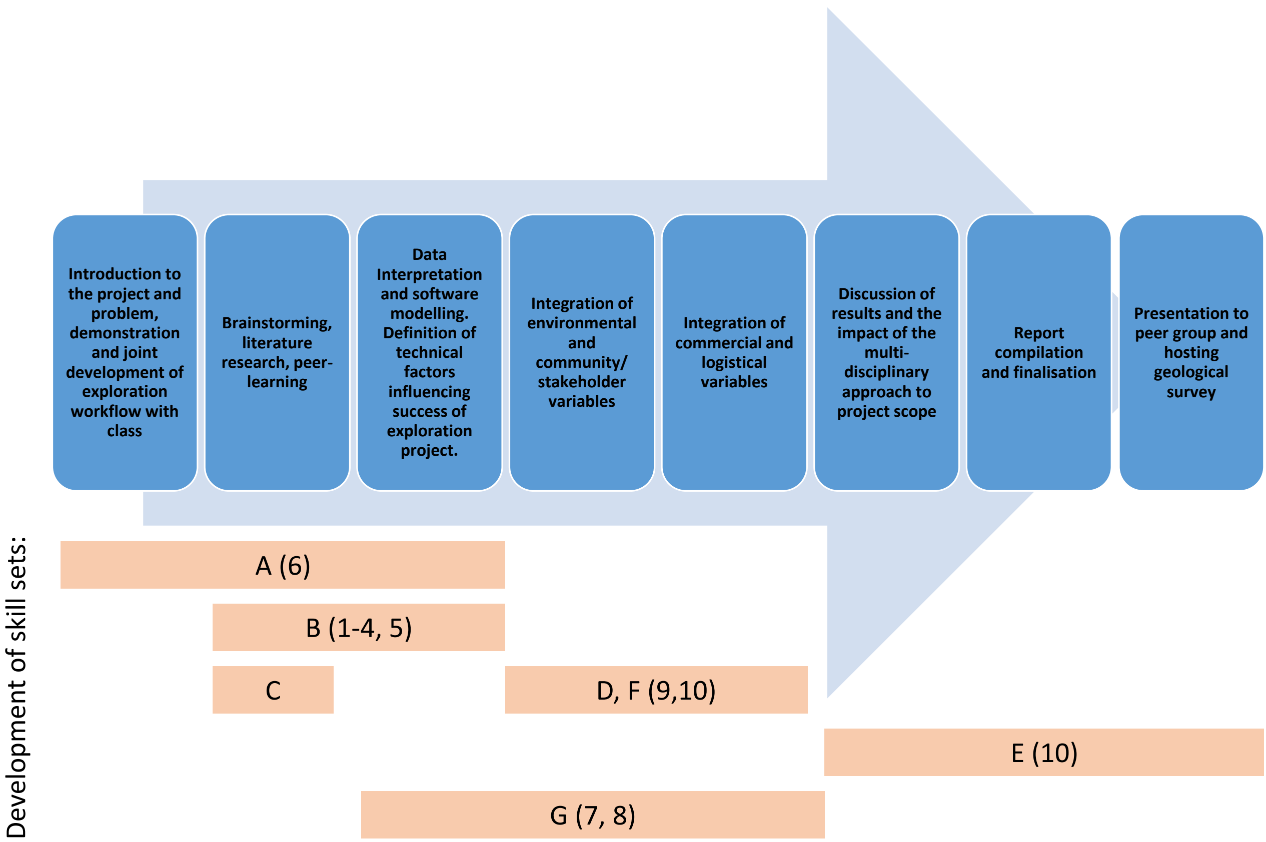

*Figure 3: Workflow illustrating the educational concept of the recently developed exploration targeting module. Skill sets and Intended Learning Outcomes (in numerical values, **Table 3**) are developed as part of a comprehensive research into a publicly available dataset and meet the requirements (in 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) 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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Interactive methods of studying geology with Z-generation children

Hanna Liventseva[1] and Maryna Krochak[2]**

This article describes methods of working with students in the framework of the Ukrainian educational project "Depths of the Earth, the spiritual depths" (UAG). The main aim of this project is to increase the interest of students in geosciences and the profession of geologist. Among the project stakeholders are children of the Z-generation. The article describes the interactive methods of working implemented in the educational process. Many different events were prepared and created for students and teachers within the framework of the project: more than 100 lectures, seminars, scientific conferences, excursions, geological quizzes/quests in museums, field Olympiads and festivals.

Cet article décrit les méthodes de travail avec les étudiants dans le cadre du projet éducatif ukrainien « Profondeurs de la Terre, les profondeurs spirituelles » (UAG). L'objectif principal de ce projet est d'augmenter l'intérêt des étudiants pour les géosciences et le métier de géologue. Parmi les parties prenantes du projet figurent des enfants de la génération Z. L'article décrit les méthodes de travail interactives mises en œuvre dans le processus éducatif. De nombreux événements ont été préparés et créés pour les étudiants et les enseignants dans le cadre du projet : plus de 100 cours, séminaires, conférences scientifiques, excursions, quiz / quêtes géologiques dans les musées, olympiades et festivals.

Este artículo describe métodos de trabajo con estudiantes en el marco del proyecto educativo ucraniano "Profundidades de la Tierra, las profundidades espirituales" (UAG). El objetivo principal de este proyecto es incrementar el interés de los estudiantes por las geociencias y la profesión de geólogo. Entre las partes interesadas del proyecto se encuentran los niños de la generación Z. El artículo describe los métodos interactivos de trabajo implementados en el proceso educativo. Se prepararon y crearon muchos eventos diferentes para estudiantes y profesores en el marco del proyecto: más de 100 conferencias, seminarios, conferencias científicas, excursiones, concursos / misiones geológicas en museos, Olimpiadas de campo y festivales.

Introduction

In Ukraine, there is an acute issue of encouraging young people to enrol in the geological faculties of domestic universities, since the prestige of the profession of geologist has fallen in recent decades. However, the demand for specialists in this field of science and production remains considerable. A few decades ago, the profession was fashionable and popular, stirring the minds of the grandparents of today's students. The romanticism of geological expeditions to the farthest corners of the planet, the delightful feeling of the explorer, the delight of finding new deposits are of little concern to the new generation.

Today's students are not familiar with the profession of a geologist; they are not aware of what geological science is and why it is necessary. At best, geology is associated with mining. Systematic educational and dissemination activities and corresponding competitions are needed to attract school youth to geology. It is important for us to reveal to students the diversity of fields of geological science, show a kaleidoscope of objects and phenomena, and tell them about modern professional methods and the use of computer technologies in exploration and production geology. This is an important task not only for individual organisations and volunteers but also for the state as a whole.

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Transformation of working methods with modern children

The project "Depths of the Earth, the spiritual depths" was created in 2011. The mission of this project is not only to encourage young people to study geological science but also to increase the general knowledge base for students, to expand their access to information. The project started more than nine years ago at the initiative of the authors of the article with the full and comprehensive support of NADRA GROUP, a company providing integrative solutions in the field of effective use of natural resources. The project partner is the Institute of Geology of the Taras Shevchenko National University of Kyiv.

The aims, tasks, and issues of the project, the work packages within the project, and the results have been described in a number of publications. Over these years we have done a great deal of work and had amazing invaluable experiences, we have used traditional methods of communicating with students and we have created new ones, had successes, and – as in any business – failures. We have learned from our experience. We concluded experimentally that today interactive methods of work are beneficial in working with modern school-age children (Liventseva & Krochak 2014).

According to the famous generational theory of Neil Howe and William Strauss, different generations show different characteristics (Howe & Strauss, 1991). Children born after 2000 are currently preparing to become students. These are children of Generation Z. They are distinguished by a special attitude to learning, methods of obtaining information, the uniqueness of their perception and personal motivation to learn (Gurova & Evdokimova 2016a, 2016b; Cilliers, 2017). For the Z-generation, our experience shows that it is necessary to develop new forms of training and introduce modern methods based first on the visualisation of information, on the phased presentation of material with the achievement of the final concrete result. That makes them very different from children who went to school forty or even twenty years ago. Their successful training, learning, and skills cannot be based on a sense of duty, on fear of parents and teachers, but solely on interest. They are progressive youth, born in the Internet era, who are able to instantly process a huge amount of information, provided they are interested in it (Kozyr 2017).

Therefore, when they choose a learning format, they do not tolerate long boring lectures and notes. They prefer YouTube streaming content that is short in duration and with a clear message. True, they read paper books less and listen to audio books at an accelerated rate. In addition, the formula is perceived only after the teacher has framed it (like a graphic drawing). This is because, according to doctors and psychologists, they have a better-developed part of the brain that is responsible for receiving information visually. Consequently, they perceive it better in the form of tables, iconography, presentations and video. They are receptive to practical tasks with a clear purpose and specific results, but they get tired of theory. And in practical tasks, they prefer to move from one block of tasks to another in the form of a kind of intellectual quest (Gurova & Evdokimova, 2016a, 2016b).

We have encountered similar features of Z-generation children in practice. In 2012 the first educational project was a geological lecture hall/room, held in the Kyiv Palace of Children and Youth - the largest out-of-school educational institution in Ukraine. The lecture hall/room project was not very successful, although the topics of the lectures were very interesting, such as "Animals and Dinosaurs: An Evolutionary Arms Race for 200 million years (the problem of extinction of dinosaurs)", "Fire-breathing mountains (volcanoes)", "Geological research of Ukrainian scientists in Antarctica", etc. During the lectures, lively presentations were used all the time, but it was quite difficult to keep the attention of the audience for 45-60 minutes. The lecture hall/room approach was in operation for only one year and, according to polls of teachers, did not arouse much interest among children.

In 2013 two approaches were taken. The first was scientific readings dedicated to the anniversaries of famous Ukrainian geologists – Volodymyr Vernadsky, Pavlo Tutkovsky, Yevgen Lazarenko, Volodymyr Bondarchyk and others. This was more successful, but still not the best format. The second was giving children the task to prepare reports on their own experiments, on observations in inanimate nature, on exploration of caves, etc. This format was more successful, reaching more than 300 children from different schools in the city, and arousing significant interest. Direct participation of children in discussions and presentations of their own research results worked for a positive result. All of the young participants were glad to receive books about geologists offered by the organisers as an award.

The next stage (2014) was geological quizzes. Teams of eight students answered questions, completed practical tasks in geology, drew, sculpted, sang and created living sculptures. And everything was related to geology. The spirit of competition, the desire to become the best, to win and receive the first prize became a significant incentive for students to learn more about geology and to acquire practical skills. Children learned how to properly assemble a hiking backpack, or identify rocks or document samples. During creative competitions, they used modelling clay to create a model of the solar system, a jewellery box with gems, and much more. This form of work has become one of the favourites of both the organisers and the participants. Geological quizzes are in the schedule of the annual work within the framework of our project.

Thus, the leaders of the project "Depths of the Earth, the spiritual depths" gradually came to realise that it is necessary to develop new and non-standard forms of education for children of Generation Z. This presupposes the introduction of new methods based primarily on the visualisation of information and the stage-by-stage presentation of the material (divided into semantic and logic blocks). The new methods take into account the desire of children to try their own strength, independently find answers to questions and draw the right conclusions, and to create models of geological objects with their own hands based on the information received. The adults learned to understand the motivation of children and tried to shape events in such a way as to arouse a keen interest in learning geology.

A further step in our work (2015) was the transfer of geological competitions to field conditions. This did not imply an expeditionary regime; the conditions of the city park were sufficient. This location has greatly expanded our capabilities. We were able to add tasks for orientation in the terrain using a map and a compass, tasks using the simplest geophysical instruments,

Figure 1 and 2: Scenes from the GeoQuest competition 'Natural Resources of Ukraine' held in the Natural Science Museum of the National Academy of Sciences of Ukraine for students of Kyiv schools, with the support of the Ukrainian Association of Geologists.


Figure 3 and 4: Scenes from the GEOFEST Geological Festival held in the Kyiv Palace of Children and Youth, dedicated to the 100th anniversary of the Geological Service of Ukraine and attended by 80 Kyiv students.

Figure 5: A drawing made with oil/petroleum from the creative task in the GEOFEST competition.

and activities involved in organising the expeditionary life of geologists (setting up a tent, packing a backpack, etc.). We taught students how to describe landforms and how to sample sediments and rocks. Prerequisites for all stages: all competitions must be held in a dynamic form as concrete practical tasks. Not by boring lectures! At the final stage an award is given to each participant.

Excursions to geological museums are an important form of work with students. There are several dozen such museums in Ukraine. In the city of Kyiv, where the project "Depths of the Earth, the spiritual depths" has been implemented, there are seven geological museums, not counting private collections available for viewing. Over the years of the project, we have conducted dozens of excursions, including thousands of students. The excursions introduce children to geological objects and phenomena, broaden their horizons, and give new knowledge about the earth sciences. Some of the children, and sometimes most of the group, get bored and do not listen to the guide, no matter how interesting and lively his speech is. Unfortunately, this fits into the psychological profile of Gen Z children. They do not see the point in the information they have heard and they lose interest in it.

During 2016-2017, we developed a new form of work in geological museums in the form of a quest. This is a kind of competition, where students receive a route sheet through the halls of the museum with tasks that can be completed only after studying the exhibits and stands of the museum. In this case, the child is motivated to find the right answer, he has interest and passion. At each stage of a quest, the participant receives a token, to which at the finish he can add a picture or a map, for which he/she receives a prize. The most common prizes are candy and chocolate. We conduct similar quests in geological museums every year. They are especially liked by children and their teachers, they are active and fun. The result is new information which is fixed in the memory, as it was obtained in the process of independent searching (***Figures 1 and 2***).

One of the most successful and interesting forms of work to popularise the earth sciences and the profession of a geologist is a geological festival, which we dedicate to great anniversaries. The festival took place in the halls of Kyiv Palace of Children and Youth. We created and prepared ten locations with games and assignments on geological topics (***Figures 3-5)***. At one location, students played chess from samples of combustible minerals. In another place, a model of an oil and gas reservoir was created from different types of chocolate. At one more point, they made up the route from Kyiv to Vienna of the first cars that drove on kerosene from one pharmacy-filling station to another. A location was dedicated to the history of oil production in Ukraine was presented. Children dressed up as fire fighters or rescuers worked on the sports ground. In the art studio, children painted pictures with oil and coal, in the concert hall they sang songs about geologists. These competitions and games were not only entertaining but also gave bits of information about geology and geologists.

At each location the teams received points, which were added up to reveal the winner. But all the participants of the festival became winners, who at the end of the event received valuable gifts from sponsors (NADRA GROUP, JSC Ukrgasvydobuvannya). It is noteworthy that there were six of the most highly-qualified scholars among the mentors (organisers, trainers, jury members).

So, step by step, we developed and improved our activities, introduced new methods of working with the students, taking into account the characteristics of their generation, combining the accumulated practical experience and theoretical knowledge.

An important point in the interactive teaching of geology for Generation Z children is the development of teaching materials. We have developed a "Workbook for Geology Studies". The workbook consists of thematic units for students to work with on their own. Each unit contains short illustrated information, which is interspersed with practical exercises. Completing assignments involves working with school textbooks on geography, atlases and maps, and searching for information on the Internet.

Some hands-on jobs require creative tasks such as drawing, writing essays and short stories. To consolidate the material and assess the knowledge gained, tests with

Table 1: Changes in knowledge and ideas of schoolchildren about geology.

Year	Do you know someone who is working as a geoscience professional?				
	Number of children taking part in the survey	Number of children who answered 'Yes'	Percentage of children who answered 'Yes'	Number of children who answered 'No'	Percentage of children who answered 'No'
2011	225	3	1.3%	222	98.7%
2020	205	96	46.9%	109	53.1%
	Would you consider working as a geological professional?				
2020	205	56	27.1%	149	72.9%

questions have been developed. "Workbook" has successfully passed approbation in the study of the special course "Fundamentals of Geology" in schools in Kyiv and in out-of-school institutions. In the program of the course for secondary school "Depth of the Earth (foundations of geology)", the authors were issued a Certificate of Registration of Copyright for the work (Liventseva & Krochak, 2019).

The project is now in its ninth year and is fulfilling the goals set for it. The European project ENGIE (Encouraging Girls to Study Geosciences and Engineering) helped to evaluate the results of our work qualitatively and quantitatively. We took part in it from the Public Organization "Ukrainian Association of Geologists". Our participation in the European ENGIE project was a logical continuation of our systematic and consistent work with students.

A survey of schoolchildren (ages 12–17 conducted before the start of the project "Depths of the Earth, the spiritual depths", showed an almost complete lack of knowledge of geology among children. During a youth conference in the National Ecology and Nature Centre of Ministry of Education and Science of Ukraine (NENC) (2011), where children from 22 regions of Ukraine were present, we asked "Do you know someone who is working as a geoscience professional?" "Yes" – answered 3 children from 225!

From that moment, we began work to spread knowledge about geology and geologists among children. Sociological surveys of students about their interest in geology have become an important component of the ENGIE project. The results of the polls (***Table 1***) showed a significant increase in interest in earth sciences among children participating in the project "Depths of the Earth, the spiritual depths". After nine years, almost half of the children participating in the survey were informed about the profession of a geologist, and we were able to interest children in geology as a field of activity.

Summary

Thus, during the course of the project, we have modernised our work with children of Generation Z, taking into account their peculiarities in receiving and perceiving information. We stimulated the motivation of students to acquire knowledge using different methods. The range of activities carried out within the framework of the project opened up the exciting world of geological phenomena and objects to hundreds of children. We told the younger generation about the wonderful profession of a geologist who learns the secrets of nature and the Earth. We have empowered children to be the geoscientists of tomorrow. We hope that by working in the trend of modern educational programs, we have planted in children's souls and minds the desire to connect their future profession with the knowledge of the Earth and that the motto "Let's be geologists" will become the motto of their lives.

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Promoting the Earth System approach and the meaning of learning

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Although earth science is important in every aspect of our lives, there is a disturbing gap between its relevance to society and its low status in schools worldwide. One of the approaches to bridge this gap is the International Earth Science Olympiad (IESO). IESO is a unique educational Olympiad designed to promote the Earth System approach and the meaning of learning. International Team Field Investigation and the Earth System Project are two educational tools for promoting learning in a social context, based on the Earth System approach. The implementation of this progressive, novel educational approach within national curricula poses a formidable challenge and merits cooperation and support of the international geoscientific community.

Bien que les sciences de la Terre soient importantes dans tous les aspects de nos vies, il existe un fossé inquiétant entre sa pertinence pour la société et son faible statut dans les écoles du monde entier. L'Olympiade internationale des sciences de la Terre (IESO) est l'une des approches pour combler cette lacune. IESO est une Olympiade éducative unique conçue pour promouvoir l'approche du système terrestre et le sens de l'apprentissage. L'International Team Field Investigation et le Earth System Project sont deux outils pédagogiques pour promouvoir l'apprentissage dans un contexte social, basés sur l'approche du système terrestre. La mise en œuvre de cette approche éducative novatrice et progressive dans les programmes d'études nationaux pose un défi de taille et mérite la coopération et le soutien de la communauté géoscientifique internationale.

Aunque las ciencias de la tierra son importantes en todos los aspectos de nuestra vida, existe una brecha inquietante entre su relevancia para la sociedad y su bajo nivel en las escuelas de todo el mundo. Uno de los enfoques para cerrar esta brecha es la Olimpiada Internacional de Ciencias de la Tierra (IESO). IESO es una Olimpiada educativa única diseñada para promover el enfoque del Sistema Tierra y la relevancia de su aprendizaje. "International Team Field Investigation" (Equipo internacional de Investigación de Campo) y Earth System Project (Proyecto Sistema Tierra) son dos herramientas educativas para promover el aprendizaje en un contexto social, basado en el enfoque del Sistema Tierra. La implementación de este enfoque educativo novedoso y progresivo dentro de los planes de estudio nacionales plantea un desafío formidable y merece la cooperación y el apoyo de la comunidad geocientífica internacional.

Introduction

Earth science touches almost every critical component of our life on Earth. As a result, the economy of every country is crucially dependent on its geological, hydrological, and atmospheric assets such as raw materials, mineral resources, energy resources, metals, water, and landscapes such as mountains, glaciers, lakes, rivers and deserts, which constitute the basis for the tourism industry. Earth science also deals with natural hazards such as earthquakes, hurricanes, floods, tornados, and landslides, which each year threaten billions of citizens worldwide.

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Earth Science plays a pivotal role in promoting environmental literacy. It is connected with several central environmental issues. For example,

- interactions between natural systems (human involvement excluded) such as how the chemical weathering of rocks influences the carbon dioxide balance and, as a result, changes in climate;
- the influence of human intervention on nature, such as changes in atmospheric composition which cause air pollution, pollution of the oceans, and freshwater resources. Other influences include the overuse of natural resources, intervention in coastal processes, the disposal of waste and its influence on the environment, and the increase in both the frequency and magnitude of floods;
- the ability to forecast natural hazards such as floods, storms, earthquakes, volcanic eruptions, mudslides and avalanches;
- the use of the physical environment to produce energy from resources such as fossil fuels and organic materials, and alternative energy sources such as solar, wind, nuclear, and chemical energy;
- sustainable use of natural resources;
- the impact of human activities on global climate change.

Other issues such as energy sources, producing raw materials and utilising natural resources are also crucial; citizens must become aware of and must internalise them. Thus, understanding earth science phenomena is crucial for the future of humankind. Earth science can endow citizens with knowledge and the ability to draw conclusions about saving energy, effective use of energy resources, saving water, and the proper use of the Earth's resources. Citizens who better understand their environment and its processes will be able to better judge and evaluate the changes that occur and, as a result, will behave in a more scientifically literate and environmentally responsible way. The economic and environmental aspects that make earth science highly relevant to responsible citizenship are well documented and acknowledged (Achieve Inc., 2013; Cheek, 2010; LaDue & Clark, 2012).

Despite the crucial importance and relevance of earth science to humankind, recent surveys (Greco & Almberg, 2018) have revealed that earth science education in schools worldwide continues to have as low a profile as in the previous century (Orion *et al.*, 1999).

The International Geoscience Education Organization (IGEO)

The International Geoscience Education Organization (IGEO; ***www.igeoscied.org***) was formally launched in 2000. Its main aims are to promote earth science education at all levels, to enhance public awareness of earth science across the globe and to bridge the disturbing gap between the importance of earth science to humanity and its low profile in schools worldwide. These goals are promoted by IGEO's activities, some of which are listed below:

a. The International Earth Science Olympiad (details below).
b. The Quadrennial International Conference on Geoscience Education (GeoSciEd).
c. Teacher Training Workshops, organized especially during GeoSciEd conferences, International Earth Science Olympiads and other congregations (***Figure 1***). School teachers carry out hands-on experiments, followed by critical thinking and analysis to make deductions (Shankar *et al.*, 2017). Recently, IGEO and the EGU Education Committee trained a dozen Field Officers to provide practical workshops for teachers at the local level (***https://www.egu.eu/education/field-officers/***).
d. International Geoscience Syllabus and Textbook Program published by IGEO (***www.igeoscied.org***).

The International Earth Science Olympiad (IESO)

The International Earth Science Olympiad (IESO) is an annual earth science event for secondary school students. It is the flagship activity of IGEO and a platform to expose both school students and geoscience educators to the innovative earth system educational approach.

While all scientific educational Olympiads follow the idea of Olympic games, IESO resonated with the spirit of Pierre de Coubertin, the founder of the modern day Olympic Games, who viewed Olympics as a means for promoting brotherhood and closeness among peoples. His philosophy was "In these Olympiads, the important thing is not winning, but taking part" (Durry, 1997).

The objectives of IESO are to (a) raise student interest in and public awareness of earth science, enhance earth science learning of school students, (b) improve the teaching of earth science in schools, (c) promote international cooperation in exchanging ideas and materials about earth science and earth science education, and (d) encourage friendly relationships among young learners from different countries, and (e) promote talented and gifted students in earth science.

In promoting these goals, the IESO lays special emphasis on the earth system, and this provides better visibility of earth science in the eyes of students, teachers and common people, and helps teachers in teaching earth science more effectively.

So far, 53 national teams have participated in IESO, including 17 from Europe. Each national team comprises a maximum of four students and two mentors. Only secondary school students are eligible for participation in IESO. Further, they must not have entered a college or university while participating in IESO. Mentors must be earth science educators or earth scientists with some background in school teaching. They are expected to contribute and discuss questions for IESO, and translate them into their native language, if necessary. They must present the status of earth science education in their countries, including aspects like strategies adopted to promote earth science education, what could be achieved and the obstacles faced.

A major attraction for students and particularly for some mentors is the medals. However, IGEO considers IESO as a vehicle for promoting earth science education, and the medals awarded thereof as only "toffees" to students.

The assignments/activities of IESO

All activities of IESO (***https://www.ieso-info.org/***) are based on system thinking skills, critical analysis, team work, field observations, data collection, Internet searching for reliable information, and communication skills (oral and textual). The common thread that runs through all assignments in IESO is the earth system approach – the understanding that Planet Earth is one single system, comprising various subsystems that interact amongst themselves. We consider that it is important to impress this concept upon young minds.

Like other Olympiads, IESO includes individual tests - written test and field and lab practical tests. However, this article focuses on the other components of IESO – the cooperative activities – that are unique and special when compared to other science Olympiads. They promote teamwork, international co-operation and collaboration, and forge bridges of friendship among

Figure 1: Field studies – an integral part of teacher training. Teacher Training Workshop, Hyderabad, India, 2014.

Figure 2: ITFI members trying to answer the question "Why does this rock have this shape?" IESO, Pocos de Caldas, Brazil, 2015.

young students across the world.

The two co-operation activities are the International Team Field Investigation (ITFI) and the Earth System Project (ESP). The spirit behind these activities is co-operation, and the coming together, mingling and working together of students from different nationalities, diverse cultures and varied backgrounds. This is particularly important today, and even more so in future, because major strides in scientific research are no longer possible through the efforts of individuals but rather through groups of scientists.

Each team typically consists of 6–8 students drawn from different national teams; efforts are made that they represent a wide spectrum of cultures, socio-economic development, languages, etc. This ensures that they not only work on the ITFI and ESP assignments, but also exchange ideas and information about their countries and cultures, lives and lifestyles. Such interactions, though only for a few days, have created such strong bonds among participating students that they keep in touch years after participating in IESO.

The International Team Field Investigation (ITFI)

This is an assignment which poses a research question pertaining to a concrete earth system phenomenon in a field site. The selection of the studied phenomena is based on the following criteria:

a. The phenomenon represents earth system interactions;
b. The research question has an environmental component;
c. Data collection includes the use of field instruments and/or sample collection for lab measurement;
d. A long-term data set may be provided to students following one-time measurements at the field site.

Table 1 presents eight suggestions of generic ITFI projects. To meet the ITFI

Table 1: Examples of ITFI projects.

1. An example of a lake environment ITFI project:	
Subject:	*Lake's water depth profiles*
Possible objective:	*to identify changes in the physical-thermal-chemical conditions in the water column in space and time*
Possible research question:	*What are the relationships between biological processes and physical-thermal development of the water column of the lake?*
2. An example of a soil ITFI project:	
Subject:	*Soil salinisation*
Possible objective:	*Understanding the mechanism for salinising of the soil in a specific basin, providing a forecast for the future of the soil salinisation based on the current situation and past measurements*
Possible research question:	*What are the factors that influence the salinizing of the soil? What is the rate of the soil salinization?*
3. An example of a geological economy ITFI project	
Subject:	*Prospect of rare metals*
Possible objective:	*Understanding geo-economy principles and quantitative evaluation of metals discovered. Performing economic, environmental and ethical analysis.*
Possible research questions:	*What is the economical prospect of the rare metals found in this area? What is the economic profit of the metal production compared to the environmental impact of the production process?*
4. An example of an aquifer and springs ITFI project	
Subject:	*Hydrological model of an aquifer and the underground water composition*
Possible objective:	*Understanding the interrelationships between rocks and water in the studied area*
Possible research questions:	*What influences the composition of spring water in a particular area? Do all sources represent one aquifer or aquitard?*
5. An example of a seasonal pond (or wetland) environment ITFI project	
Subject:	*Pond sediments as heavy metal pollution recorders*
Possible objective:	*Interrelationships between the earth systems and its environmental application*
Possible research questions:	*To what extent do the sediments that accumulate in pond constitute a tool for monitoring heavy metal pollution?*
6. An example of a global warming ITFI project	
Subject:	*The use of recent benthonic foraminifera as a model system for rising ocean water temperature*
Possible objective:	*To identify which species of foraminifera manage to survive in the heat spots of power plants turbines cooling wastewater. To find the temperature range in which each species manages to grow its shell.*
Possible research questions:	*What is the influence of hot water on the skeleton growth of benthonic foraminifera?*
7. An example of a geosphere ITFI project	
Subject:	*The development of the crystalline basement of a specific area.*
Possible objective:	*Reconstruction of a sequence of geological processes and events.*
Possible research questions:	*What were the conditions of formation of the various rock bodies? In what tectonic environments did the processes take place? What are the relationships between the geological development and human life in this area today?*
8. An example for wetland with heavy human intervention ITFI project	
Subject:	*The ability of a wetland to act as a nutrient sink.*
Possible objective:	*To understand the balance of nutrients in a wetland with heavy human interference.*
Possible research questions:	*Is the wetland acting as sink or source of nutrients? What influences the nutrient balance? How does the occurrence in this wetland affect the environment downstream from the wetland?*

Figure 3: An ESP team explaining their project to jury members through their poster, IESO, Mie, Japan, 2016.

criteria, IESO organizers must closely collaborate with geoscientists from universities located close to the IESO venue both in the design and implementation stages.

Each multinational team is provided with minimal basic information and data for the site. The team carries out field investigations at the site, collects relevant field data, takes photographs, and makes field notes.

Off site, team members search the Internet for more information, discuss the data collected and the data provided by the organisers, and build hypotheses to answer the research questions. The team has to engage in logical scientific argumentation, i.e., develop a logical sequence that progresses from observations to conclusions, by using geological principles, common knowledge that is related to the geological principles and external information. The team is encouraged to come up with as many hypotheses as are feasible given the field observations and data for the site, discuss the strengths and weaknesses of each hypothesis and reject or accept them – the way a research scientist does.

Finally, the team has to present its findings through a 12-minute slide presentation in front of all students, mentors and observers, followed by a 3-minute discussion.

It is important to distinguish ITFI from practical tests. The former poses research questions about long-term earth system phenomena and the use of field/lab analytical instruments, whereas the latter is based on field investigations of a small-scale geological exposure. The ITFI is a teamwork task and it encompasses all the components of open-minded scientific research, whereas a practical test requires ticking multiple-choice answers to short and clear questions.

The Earth System Project (ESP)

A major challenge for IESO is to showcase the current state of 21st century science in general and earth science in particular. To address this challenge, a new activity called the "Earth System Project" was introduced at the 7th IESO organized in India in 2013 (***https://ieso2013.webs.com***). A phenomenon that is local or regional for the host country is proposed as the research project/topic for ESP. The phenomenon must involve many sub-spheres of Planet Earth and must impact the economy, the lives and the society of the host country.

Multinational groups of students research the topic using and analysing the data they collect from the Internet. They discuss various aspects of the topic, including the origin, processes involved, earth system interactions, and impacts on biosphere (including humans) and remedial measures, if relevant. They present their results and findings in the form of posters that are viewed by students, mentors and observers.

The educational message of IESO

As mentioned earlier, the objective of IGEO and IESO is improving the quality of earth science education in schools. Several mentors and observers that lead national teams to IESO are school teachers. Therefore, IESO also includes workshops for mentors and discussions on aspects of importance and relevance to earth science education. Moreover, students and mentors are taken on a visit to local secondary schools. They visit the school facilities and interact with students and teachers of the local school to exchange information on syllabus, best practices in teaching, problems faced, etc.

Conclusions – the contributions of IESO to promote earth science education

Shankar (2019) gave a detailed account of how IESO over the years has contributed to earth science education and a better visibility for earth science. Among others, he mentioned IESO's contributions such as

i. promoting the educational earth system approach,

Figure 4. Teacher workshop: How to teach natural hazards at school, Guadeloupe, France, 2019.

ii. promoting inquiry-based learning, and importantly,
iii. the transition from information transfer-based teaching and rote learning to an earth science teaching-learning that promotes the development of high order thinking skills, and
iv. the transition from school-based teaching to the integration of the concrete earth system (outcrops of rocks, rivers, beaches, caves, lakes, ponds etc.).

Exposure to field studies can attract young minds. The awareness that earth science is "the great outdoors" can sustain students' interest in this discipline. The following transitions have been crucial:

a. from multiple-choice testing to project-based assessment like ITFI, ESP and practical tests;
b. from teaching that isolates students to a team work-based learning and development of social wellness skills; and
c. from teaching that focuses on passive listening of students to a teaching that develops communication skills of ideas, information or data and conclusions.

IESO holds great potential but unfortunately, this has not been realised effectively (Greco & Almberg, 2018). A possible reason for this situation could be that many mentors in IESO are geoscientists and not geoscience educators. A second possible reason could be that whereas IGEO views IESO as a tool to promote effective earth science education worldwide, many of the mentors may view IESO purely as a competition.

The conservative attitude of some of the mentors towards IESO's goals needs to be changed to enable a stronger connection with the geoscientific community. We hope that participation of mentors in intensive workshops in the future on effective implementation of the progressive educational assignments of IESO may help them promote ESE in their respective countries.

Orion (2017) claimed that the tendency of geoscientists worldwide to stay away from public activity, including the educational system, amplifies the disturbing gap between the importance and relevance of Earth science to society and its low status in schools worldwide. A profound change in the status of Earth science education in schools demands a profound change in the attitude of geoscientists towards their social responsibility. This responsibility is part of the professional geoethics of a geoscientist (Di Capua *et al.*, 2017).

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INTERMIN (International Network of Raw Materials Training Centres)

*Antonio Alonso Jiménez[1,2], Manuel Regueiro y González-Barros[*1], Francisco Elorza Tenreiro[2] and Vitor Correia[3]*

INTERMIN has created a long-term lasting international network of training centres for professionals. This project involves educational and research institutions in the EU and leading counterparts in third countries, based on specific country expertise in the primary and secondary raw materials sectors.

INTERMIN a créé un réseau international pérenne de centres de formation pour les professionnels. Ce projet implique des établissements d'enseignement et de recherche de l'UE et des homologues de premier plan dans des pays tiers, sur la base d'une expertise nationale spécifique dans les secteurs des matières premières primaires et secondaires.

INTERMIN ha creado una red internacional a largo plazo de centros de formación para profesionales. El proyecto incorpora a instituciones de educación y de investigación en la UE y de las principales contrapartes de terceros países basado en la experiencia específica de cada país en los sectores de las materias primas primarias y secundarias.

Introduction

The raw materials sector is undergoing significant structural changes. On the one hand side the skills required by emerging technologies and ever more challenging mineral deposits are changing more quickly than today's workforce capacity to update. On the other hand, the educational sector is mainly focusing on "classical" education in raw material related topics (ranging from geology to mining and mineral processing) and delivery methods (lectures during a whole semester). It is critical that industry and education players understand the needs and constraints of each other. This paper aims at generating a knowledge base for future analysis of raw materials education, identifying currently taught skills and the structure of higher education in the sector. For that a definition of skills, knowledge, and teaching areas is presented, leading to a comprehensive "skills catalogue". This catalogue builds the basis for an inventory of raw materials education worldwide. From the catalogue, it can be seen that this educational sector is focused in Europe and that English, and Spanish are the most common teaching languages, even in countries where these languages are not the mother tongue. Raw materials education turns out to be very one-sided. Almost all institutions teach topics related to basic geology or mining, whereas the share of new technologies and of soft skills such as communication and management is quite limited.

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Objectives

INTERMIN has created a self-sustainable, long-lasting international network of technical and vocational training centres for mineral raw material professionals.

The main specific objectives of the network are:

- to develop common metrics and reference points for quality assurance and recognition of training;
- to develop a comprehensive competency model for employment across the primary and secondary raw materials sector;
- to introduce an international qualification framework for technical and vocational training programmes;
- to create a conceptual framework for the development of joint educational training programmes based on present and future requirements by employers;
- to create and launch a joint international training programme by a merger of competences and scopes of existing training programmes;
- to optimize future interaction and

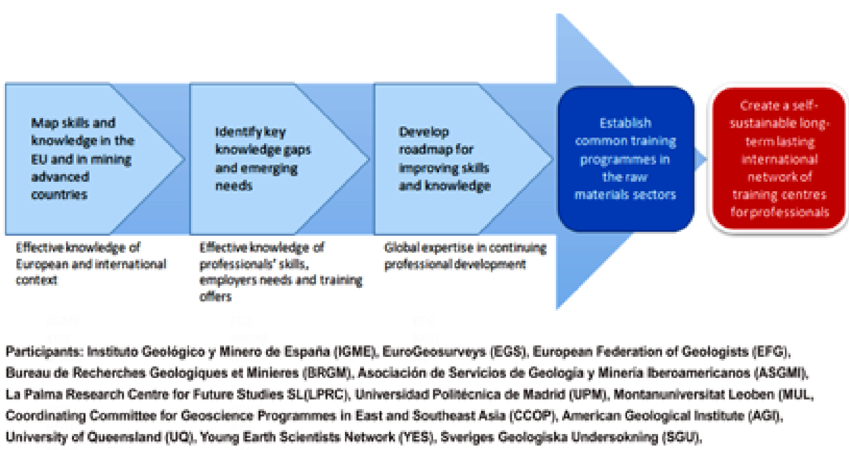

Figure 1: Distribution of the work to be done and the consortium member who carried it out.

Figure 2: Example of the model sectorial qualification framework employed in INTERMIN for some training programmes.

collaboration in Europe and internationally with the help of the INTERMIN online educational platform.

To build up this network INTERMIN is signposting critical disconnects between available education and employers' needs and it will advance short and medium-term actions to close current skill gaps and enhance existing education and training at the international level. In the long-term, INTERMIN will enable mutual recognition of curricula, and will foster cooperation between employers, educational institutions and professional organisations to create technical and vocational training programmes that offer continuing professional development and address future qualifications and skills' needs.

The INTERMIN international network of technical and vocational training centres for professionals will ensure that shared resources are leveraged to their best potential to create training programmes that match the needs of employers and professionals in the raw materials field, a sustainable objective. The collaboration will take full advantage of specialisation/capabilities of the network members, communication technologies and globalisation, hence using the educational platform to deliver interactive online services that provide trainers and learners with information, tools and resources to support and enhance training delivery and management.

The project has been formed by a consortium of recognized institutions that divided the work of the different work packages into which the project has been separated (***Figure 1***).

The INTERMIN Network Portal capitalises on the work carried out in the other INTERMIN work packages (especially WP1, WP2 and WP3) to improve the framework conditions and competiveness of raw materials training and education in the EU and globally. In particular the portal is based in a model of the sectorial qualification framework included in the portal (from WP3 results) (***Figure 2***).

The aim is to tackle longer-term challenges through continued international cooperation and materialising a feasible, long-lasting international network of technical and vocational training centres for raw material professionals. This requires the definition of a clear mission, statutes, supporting infrastructure and procedures.

Creating and implementing the Network Infrastructure

Figure 3 shows the scheme of the IT infrastructure of the INTERMIN portal. An information catalogue has been established that allows searching, consulting and downloading of the deliverables and the individual components of project deliverables, as well as of information produced by

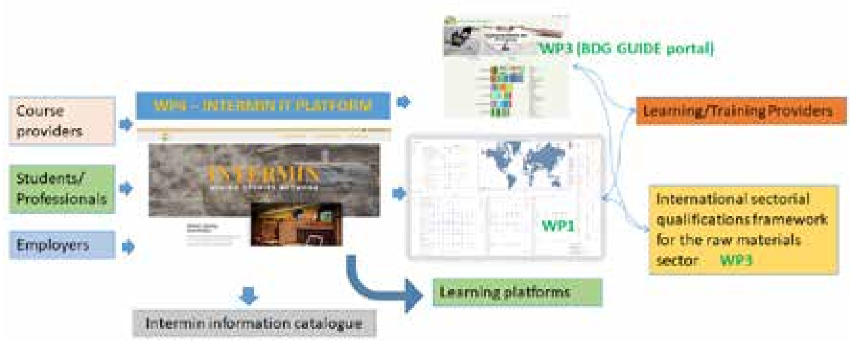

Figure 3: IT infrastructure of the INTERMIN portal.

external training providers. The catalogue contains international training providers' metadata, and is a "distributed catalogue" where all data providers (training centres) can create and modify their own metadata.

Other aspects to be included in the portal are:

- Mobility, language of the studies, internships, etc.
- Where to study abroad
- Decision-making tools for prospective students:
  - Best fit (academic, geographical and cost aspects)
  - Student reviews (alumni)
- Tips for applying for a particular master's degree.

The system will also address:

- Comparison of academic skills for different degrees and learning programmes
- The international sectorial qualifications framework
- Skill gap detection
  - Training centres by country
  - Potential university rankings.

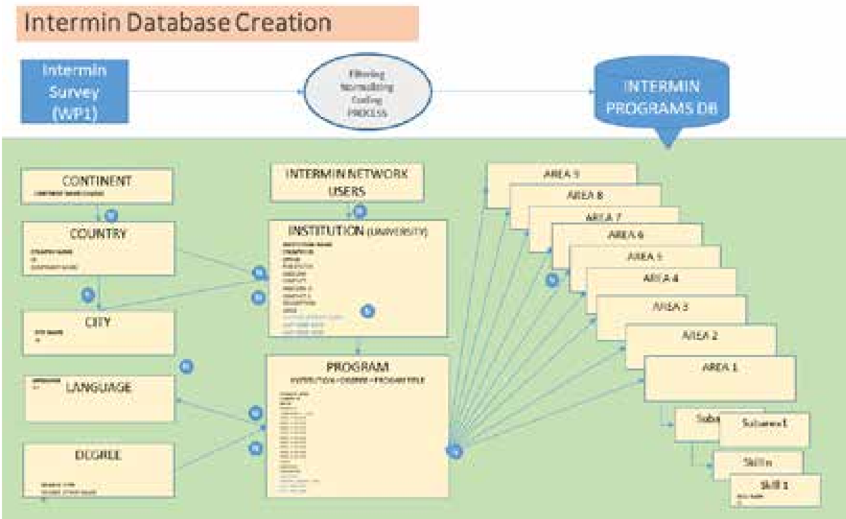

Figure 4: INTERMIN database creation procedure.

The technical solution for the portal has been:

1. Technological platform based on WordPress, a CMS (Content Management System) of proven capacity and reliability. Wordpress is currently the basis of 25% of the world's websites, and even more so if it is a place where there are edition and publication of content in the form of articles or documents.
2. The repository of courses will be integrated into a WordPress database using the MySQL database manager. Wordpress and MySQL are open-use tools, easily accessible and integratable with apps and web applications.
3. The database has been designed and created. A first version is currently available with all the metadata used in the INTERMIN Survey (WP1). It has countries, cities, institutions, programmes, degrees, and the nine INTERMIN training areas with the hierarchy of skills. (***Figure 4***)

Main aspects of the online portal are:

- A private network of users on WordPress for users of the provider centres and administrators (created).
- The internal structure of the web application to connect and search the database (created).
- Search engine for academic programmes, accessible to the public,

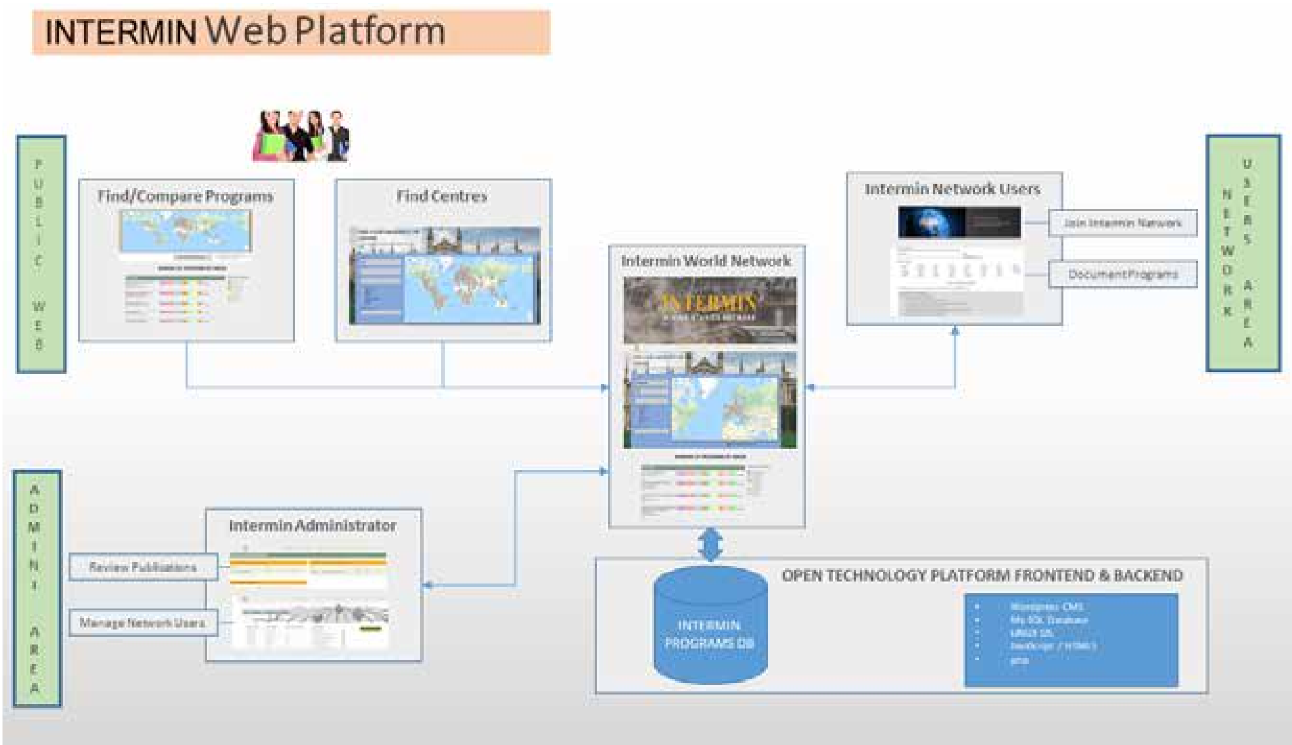

Figure 5: Operational scheme of the INTERMIN portal.

Figure 6: The INTERMIN portal (**https://portal.interminproject.org/**).

Figure 7: GUIDE web page.

Figure 8: Search in the INTERMIN portal by study programmes.

based on filters.

- Queries and creation of records in the database, accessible only to identified Internet users.
- A web portal (***Figures 5 & 6***) of public content, with the offer of learning programmes from the catalogue, and tools for searching content and training centres visually.
- A private area in the web portal for the private network of users, who can access it to manage their own offer of training programmes contained in the catalogue, including downloadable material.
- A backend tool on WordPress for the administration of the user network, Course catalogue and additional content of the website and a tool for backup and bulk loading of the catalogue to and from backup files in CSV (Excel) format.
- The web portal will also be fully functional on small screen devices, such as mobile phones and tablets.
- Configuration of an analytic module: integration with the Google Analytics analysis tool to obtain analytical reports about users, consultation visits, downloads of content made, visitors sent to schools' websites and other rankings and usage parameters, useful for the exploitation and evolution of the web portal.

The portal will also be linked to a dedicated webpage (hyperlink) detailing university programmes (Bachelor and Master) offered by European Universities (GUIDE – beta version available at ***https://www.geoscience-studies.org/***). The information provided by GUIDE (***Figure 7***) includes detailed data on curricula of geoscientific BSc and MSc programmes relevant to the primary and secondary raw materials sector in Europe.

The INTERMIN project will also define a Plan of Sustainability for the training network that will include:

- Scope and structure of membership;
- Scope of cooperation strategies/agreements between associated training centres;
- The legal and financial basis of cooperation;
- Design of the network structure and roadmap for its implementation.

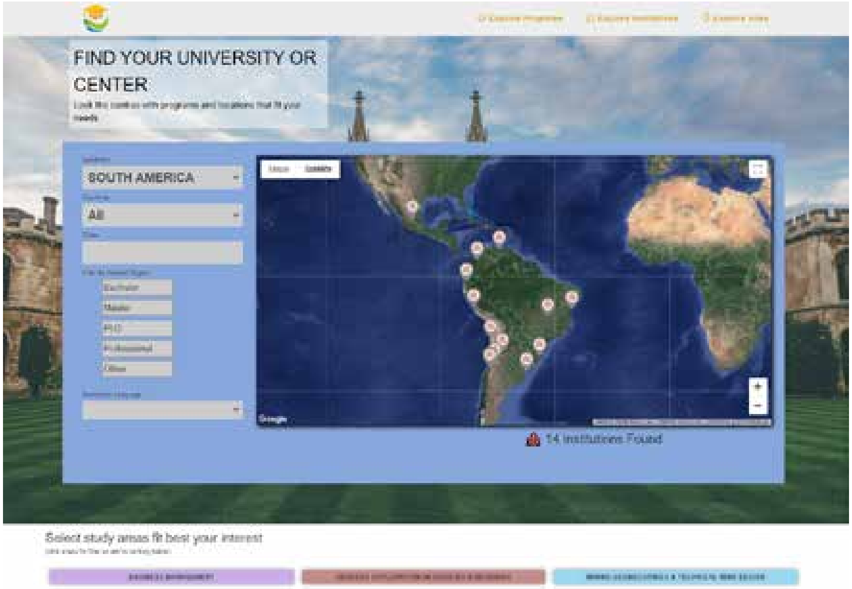

Figure 9: Search in the INTERMIN portal by institutions.

Figure 10: Search in the INTERMIN portal by geographical location.

Search system in the INTERMIN portal

The INTERMIN portal allows simple searches by study programme (***Figure 8***), by institution (***Figure 9***) or by geographical location (***Figure 10***).

Conclusions

The International Network of Raw Materials Training Centres (INTERMIN) has created a feasible, long-lasting international network of technical and vocational training centres for mineral raw material professionals.

The new INTERMIN portal will assist graduate professionals of different industrial sectors of raw materials from all around the world to find the appropriate specialised training in centres registered in the portal and find the face-to-face or online training they desire.

The selection system designed by INTERMIN is unique, as it is centred in the skills acquired instead of the study subjects, is a result of an extensive analysis of the educational offer, the industrial skills needed and on the geographical offers

The advantages for the graduates in a globalized – and now one under the pressure of a global pandemic world – are obvious. Training centres also benefit from a centralised repository of existing raw materials courses and the skills provided.

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Can we teach children geology using one of the world's most popular video games?

Pontus Westrin [1], Théo Berthet[2], Rok Brajkovič[3], Eric Pirard[4], Mariaelena Murphy[5], Luca Bellucci[6], Karin Käär[7], Juan Herrera[8] and Rachel Kavanagh[9]*

With an increasing global demand for raw materials, along with an ageing work force in Europe and public distrust for the sector at large, there is a rapidly growing need to work with public awareness and education within the subject of geology. By using innovative tools and models such as gamification, we can develop and nurture interest in raw materials and geology for the future workers and policy makers within the EU. BetterGeoEdu is a project that targets primary schools by providing teacher resources on raw materials, circular economy and sustainability using BetterGeo – a modification of the immensely popular video game Minecraft. The gamification model is used to engage and motivate students by inspiring creativity and learning while having fun.

Avec une demande mondiale croissante de matières premières, une main-d'œuvre vieillissante en Europe et la méfiance du public à l'égard du secteur dans son ensemble, il est de plus en plus nécessaire de travailler avec la sensibilisation et l'éducation du public dans le domaine de la géologie. En utilisant des outils et des modèles innovants tels que la « gamification », nous pouvons développer et nourrir l'intérêt pour les matières premières et la géologie pour les futurs travailleurs et décideurs politiques au sein de l'UE. BetterGeoEdu est un projet qui cible les écoles primaires en fournissant des ressources pédagogiques sur les matières premières, l'économie circulaire et la durabilité en utilisant BetterGeo - une modification du jeu vidéo extrêmement populaire Minecraft. Le modèle de gamification est utilisé pour engager et motiver les étudiants en inspirant la créativité et l'apprentissage tout en s'amusant.

Con una creciente demanda mundial de materias primas, junto con una fuerza laboral que envejece en Europa y la desconfianza del público en el sector en general, existe una necesidad cada vez mayor de trabajar con la conciencia pública y la educación en Geología. Mediante el uso de herramientas y modelos innovadores como los video juegos podemos desarrollar y fomentar el interés por las materias primas y la geología para los futuros trabajadores y responsables políticos de la UE. BetterGeoEdu es un proyecto que se dirige a las escuelas primarias al proporcionar recursos para maestros sobre materias primas, economía circular y sostenibilidad utilizando BetterGeo, y una modificación del inmensamente popular videojuego Minecraft. El Video Juego se utiliza para involucrar y motivar a los estudiantes al inspirar la creatividad y el aprendizaje mientras se divierten.

Background

With an increasing global population and a steadily growing middle class, our need for raw materials has never been bigger. On top of that, decarbonisation of our energy system has sparked interest in new technologies requiring large amount of special minerals and metals, critical in the production of for example batteries, electric motors, and green energy. These raw materials have one thing in common: most of them are still in the ground.

Today, the amount of exploration and mining in the EU is small in comparison to our consumption of raw materials. The reasons for this are numerous, but one of the core issues stems from mining in the EU being considered as an unattractive investment by several large players within the mining industry. One of the reasons behind the unwillingness to invest derives from the lack of social acceptance and trust towards mining operations. As put by the EU commission themselves in the strategic implementation plan of the European innovation partnership on raw materials, there is a prevailing public distrust in the mining industry – a key problem leading to difficulties in establishing operations. The lack of trust appears to be based on the historical mining legacy and lack of public awareness regarding raw materials and their extraction and use in modern society. One thing is clear – if the public directly opposes mines, a socially sustainable sector will be impossible to secure.

Building public awareness, and by extension trust, for an entire sector across a continent requires both short- and long-term commitments focused for different target groups. The youngest citizens in the European Union, who will grow up to be the next generation of industry workers and policy makers, are vital to this strategy, making primary schools particularly important. However, in many EU countries, especially those represented by the authors of this text, geoscience has been found to have a very low presence in national school curricula in primary schools. As such, it is no wonder that people of all ages have an outdated perception of modern mining,

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Figure 1: The diverse geology of BetterGeo.

especially in areas far away from active mine sites (SGU, 2017).

Moreover, we face the issue of an ageing workforce which will need to be replaced by a younger generation in the not-so-distant future (Johansson *et al.*, 2018). But if European youths associate jobs in the raw material sector as dangerous, dirty or male-dominated, then who will choose to work there?

Innovative methods of teaching and gamification

As geology and raw materials may not be stand-alone subjects in many of the EU countries' school systems, an extra incentive might help teachers to discuss the issues in other subjects, such as chemistry, physics, history or social science. This may be done by making all the material digital, with an emphasis on innovation and technical skills. Digitalisation of educational methods, for example by introducing more technical tools in teaching, is increasingly popular and even pushed in the EU agenda. The EUs Digital Education Action Plan aims to provide better digital readiness and tools for schools – for example, helping provide fast broadband connections in the Connected Schools Programme. This goes together well with the notion that future workers within the mining industry will need more digital skills due to the shift to new technologies such as remote-controlled operational systems and autonomous drones and vehicles (EY, 2019). Can we entice teachers with innovative digital material, meeting the goals within the school curriculum while keeping the interest of digital natives?

Enter gamification, the application of games in non-game contexts, as defined by Deterding *et al.* (2011). Games are amazing in the way they catch the interest of the gamer, whether it is by completing different scenarios, getting to the top of the scoreboard, or telling a captivating story. Gamification takes these applications, such as feelings of achievement, cooperation, competition, and storytelling, and uses it in new contexts which are not games in themselves. Many people come into contact with gamification elements every day without even noticing it. Popular gamification applications are for example Duolingo, an app on your phone that teaches foreign languages. The app splits up lessons into different steps you can achieve and gives you incentives such as daily streaks to keep you motivated. Or "Zombies Run", a running app which makes you run faster by telling a gruesome story through your headphones of zombies chasing you while you gather supplies to defend yourself. Or why not LinkedIn, which shows how far you have come in filling out your profile by displaying colorful progress bars and pushes you to create more content by showing statistics, almost similar to leaderboards?

Today, people of all ages spend a significant part of their day playing games, whether it is on a mobile phone, TV or computer. Studies suggest that as children grow older screen time increases, with about 6 hours per day for children ages 8-12 and 9 hours per day for ages 13-18, outside of schoolwork (Rideout, 2015). A significant part of this time is spent either playing or watching others play games, similar to how many watch others play football. Why not use the motivation behind games to learn at the same time as having fun? And why not use it within one of the most popular games in the world?

Minecraft – a game about raw materials and geology

Minecraft is one of the most played video games in the world, with over 100 million copies sold worldwide. It revolves around surviving in an open 3D world by collecting raw materials to create tools and buildings. Mining for metals and minerals is a big part of the game and allows the player to advance in technologies, reaching new environments quicker and more efficiently. To find most of the best minerals, a popular strategy is digging as far down as you can in the crust and systematically searching using tunnels. Naturally, different minerals such as diamonds, iron, coal and gold can be found in the same host rock – simply called "stone". It is not uncommon to find diamonds next to a cluster of iron, coal or gold, or all together within a few meters. While the game is undeniably hugely popular, and does teach the player something about different raw materials and where they come from (i.e. from the bedrock), the geology in the game is very simplified and encourages ideas of mining being a low-tech field, built on manual labour, searching for minerals in deep tunnels under ground.

One of the reasons that Minecraft has become so popular is the huge community built around modifications for the game. A

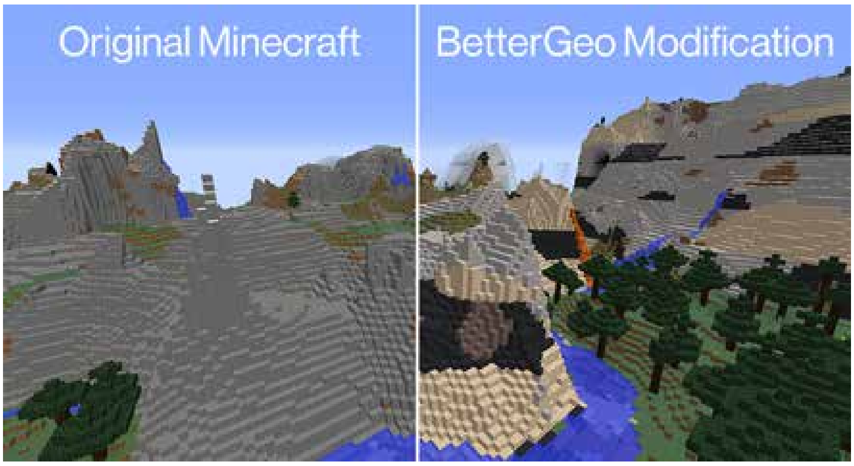

Figure 2: A comparison between original Minecraft and BetterGeo world generation. Note the bedrock diversity in the BetterGeo modification, the first indication for finding the raw material one needs.

Figure 3: Students playing BetterGeo in Limerick, Ireland.

modification, or "mod" for short, alters the original game in different ways, for example by adding new items, blocks or features. Mods are created by players for players and can be reached through different player-made platforms. Some mods are small, perhaps adding niche items, while others are huge, even to the point of altering the whole game experience.

BetterGeo – better geology in Minecraft

In 2014, a small team at the Geological Survey of Sweden started to create a mod in order to introduce more realistic geology in Minecraft. The project was part of a larger public awareness measure for geology included in the Swedish mineral strategy. The idea was to meet the target audience in their own arena – gaming. BetterGeo was developed by programmers, communicators, and geologists, with constant input from the gaming community via the player-made platforms for mods.

The BetterGeo mod adds multiple new rock types, including corresponding ores along with realistic locations for them in the virtual world (***Figure 1***). What was called "stone" in the original version is now gabbros, limestones, kimberlites, banded iron formations, quartz veins, shales, schists, gneiss... the list goes on (***Figure 2***). The way Minecraft generates the world has been changed, giving the new rocks a realistic stratigraphy with everything from magmatic, metamorphic, and sedimentary rocks, along with intrusions of different kinds. Even the surface has changed, with soil types now modelled after Swedish quaternary deposits of different tills, pebbles, clay, etc., instead of the original soil that was just called "dirt".

Instead of digging deep, underground tunnels as the only method for mineral exploration, finding raw materials is best done with the knowledge or technology suitable for each specific raw material. For example, iron can be found in large deposits of banded iron formation, often near other sedimentary rocks. The magnetism in the iron-rich rocks can be found by using a magnetic compass, which spins when close to a deposit. To find metals needed in electrical equipment in the game, an electrical conductivity meter can be used. The flower Alpine catchfly grows above copper-rich bedrock, a great indicator for finding the copper ores we need in all electrical tools. While still simplified, the new tools for mineral exploration gives depth to the redefined geology and increases the emphasis on raw materials almost as treasure hunting for children.

Within the new rocks, new metals and minerals can be found and processed. In the original version of Minecraft, ores are put into a furnace to be refined. In BetterGeo, this has been expanded with the smeltery which needs to be prepared with different amounts of energy input to work. For example, it takes a lot of energy to refine aluminium, which is reflected in the energy requirements in the smeltery, while other metals might need less. The smeltery also creates by-products in the form of slag. If you have enough slag you can reprocess it for more metals, but in the end there is always going to be some waste products which you cannot use and have to store in some way. The smeltery also releases ash into the environment, which can be harmful for flora and fauna. By finding new raw materials to construct a flue gas cleaner, ash can be collected and the problem can be solved using innovation. Again, the methods are simplified even in the mod, but give the player a notion of the complexity within metal processing as well as environmental consequences – while also giving alternatives using technology.

Using new-found metals such as lithium, copper, titanium, tantalum and silver, the player can create new items and tools that can assist them in surviving. While "normal" everyday items such as phones and computers might not be intuitive or useful in the game, the new monster scanner, jet pack and heart starter are things that can really help the player overcome the dangers of the Minecraft world. These items use similar raw materials as they would in real life, for example the jet pack uses lightweight metals such as titanium and the monster scanner has a lithium battery that needs to be charged using solar power.

Finding new rocks, minerals, metals and alloys introduces the player to another new set of items – in-game educational books. For example, the first time you find a new mineral, a book is given to you at the same time. This book describes the features of the mineral in real life along with where it can be found and other useful information for young aspiring geologists. The books can be collected in bookcases and tracked through a so-called achievement system, where your progress in the game can be seen. This gives comprehensive tools for learning even more

Figure 4: Students identifying rocks and minerals by comparing with sketches made with the BetterGeo mod.

about raw materials and geology beyond the game elements themselves.

Going further – using Minecraft and BetterGeo in primary schools

It is widely known that learning while having fun increases the brain's ability to take in information. As described elegantly by neurologist Judy Willis (2007):

"When students are engaged and motivated and feel minimal stress, information flows freely through the affective filter in the amygdala and they achieve higher levels of cognition, make connections, and experience "aha" moments. Such learning comes not from quiet classrooms and directed lectures, but from classrooms with an atmosphere of exuberant discovery."

With games and gamification, we can engage students in environments where they can use more of their senses than just their ears, allowing them to explore and actively make use of their creativity (***Figure 3***). Learning by having fun increases the involvement and motivation in the student, which in turn increases the ability of the brain to create long-term memories. Many can relate to this phenomenon by looking back at their school years – there are often certain memories from classes that really stick even until adulthood, possibly due to them being particularly interesting, engaging or fun.

BetterGeoEdu was initiated by SGU, EIT RawMaterials and partners all over the EU to provide primary school teachers with material to teach about raw materials, circular economy, and sustainability with Minecraft and BetterGeo. Teaching resources, installation guidelines and step-by-step instructions are provided freely through the website ***www.bettergeoedu.com***, no registration or payment required.

The idea behind BetterGeoEdu is to use the gamification model, specifically related to Minecraft and BetterGeo, to drive the motivation to learn more about school subjects. In addition, and because some students are already familiar with the concept of Minecraft, a flipped classroom approach can rapidly be implemented as an educational strategy by the teacher using BetterGeoEdu. Exercises provided by the project can be used either "online" with computers, letting students actively play the game, or "offline" by using game elements and inspiration without using computers. Two examples are summarised below.

Using computers, one exercise on the BetterGeoEdu platform called "Rocks and minerals" takes the students through a set of rooms in the virtual world. In each room, the students examine a rock or mineral and sketch it on paper while trying out hardness and other features of the samples. When all rooms have been completed, the students put away the computers and get to identify real samples of rocks and minerals by comparing them to the sketches and experiments they made in the game (***Figure 4***). A discussion can be held in the class to introduce the students to the rocks and minerals and what metals we can extract from them in real life.

An "offline" example of an exercise is the "Rock memory". This exercise uses real rocks and minerals that are supposed to be paired with pictures of the same within the BetterGeo mod. While the students try to match the right samples with the pictures, the teacher can discuss and make the connection between the game and real life. This is a short, simple exercise that requires little preparation.

As of November 2020, BetterGeo has been downloaded more than 50,000 times. Train-the-trainer workshops have been held with hundreds of teachers throughout the EU, and more will be held in the continuation of the BetterGeoEdu project. Today, the BetterGeoEdu 2.0 project is coordinated by the Geological Survey of Sweden in collaboration with the Technical University of Madrid, the Geological Survey of Slovenia, Trinity College Dublin, Tallin University of Technology, the University of Liège, the National Research Council in Italy and Montanuniversitaet Leoben. The project is funded by the European Institute of Innovation and Technology (EIT), within the Knowledge and Innovation Community called EIT RawMaterials.

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News corner:
Compiled by Anita Stein, EFG Office

EFG endorses the launch of the European Raw Materials Alliance

Earlier in September, the European Commission announced the launch of a new industry alliance relating to raw materials. The aim of the European Raw Materials Alliance (ERMA) will be to secure access to raw materials critical for the digital and energy transition. This new Alliance is part of a broader EU Action Plan on Critical Raw Materials and will be managed by EIT RawMaterials. The official launch event took place on 29 September 2020 on the occasion of the EIT RawMaterials Summit.

The European Federation of Geologists (EFG) and its Panel of Experts on Minerals endorse the launch of the European Raw Materials Alliance. The Federation expresses its support for the Alliance's mission to help diversify European sources of raw materials supply and to develop our indigenous raw material resources in accordance with the United Nations Sustainable Development Goals and in compliance with Environmental, Social and Governance (ESG) standards. To that end, EFG encourages ERMA to avail of its expertise in matters relating to mineral raw materials and their availability.

For further details, please read the Position Paper released by the EFG Panel of Experts on Minerals: ***https://bit.ly/2G7JrRK***

EFG releases State of the Art Report on CCS

The European Federation of Geologists (EFG) is pleased to present its Carbon Capture and Storage (CCS) State of the Art Report. The report has been produced by the EFG Panel of Experts on CO_2 Geological Storage. Reducing the amount of carbon dioxide (CO_2) released to the atmosphere is crucial to meet the climate targets outlined in the European Green Deal. Naturally, it is vital to find ways to cut down on emissions produced, and various measures will be needed to achieve substantial gains in reducing the amount of CO_2 released into the atmosphere. Some approaches involve capturing CO_2 before release and then either fixing it or using it for another purpose.

The report offers an introduction to carbon sequestration technologies in use or being investigated, especially in the energy industry, which emits a considerable amount of CO_2 in the course of producing the materials, fuel and power that make our lifestyles possible. The earth sciences are fundamental in many of these technologies, meaning that geoscientists and geoengineers have an essential role in sustainable progress.

Read the full report here:
https://bit.ly/3o69Bpc

EU projects

Horizon 2020 is the biggest EU research and innovation programme ever, with nearly €80 billion of funding available to secure Europe's global competitiveness in the period 2014–2020. EFG is currently involved in six active Horizon 2020 projects: INFACT, INTERMIN, ROBOMINERS, CROWDTHERMAL, REFLECT, SUMEX. In addition, EFG is also participating in two projects under the EIT RawMaterials initiative: ENGIE and PROSKILL. Below you will find descriptions of the topics and aims of these projects (INFACT is covered in an article on pages 48-52).

ROBOMINERS

ROBOMINERS

820971 – ROBOMINERS
Resilient Bio-inspired Modular Robotic Miners
START DATE: 1 June 2019
DURATION: 48 months
http://robominers.eu

Objectives:

ROBOMINERS will develop a bio-inspired, modular and reconfigurable robot-miner for small and difficult-to-access deposits. The aim is to create a prototype robot that is capable of mining underground, underwater or above water, and can be delivered in modules to the deposit via a large diameter borehole. In the envisioned ROBOMINERS technology line, mining will take place underground, underwater in a flooded environment. A large diameter borehole is drilled from the surface to the mineral deposit. A modular mining machine is delivered in modules via the borehole. This will then self-assemble and begin its operation. Powered by a water hydraulic drivetrain and artificial muscles, the robot will have high power density and environmentally safe operation. Situational awareness and sensing is provided by novel body sensors, including artificial whiskers, that will merge data in real-time with production sensors, optimising the rate of production and selection between different production methods. The produced high-grade mineral slurry is pumped to the surface, where it will be processed. The waste slurry could then be returned to the mine where to backfill mined-out areas.

ROBOMINERS will deliver proof of concept (TRL-4) of the feasibility of this technology line that can enable the EU have access to mineral raw materials from otherwise inaccessible or uneconomical domestic sources. This proof of concept will be delivered in the format of a new amphibious robot Miner Prototype that will be designed and constructed as a result of merging technologies from advanced robotics, mechatronics and mining engineering. Laboratory experiments will confirm the Miner's key functions, such as modularity, configurability, selective mining ability and resilience under a range of operating scenarios. The Prototype Miner will then be used to study and advance future research challenges concerning scalability, swarming behaviour and operation in harsh environments.

REFLECT

850626 - Redefining geothermal fluid properties at extreme conditions to optimize future geothermal energy extraction
START DATE: 1 January 2020
DURATION: 36 months
https://www.reflect-h2020.eu/

Objectives:

The efficiency of geothermal utilisation depends heavily upon the behaviour of the fluids that transfer heat between the geosphere and the engineered components of a power plant. Chemical or physical processes such as precipitation, corrosion, or degassing occur as pressure and temperature change, with serious consequences for power plant operations and project economics. Currently, there are no standard solutions for operators to deal with these challenges. The aim of REFLECT is to avoid the problems related to fluid chemistry rather than treat them. This requires accurate predictions and thus a thorough knowledge of the physical and chemical properties of the fluids throughout the geothermal loop. These properties are often only poorly defined, as in situ sampling and measurements at extreme conditions are hardly possible to date. As a consequence, large uncertainties prevail in current model predictions, which will be tackled in REFLECT by collecting new, high quality data in critical areas. The proposed approach includes advanced fluid sampling techniques, the measurement of fluid properties in in-situ conditions, and the exact determination of key parameters controlling precipitation and corrosion processes. The sampled fluids and measured fluid properties cover a large range of salinity and temperature, including those from enhanced and super-hot geothermal systems. The data obtained will be implemented in a European geothermal fluid atlas and in predictive models that both ultimately allow operational conditions and power plant layout to be adjusted to prevent unwanted reactions before they occur. That way, recommendations can be derived on how to best operate geothermal systems for sustainable and reliable electricity generation, advancing from an experience-based to a knowledge-based approach.

ENGIE

Encouraging Girls to Study Geosciences and Engineering
START DATE: 1 January 2020
DURATION: 36 months
https://www.engieproject.eu/

Objectives:

ENGIE aims to turn the interest of 13-to-18-year-old girls towards studying geosciences and related engineering disciplines. As career decisions are generally made in this period of life, the project aims to improve the gender balance in the fields of these disciplines. During the implementation of the three-year-long project an awareness-raising strategy will be developed and an international stakeholder collaboration network will be established for the realisation of a set of concrete actions. These actions include family science events, outdoor programmes, school science clubs, mine visits, mentoring programmes, international student conferences, competitions, publication opportunities, summer courses for science teachers and production of educational materials. The actions will be carried out in more than twenty countries throughout Europe.

PROSKILL

Development of a Skill Ecosystem in the Visegrád Four countries
START DATE: 1 January 2020
DURATION: 36 months
www.proskillproject.eu

Objectives:

The European Union puts emphasis on raising productivity as an important factor in maintaining economic growth. In order to improve productivity, it is vital to offer products and services with a high added value, and for that purpose highly qualified employees are required. Companies and professional organisations in the raw materials industries have stressed the need to improve the soft skills of students in order to meet the requirements of the labour market. The engineers of the future have to accept that engineering problems – as well as their solutions – are embedded in complex social, cultural, political, environmental and economic contexts. Engineers have to access, understand, evaluate, synthesise, and apply information and knowledge from engineering as well as from other fields of study. They have to find and achieve a synergy between technical and social systems. ProSkill has a double purpose. From the one side it adopts a 'skill ecosystem' concept, looking at what (hard and soft) skills are missing in the raw materials sector, which areas are affected by skill problems (shortages, mismatches and gaps) and what strategies can work. A high-skill ecosystem strategy supplemented with an action plan is developed. To ensure sustainability, the project focuses on lecturers in higher education ('train the trainer'). The main goal is to develop their knowledge about new and innovative educational techniques and to reshape outdated curricula. On the other side, a pilot project is launched involving the colleges for advanced studies in partner HEIs. Short-term and long-term programmes help to implement the strategy with the targeted development of selected soft skills.

SUMEX

101003622 - SUstainable Management in EXtractive industries
START DATE: 1 November 2020
DURATION: 36 months
https://www.sumexproject.eu/

Objectives:

SUMEX is a 36-month project funded by the European Commission that started on 1 November 2020. The project supports the set-up of a European sustainability framework to improve the permitting procedure along the extractive value chain (prospecting, exploration, extraction, processing, closure, post-closure activities), to guarantee timely decisions, a transparent governmental regulatory regime, appealing financial and administrative conditions and sustainable natural environmental and social conditions. The main mission of SUMEX is to assist policymakers and other stakeholders in seizing this opportunity.

In order to foster more extensive but sustainable mineral production in the EU, SUMEX (SUstainable Management in EXtractive industries) will establish a sustainability framework for the extractive industry in Europe. It does so by considering the Sustainable Development Goals, the European Green Deal, as well as EU Social License to Operate considerations and will involve stakeholders from industry, government, academia and civil society backgrounds from all across the EU.

INTERMIN

776642 – INTERMIN
INTERNATIONAL NETWORK OF RAW MATERIALS TRAINING CENTRES
START DATE: 1 February 2018
DURATION: 36 months
http://interminproject.org

Objectives:

INTERMIN is intended to create a feasible, long-lasting international network of technical and vocational training centres for mineral raw materials professionals. Specific objectives:

- Develop common metrics and reference points for quality assurance and recognition of training;
- Develop a comprehensive competency model for employment across the primary and secondary raw materials sectors;
- Introduce an international qualification framework for technical and vocational training programmes;
- Create a conceptual framework for the development of joint educational training programmes based on present and future requirements by employers;
- Create and launch a joint international training programme by a merger of competences and scope of existing training programmes.

CROWDTHERMAL

857830 – CROWDTHERMAL
Community-based development schemes for geothermal energy
START DATE: 1 September 2019
DURATION: 36 months
http://crowdthermalproject.eu

Objectives:

CROWDTHERMAL aims to empower the European public to directly participate in the development of geothermal projects with the help of alternative financing schemes (crowdfunding) and social engagement tools. In order to reach this goal, the project will first increase the transparency of geothermal projects and technologies by creating one-to-one links between geothermal actors and the public so that a Social Licence to Operate (SLO) could be obtained. This will be done by assessing the nature of public concerns for the different types of geothermal technologies, considering deep and shallow geothermal installations separately, as well as various hybrid and emerging technology solutions. CROWDTHERMAL will create a social acceptance model for geothermal energy that will be used as baseline in subsequent actions for inspiring public support for geothermal energy. Parallel and synergetic with this, the project will work out details of alternative financing and risk mitigation options covering the different types of geothermal resources and various socio-geographical settings. The models will be developed and validated with the help of three case studies in Iceland, Hungary and Spain and with the help of a Trans-European survey conducted by EFG Third Parties. Based on this feedback, a developers' toolbox will be created with the aim of promoting new geothermal projects in Europe supported by new forms of financing and investment risk mitigation schemes that will be designed to work hand in hand with current engineering and microeconomic best practices and conventional financial instruments.

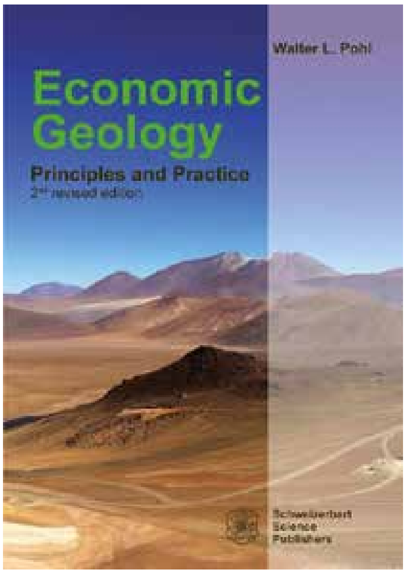
Book review by János Földessy, Professor Emeritus, University of Miskolc

Economic Geology, Principles and Practice: Metals, Minerals, Coal and Hydrocarbons – an Introduction to Formation and Sustainable Exploitation of Mineral Deposits.

by Walter L. Pohl:

Published by: Schweizerbart Science Publishers, Stuttgart, Germany, 755 pp, 2020

ISBN: 978-3-510-65435-2



Professor Emeritus W.L. Pohl, a renowned Austrian scientist, former Professor at the Technical University of Braunschweig (Germany) and experienced consulting geologist, now has provided a fully updated version of his earlier opus. Economic Geology is the application of earth science to provide society with metals, minerals and energy. The 2nd edition is not purely a face-lift of the book published in 2011, but a deeply modernised presentation reflecting the rapid advance of applied earth science.

In this new book, the author undertakes the challenging mission to amalgamate genetic principles of a wide range of raw materials with the techniques of their exploration, evaluation and sustainable extraction. The book comprises four parts: (I) Metalliferous Deposits, (II) Non-metallic Minerals, Rocks and Salts, (III) The Practice of Economic Geology, and (IV) Fossil Energy Materials.

Topics covered offer a broad view across the whole field of economic geology. The *Introduction* addresses the role and nature of mineral deposits, and their origin by concentration of useful materials in the Earth's process systems, which are driven by internal and external (solar) heat flow. In *Chapter 1*, the formation of ore deposits within the six great petrogenetic-tectonic Earth process systems is introduced and illustrated. It clearly shows the many novel insights and models of current ore deposit science. Traditional metallogeny is reborn in digitised clothes. The metallogenetic evolution of Europe is described as an example (Box 1.15). *Chapter 2* systematically covers some 50 individual metals with information on ore minerals, use, possible toxicity, geochemistry, environmental issues, deposit types and genetic classes, specific exploration properties, global production, main producing countries and reserves/resources. Non-metallic Minerals and Rocks (*Chapter 3*) offers a menu of industrial raw materials, which – in my opinion – are ever more important and closer to the user due to their application in many everyday objects, such as in buildings, cars and tools, and in environmental engineering. Salt rocks (*Chapter 4*) still have their traditional role as an essential nutritional amendment for plants and humans, but also for underground storage of energy, toxic and radioactive waste. *Chapter 5* highlights the applications of economic geology in 50 dense pages. Following the life of mine concept, topics cover the principles and methods of exploration, such as the mineral systems concept, mineral prospectivity modelling, remote sensing, geochemistry and drilling, resource estimation, the mining environment, mine closure, and restitution of ecosystem services. *Chapters 6 and 7* present the geological essentials of coal, gas and oil. Here, the interested reader may find brief facts about climate, CO_2 and geological aspects of reducing emissions. Unconventional petroleum and natural gas deposits are explained (including the fracking method), interwoven with the conventional hydrocarbons. The novel technology wiped out all speculations of an 'end of oil'. Each chapter is concluded by a brief summary and list of further reading.

Naturally in a book that condenses whole libraries, the depth of treatment is limited. For an advanced level of enquiry, abundant references to important printed and online sources are provided throughout. The referenced bibliography and Indexes are valuable components of the book. References occupy some 80 pages, offering a good start for more in-depth research. The General Index is lean at 14 pages but a detailed online version is in preparation. The 12-page Location Index takes us through the mentioned sites and mines. With some 300 figures, the book is well illustrated and equipped with 32 colour plates, as well as 81 equations, 32 tables and 25 boxes. Boxes feature case histories relevant to important topics of the host chapter and illuminating text with maps and sections of deposits. Most equations illustrate chemical processes concerning ore formation.

The author challenges some petrified public perceptions about mineral raw materials. Ever again, an impending depletion of some metal or mineral is announced by 'experts' and is taken up eagerly by the media. Throughout the book, current published reserve and resource figures of metals and minerals are cited, which show no historic decrease in the availability of resources, evidencing that human creativity is unlimited. *The Epilogue* reaffirms that green mining is under way and must be the future to maintain sustainability.

For students and teachers, a companion page on the website of the publishers will support users of the book (***www.schweizerbart.de/9783510654352*** Soft cover).

Submission of articles to European Geologist Journal

Notes for contributors

The Editorial Board of the European Geologist journal welcomes article proposals in line with the specific topic agreed on by the EFG Council. The call for articles is published twice a year in December and June along with the publication of the previous issue.
The European Geologist journal publishes feature articles covering all branches of geosciences. EGJ furthermore publishes book reviews, interviews carried out with geoscientists for the section 'Professional profiles' and news relevant to the geological profession. The articles are peer reviewed and also reviewed by a native English speaker.
All articles for publication in the journal should be submitted electronically to the EFG Office at ***info.efg@eurogeologists*** according to the following deadlines:

- Deadlines for submitting article proposals (title and content in a few sentences) to the EFG Office (***info.efg@eurogeologists.eu***) are respectively 15 July and 15 January. The proposals are then evaluated by the Editorial Board and notification is given shortly to successful contributors.
- Deadlines for receipt of full articles are 15 March and 15 September.

Formal requirements

Layout

- Title followed by the author(s) name(s), place of work and email address,
- Abstract in English, French and Spanish,
- Main text without figures,
- Acknowledgements (optional),
- References.

Abstract

- Translation of the abstracts to French and Spanish can be provided by EFG.
- The abstract should summarise the essential information provided by the article in not more than 120 words.
- It should be intelligible without reference to the article and should include information on scope and objectives of the work described, methodology, results obtained and conclusions.

Main text

- The main text should be no longer than 2500 words, provided in doc or docx format.
- Figures should be referred in the text in italic.
- Citation of references in the main text should be as follows: 'Vidas and Cooper (2009) calculated…' or 'Possible reservoirs include depleted oil and gas fields… (Holloway *et al.*, 2005)'. When reference is made to a work by three or more authors, the first name followed by '*et al.*' should be used.
- Please limit the use of footnotes and number them in the text via superscripts. Instead of using footnotes, it is preferable to suggest further reading.

Figure captions

- Figure captions should be sent in a separate doc or docx file.

References

- References should be listed alphabetically at the end of the manuscript and must be laid out in the following manner:
- Journal articles: Author surname, initial(s). Date of publication. Title of article. Journal name, Volume number. First page - last page.
- Books: Author surname, initial(s). Date of publication. Title. Place of publication.
- Measurements and units
- Measurements and units: Geoscientists use Système International (SI) units. If the measurement (for example, if it was taken in 1850) was not in SI, please convert it (in parentheses). If the industry standard is not SI, exceptions are permitted.

Illustrations

- Figures should be submitted as separate files in JPEG or TIFF format with at least 300dpi.
- Authors are invited to suggest optimum positions for figures and tables even though lay-out considerations may require some changes.

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Subscription to the journal:

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Advertisements

EFG broadly disseminates geology-related information among geologists, geoscientific organisations and the private sector which is an important employer for our professional members, but also to the general public.

Our different communication tools are the:

- EFG website, ***www.eurogeologists.eu***
- GeoNews, a monthly newsletter with information relevant to the geosciences community.
- European Geologist, EFG's biannual journal. Since 2010, the European Geologist journal is published online and distributed electronically. Some copies are printed for our members associations and the EFG Office which distributes them to the EU Institutions and companies.

By means of these tools, EFG reaches approximately 50,000 European geologists as well as the international geology community.

With a view to improving the collaboration with companies, EFG proposes different advertisement options. For the individual prices of these different advertisement options please refer to the table.

Prices for advertisements

EGJ	**One Insertion**	**Two Insertions**
Full page (colour)	820 Euro	1320 Euro
Half page (colour)	420 Euro	670 Euro
Quarter page (colour)	220 Euro	350 Euro
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Half page (black and white)	220 Euro	350 Euro
Quarter page (black and white)	120 Euro	200 Euro
Business card size	90 Euro	150 Euro
Preferential location	25% plus	
Price for special pages:		
Outside back cover (colour)	1200 Euro	1900 Euro
Second page (colour)	1000 Euro	1600 Euro
Second last page (colour)	1000 Euro	1600 Euro

Geonews	**Annual Price**
Ad and regular newsfeed	1500 Euro
EFG Homepage	
Ad and regular newsfeed	1500 Euro
University ad	
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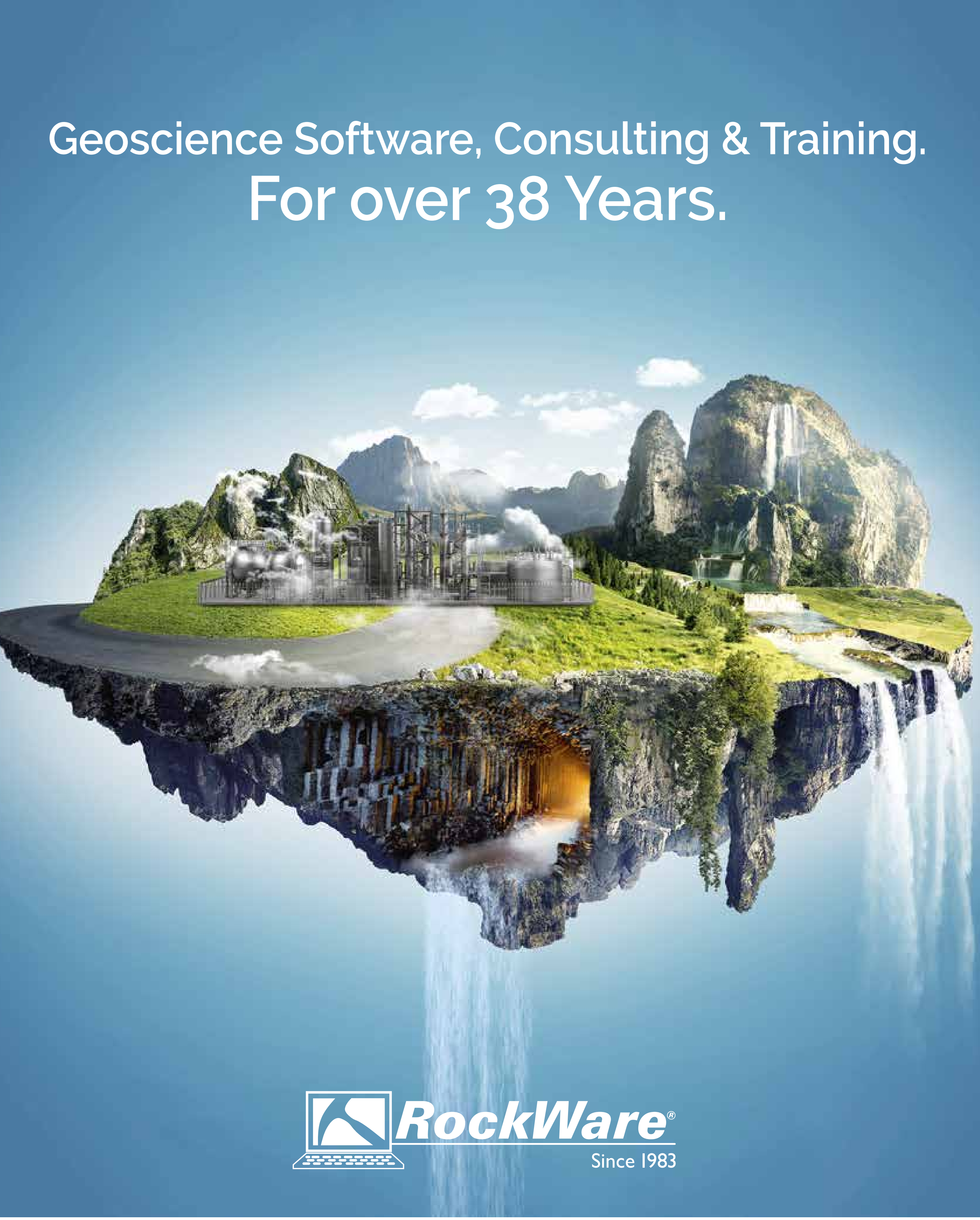
Annual package	
Business card size ad in EGJ, GeoNews and homepage.	3000 Euro



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