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Cooperative Projects to Share Good Practices towards More Effective Sustainable Mining—SUGERE: A Case Study

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Abstract: The supply of raw materials is a global challenge to be addressed; themes such as "sustainability", "responsibility", and "eco-compatibility" represent the cornerstones for proceeding towards a "wise" management of georesources. According to the United Nations' SDGs, the economic development of countries must go hand in hand with the improvement of their environmental, health, and social sustainability. From this perspective, the exploitation of georesources needs to be handled with an interdisciplinary approach that tackles not only the technical, economic, and environmental issues, but also the social, legislative, and human health ones. In recent years, Europe has promoted several cooperative projects aimed at boosting sustainability in the extractive industry. To achieve and guarantee concrete and truly sustainable mining, it is necessary to build and strengthen educational and training skills. With these objectives in mind, the first results of the EU–Africa SUGERE Erasmus+ project are presented here. The objects of the project are the implementation of Bachelor, Master, and doctoral curricula in geology and mining engineering and the promotion of socioeconomic development thanks to the training of experts who are able to cooperate and work in an interdisciplinary manner for a sustainable approach to local mine exploitation.

Keywords: EU–Africa cooperation projects; sustainability of georesources; local economic development (LED); geology and mining engineering high education; responsible mining

1. Introduction

Supplies of raw materials (RM) and critical raw materials (CRM) are a matter of concern and a global challenge to face for a sustainable way of living. When considering the exploitation of natural resources (e.g., RM and CRM from mining and quarrying activities) and/or anthropic resources (e.g., recycled products, byproducts, and secondary raw materials (SRM) from waste management and recycling), an interdisciplinary approach (including technical factors, environmental and human health factors, economic factors, and social and legislative factors) is needed [1].

According to the United Nations' Sustainable Development Goals [2] (SDGs), and as addressed in the Johannesburg Plan of Implementation (JPOI) [3], economic, environmental, health, and social issues need to be managed in a contemporary way that guarantees the enhancement of sustainable industries and, in particular, of the mining sector (the object of the present study).

The minimization of waste generation, the reduction in its impacts on the environment, and the preservation of natural resources, together with the opportunity for the reuse/recycling of waste materials, are in line with the EU policy expressed in the Europe 2020 strategy for smart, sustainable, and inclusive growth [4], as well as in the EU Sustainable Development Strategy [5,6] and the Paris Agreement document [7].

A recent interesting project funded by the EC is SUMEX [8], which aims to establish a sustainability framework for the extractive industry in Europe with the involvement of stakeholders from civil society, academia, industry, and government backgrounds from countries across the EU.

In recent years, Europe has developed cooperative projects related to the sustainability of the extractive industry and the definition of shared standards with other countries, particularly with those in Africa. The Erasmus+ program aims at developing models of best practices and at a playground for common activities to promote innovative educational and professional perspectives. In general, these projects are about building the skills needed not only to provide a good technical basis for sustainable development and a shared legislation framework, but also to ensure that Africa can fully benefit from its natural resources. They involve schools and research institutions for the improved perception of the sustainable development of the investigation and extraction of RM, and in our case, a common pedagogical approach was developed for the implementation of geology and mining engineering courses in African countries. To reach and guarantee a concrete and truly sustainable mining, aside from the drafting of a shared regulatory and policy framework, education and training challenges must be overcome: Experts in different fields (from mining engineering to geology, from economics to social sciences, and from environmental to health sciences) are needed. Experts need to have a common "operative dictionary" in order to cooperate and to work in an interdisciplinary way. Thus, while thinking of sustainable mining, proper Bachelor, Master, and PhD degree courses must be implemented. Such courses should concern not only European countries, but also (and mainly) countries that are more active in the mining sector, such as African countries; starting from this point, cooperation should be promoted between EU and African universities.

This paper aims to show the first results of cooperative projects related to the extractive industry between EU and African countries. In particular, it presents an international EU–Africa project for capacity building, SUGERE, which is based on common training for promoting local economic development through the implementation, revision, and improvement of the BSc, MSc, and PhD geology and mining curricula.

The different parts of this manuscript focus on the main objective of the SUGERE project: from the promotion of a two-way transfer of knowledge between European and African institutions to the implementation of the best teaching and training practices for the updating of geologists' and mining engineers' curricula. Rather than being a research paper, this is a descriptive study that provides facts and tools arising from cooperative projects—in particular, the SUGERE project—which may help in moving forward in the direction of sustainable mining in emerging countries.

2. Sustainable Mining: Targets of the Development of Geology and Mining Engineering Curricula

Africa's mineral resources are important to the EU, and a large number of EU-listed or EU-based mining companies operate in African countries. The extent to which host-country rules constrain the behavior of companies sufficiently to ensure that they contribute to local growth rather than to be simply the agents of extraction or injustice is central to the relationship between extractive industries and development. Intercontinental cooperation and regulatory exchange can positively contribute to the formation of legislative and policy frameworks that promote 'extractive justice' by fostering a symbiotic relationship in the extractive industry between Africa and Europe [9].

Many African countries are stuck in a commodity trap, where they export high-bulk, low-value RM, and import finished products of far higher value. In response to this phenomenon is the Africa Mining Vision [10]. The AMV was articulated in 2009 (Addis Ababa) to craft a mining industry that was equitable, transparent, and inclusive; one that would operate as a flywheel for development rather than a conveyor belt for exporting RM. Countries might have well-governed extractive industries in basic compliance terms, but risk management and sustainability might be absent. True governance should place emphasis on sustainability [11].

2.1. Towards a Sustainable Path in Mining Sector in Africa

Africa hosts about a third of the world's RM reserves [12]; there are currently around 700 active mines and many other sites that are under investigation, considering the global transition to a low-carbon future [12,13]. International standards, such as the United Nations Global Compact (UNGC), also require mining companies operating in Africa to address social and environmental issues, in accordance with the principle of sustainability [14–17].

Globally, since 2006, when the United Nations Principles for Responsible Investment [18] (PRI) were launched, an increasing proportion of companies report on environmental, social and governance (ESG) data. Investors have also committed to include ESG data in their investment analysis, with many criticisms [19] related to the fact that the analysis of a single assessment should hide deficiencies in any of the other two pillars. A rigorous approach requires separate in-depth analyses for each pillar.

Some authors propose a holistic assessment of the local sustainability of the mining sector by combining indicators that describe the environmental, social, economic, and institutional impact [20], according to community perspectives and expert advice.

The impacts are strongly related to the features of the area and communities interacting with the mining activity; thus, it is essential that mining companies discuss with local communities, in compliance with the law and human rights, to build the necessary level of social acceptance to guarantee proper development of the activity. The social and environmental impacts usually capture the attention of journalists, who can negatively influence an uninformed audience [21] and hinder the extraction of the RM.

Industrial mining projects can play an important role in global sustainable development and be a driving force for the economic development of low–medium-sized countries income and, therefore, can play a critical role in the framework of the Agenda 2030 for Sustainable Development [22–24]. Indeed, mining activity can have positive effects on the health, well-being, and economy of local communities, in relation to several factors, such as the quality of governance, the type of extraction technology, the geographic location, the economic environment, the technical skills of the company, the typology of mines [25,26], the needs of the local society, etc.

Some of the economic benefits of mining activities include foreign direct investment (FDI), job creation, new infrastructure, and the improvement of essential services such as water, schools, education (both for children and adults), and primary health care [27–29].

Despite the possible benefits, potential negative effects could be produced by mining extraction and infrastructure [30–32], which must be carefully evaluated and properly managed to ensure the expected level of sustainable development [33].

Negative effects can be represented by environmental impacts such as contamination of water bodies, air pollution, degradation and changes in land use, food insecurity, loss of vegetation coverage, and damage to biodiversity [34]. The factors that affect the pollution connected to mining activities are mainly linked to the ore type, metal being extracted, exploitation method, ore processing, pollution control efforts, and the geochemical and hydro-geochemical conditions of water and surroundings [35]. Ways in which mining activities and extractive wastes (EW) facilities can affect the environment are generally due to changes in hydrography and hydrogeological settings of an area [36–38], the formation of acid mine drainage (AMD) [39–44], the contamination of sediments, the contamination of water sources with exposed metals [45–50], processing chemical pollution [51], and air dispersion of potentially harmful minerals.

Mining and smelting operations are often the most important local sources of environmental contamination by metals and metalloids [52]. Metal contamination has been documented in many mining–smelting areas of the world, and it is a matter of concern due to the metals toxicity to the environment, humans, and animals [53,54]. The effects of RM exploitation can be observed even after the cessation of mining activities.

According to [55], politicians, activists, and researchers are fighting for a more sustainable economy based on the need to develop new methodologies for analyzing environmental sustainability. These new methods should include more complex procedures such as EIA (environmental impact assessment) and LCA (life cycle assessment; an internationally standardized approach—ISO 14,040—to assess the use and life cycle of resources and their emissions). LCA should be considered a tool for estimating the environmental impacts of anthropogenic systems, such as products, companies, and nations, from a "cradle-to-grave" perspective [56]. For the sustainable management of EW, health–environmental risk analysis could be a valid tool to quantitatively assess the risks for human health related to the presence of pollutants in environmental matrices. Site investigation, sampling, and analysis are essential to provide real data for site-specific conceptual models and, subsequently, for risk analysis [57–59]. Risk assessment includes not only the identification of the "risk sources" but also the evaluation of the probabilities of actual failure, as well as the severity of the likely consequences to follow from such a failure.

The Extractive Waste Directive (EWD) [60], provides measures, procedures, and guidance to prevent and reduce as far as possible any adverse effects on the environment and human health resulting from the management of the EW. In general, the potential negative impacts of mining and processing activities are related to the release of contaminants in the environmental matrices (identified as soil, water and air [61], with detrimental effects on biodiversity and human health) to the consumption of energy, water and soil, to noise (due to machinery and logistics) and to the release of hazardous substances.

Negative effects can also be related to social impacts, such as mass migration, the displacement of people and property, overloading of existing public infrastructure and social services [62–64], social conflicts, increases in the cost of living [65,66], and a growth in the incidence of health diseases [67] such as sexually transmitted diseases [68]. Health is a fundamental element for sustainable development [69,70]: if mining companies work in partnership with local health systems, a better well-being for local communities can be achieved with positive effects on the acceptance and objectives of mining activities [71,72]. It has been demonstrated that the modernization of infrastructure and the improvement of the socio-economic conditions can produce new positive opportunities for the society, such as a decrease in child mortality and an increase in the wealth index [73–75].

Since 1980, many countries in the world have undertaken significant reforms in the mining sector, supported by the World Bank, to attract investments and stimulate the economic development of the country [76,77], and since the 1990s, many financiers have imposed specific environmental assessments in accordance with Global and European directives as a requirement for their funding [78]. These environmental assessments were then systematically integrated into the national legislation of African Countries over the next few decades [79]. In this way, the framework of good practices has been steadily strengthened, and in accordance with international or national standards, the feasibility of mining projects is now conditioned by an appropriate proactive process to prevent or minimize negative environmental, economic, and social impacts and maximize potential positive effects by the territorial and social integration of the project [80–82].

The social responsibility of the companies and the appropriate technical skills of the workers contribute to optimize the resources, reduce the risks, create favorable conditions for economic activity, improve economic disparities, and increase the well-being of the environment and health of the local communities.

2.2. Overview on Cooperation and EU Projects Connected to Sustainability in the Extractive Industry

Recently, European and international cooperation projects related to sustainability and geo-resources issues have been carried out in order to promote sustainable mining. Those can be divided into:

1. Cooperation projects based on capacity building in the field of georesources and for the development of a shared legislative and policy framework (Erasmus+ projects);
2. European projects based on Research and Innovation (Horizon 2020 projects—R&I) activities for the development of a circular economy;
3. European cooperation projects which aim at building EU–Africa partnerships on sustainable RM value chains (Horizon 2020 projects—CSA);

1. Cooperation Projects: Erasmus+ funds academic and youth mobility and cooperation between Europe and other regions in the world, including Africa. African countries can take part in Erasmus+ as Partner Countries in four types of projects in the higher education sector, and in youth cooperation projects.

Joint projects are aimed at modernizing and reforming higher education institutions, developing new curricula, improving governance, and building relationships between higher education institutions and enterprises. Structural projects can also tackle policy topics and issues, preparing the ground for higher education reform, in cooperation with national authorities. Capacity building projects can be addressed to a group of ACP (African, Caribbean and Pacific states) and African Countries or to a single country. What follows is a brief summary of the Erasmus+ projects that better represent the cooperation activities to develop higher education systems within EU and Africa, especially concerning challenges such as sustainable mining.

An example of a successful Erasmus+ mining project is MINERAL project: "Modernisation of Geological Education in Russian and Vietnamese Universities (MINERAL)" [83]; it involves academic mobility for sharing practical knowledge in geological education, introduction of innovative teaching methods, and recognition of diplomas in partner countries. It uplifts universities to an international level, assures institution internationalization and networking, and increases student and staff mobility.

Other two joint Africa–EU initiatives have been developed in recent years to guarantee a strong education system:

- Harmonization and Tuning (TUNING Africa) [84] initiative, involving 107 universities, regional bodies, and students from 42 African countries. This project uses a methodology that has already been tested internationally, which supports the systematic comparison and harmonization of higher education curricula for African universities and promotes student mobility in Africa [85]. The Tuning Methodology has been applied in the redesign of BSc degree programs in eight groups of designated subject areas, including Applied Geology.
- Harmonisation of African Higher Education, Quality, Assurance and Accreditation (HAQAA) [86], which has been established to support the development of a harmonized quality assurance and accreditation system at institutional, national, regional, and Pan-African continental levels. The general objectives are to improve the quality and harmonization of African higher education and support students' employability and mobility across the continent.

These two initiatives are examples of the excellent collaboration between the EU and the African Universities in the field of higher education.

An example of policy and regulatory sharing is the European Union's Normative Role in African Extractives Governance [87] (ENRAG) project, which seeks to promote collaboration in the EU and African research and policy communities on the topic of extractive industry governance. This cooperation project is based on the objectives of the

Africa Mining Vision [10] (AMV). The AMV, a "pathway, formulated by African nations themselves, that places the continent's long-term and far-reaching development goals at the center of all policy decisions related to mining", was implemented to ensure that Africa utilizes its mineral resources strategically for broad-based, inclusive development.

2. European projects based on Research and Innovation (R&I): the European Commission has launched an action plan for the circular economy that aims to support the transition to an economy in which valuable materials, products, and resources are kept as long as possible while reducing waste generation.

The Horizon 2020 work program includes a targeted "Industry 2020 in the Circular Economy" initiative to support the objectives of the circular economy, based on a balance of economic and environmental benefits through the development of new technologies and business models by linking different sectors and public authorities. The spectrum of priorities covered by Horizon projects is very diverse and covers more sustainable production and optimization of industrial processes, new bio-based and biodegradable products, substitution or recovery of raw materials, etc.

ERA-MIN, ERA-MIN 2 and ERA-MIN 3 projects implement a European-wide coordination of research and innovation programs on raw materials to strengthen the industry competitiveness and the shift to a circular economy [88]. These projects comprise a progressive, Pan-European network of public research funding organizations.

3. European cooperation projects concerned with building EU-Africa partnerships on sustainable raw materials value chains (CSA): one European project based on CSA is HORIZON-CL4-2021-RESILIENCE-01-05 [89]. This project promotes responsible mining practices through programs aimed at the sustainable development of the informal sector (artisanal and small-scale mining), which has become of strategic importance for several countries.

The ultimate aim of these projects is to support the informal sector through the promotion and dissemination of responsible business practices, to develop the strengthening of local governance and the business environment through cooperation with other institutions and development partners.

Moreover, the European Union supports the Extractive Industries Transparency Initiative (EITI) through funding to the EITI International Management as well as to local programs in its implementing countries. The World Bank has been supporting the implementation of the EITI since 2004 and has provided country-level grants and analytical and advisory activities globally. The UN 2030 Agenda for Sustainable Development is at the heart of the EU's international cooperation and development policy and is also reflected in the new EU Consensus on Development (2017). The EU's development assistance is one of the pillars of the EU's external action alongside foreign, security, and trade policies.

Finally, PanAfGeo and PanAfGeo-2 [90] projects have to be cited, which include 12 European Geological Surveys and EuroGeoSurveys. PanAfGeo-2 (2021–2024) is a continuation of the well-recognised PanAfGeo (2016–2019), which has provided 42 training sessions for 1068 geoscientists from 49 African countries, and generating notable impacts on the political, institutional, and technical capacity level in Africa. "PanAfGeo", short for "Pan-African Support to the EuroGeoSurveys—Organisation of African Geological Surveys (EGS-OAGS) Partnership", is a project that supports the training of geoscientific staff from African Geological Surveys through the development of an innovative training program that includes the acquisition and development of important professional skills that complement their technical ones and qualifications. The training program is implemented by world-class geoscientific experts both from African and European Geological Surveys. PanAfGeo-2 covers the entirety of the African continent, with a specific focus on those countries that are rich in mineral resources. The project is addressed to the Organisation of African Geological Surveys (OAGS) and its member organizations, as well as relevant governmental bodies such as mining authorities and geological research bodies (e.g., universities, research centers). EGS is a non-profit organization with the goal of providing neutral, balanced, and practical support to European institutions with geoscience expert knowledge from across Europe.

2.3. SUGERE Case Study: Student Careers (Geologists, Mining Engineering and Geoengineering) towards Sustainable Mining (Both at EU and African Level)

SUGERE [91] (Sustainable sustainability and Wise Use of Geological Resources) is an ERASMUS+ project (Figure 1. KA2—Cooperation for innovation and the exchange of good practices—Capacity building in the field of Higher Education). The consortium includes four partners from three European countries (University of Coimbra and Centro de Estudos Sociais—Portugal; Univrsity of Salamanca—Spain; University of Torino—Italy) and six partners from three African countries (Universidade de Cabo Verde and Universidade de Santiago—Cabo Verde; Universidade Agostinho Neto and Instituto Superior Politécnico Tundavala—Angola; Universidade Eduardo Mondlane and Instituto Superior de Ciências e Tecnologia de Moçambique—Mozambique). It started on 15 January 2019 and it will last until 14 September 2023 (extended from the original deadline due to the COVID-19 pandemic crisis).

Figure 1. SUGERE (Sustainable sustainability and Wise Use of Geological Resources).

The SUGERE project seeks the implementation of **five courses**: three BScs in Geology and Geological and Mining Engineering, one MSc in Geological Resources, and a PhD in Geology (Table 1). The aim of the project is the sharing of the common view of Local Economic Development, as set by the right balance of Geology/Mining plus Environmental Issues Plus Social Economy. The courses' curricula are being discussed among all partners, and each course is expected to have contributions from all.

Table 1. Curricula to be implemented during the project period.

Curricula Implemetation	African Institution	City
BSc—Geological Engineering degree	UAN	Lubango (Angola)
BSc—Geology degree	UEM	Maputo (Mozambique)
BSc—Geological and Mining engineering degrees	ISCTEM	Maputo (Mozambique)
MSc in Geological Resources degree	UniCV—US	Cabo Verde
PhD in Geology	UAN	Luanda (Angola)

The project focuses on local economic development (LED) as a combination of (Geology/Mining) + Environment + Social Economy. The main objective is to graduate persons that are able to oppose the "Resource Curse" [92]. The project is expected to bring new ideas back to the European Partners. The European Partners will not be just givers, but they will also be receivers (thus, a WP named Project Rebound has been set). So, in addition to a North–South influence, there will also be a South–North one. At the end of the project period, the obtained results will be brought back to the European Institutions, hopefully to contribute to improving both the quality of existing European and African courses.

The acronym of the project SUGERE (Portuguese word for SUGGEST) was chosen to reflect the posture of the European Partners: they will be suggesting alterations by demonstrating results but will never try to impose any sort of preconceived model.

The data collection, analysis, and scientific evaluation of the project will be led by an African institution.

3. Results and Rebounds from Sugere and Other Cooperation Projects

One of SUGERE's main objectives is to provide support in setting up and preparing research and teaching laboratories in the African institutions participating in the project. Setting up a laboratory not only involves the purchase of equipment and materials (which this project finances) but also the training of personnel who know how to use the equipment and interpret the results correctly (Figure 2).

Figure 2. Geological survey, laboratory activities and team meetings of SUGERE project.

Due to COVID-19, all planned SUGERE in-presence activities were cancelled as of March 2020 and postponed to 2022. For this reason, the only report on training outcomes derives from the in-person activities that took place in Salamanca in September 2019 (Table 2).

Table 2. Summing up of the carried out activities.

Sugere Activities Carried Out	How	To Whom	Number of Persons
Training Period USAL (Salamanca) Specific lectures on earth science and mining engineering (Geochemistry, Natural Stones and Architectural Heritage, Mineralogy, and others)	ON-SITE LESSONS	ALL AFRICAN PARTNERS (Teachers and researchers)	23
Specific laboratory activities (preparation of rocks for analysis, use of SEM electron microscope, practical work on cathodoluminescence for carbonated rocks determination, stable isotope analysis, ICP/OES and ICP/MS analysis and others) Geophysics laboratory, Physical and Mechanical testing lab.Visit to a technological center and the architectonic heritage of the Unesco World Heritage cities of Salamanca and Caceres	LABORATORY ACTIVITIES		23
Revision activities of curricula BSc, MSc and PhD "Need analysis" and adaptation of BSc curricula and preparation and sending of English version of UNITO BSc program on Geology program of courses and disciplines	SHARING PLATFORM MYCLOUD AND VIDEOCALL	UEM, ISCTEM	
"Need analysis" and development of MSc programs on geological resources	SHARING PLATFORM MYCLOUD AND VIDEOCALL	UNICV	
"Need analysis": Discussion about organization of PhD degrees program on geology and engineering. PhD degrees in engineering was supervised, defining the curricula, lecture books and teaching plan	SHARING PLATFORM MYCLOUD AND VIDEOCALL	UAN	
Courses developed for PhD in Geology (UAN) Data Analysis (UC) Sedimentology (USAL, UC) Mineralogy (USAL) Geochemistry (USAL) Geotechnics (UNITO, UC) Remote Sensing (UNITO) Sustainable Mining and Circular Economy (UNITO) Tectonics (UC) Natural Radioactivity (UC) Coal chemistry (UC) Geophysics (UC)	ON-LINE LESSONS	PhD in Geology in Luanda (Angola)	16

Twenty-three people including professors and researchers from African universities and the University of Salamanca participated in the training activities on earth science and mining engineering topics through specific lectures and laboratory activities. These activities were provided with the intention of helping in the preparation of research and teaching laboratories at the participating institutions. During the training period, the curricula contents were analyzed and shared by all the participants, guaranteeing a two-way approach (EU vs. Africa and Africa vs. EU).

The participants at the training in Salamanca were essentially teachers from the African HEIs; the majority of them showed an MSc degree (60%) and the minority a BSc or a PhD degree (13% and 27%, respectively). A summary of the profile of the participants is represented in Figure 3. In particular, the average age of the participants was 40 years old (73% male and 27% female). In total, 75% of the attendees were teachers, and 25% were technicians.

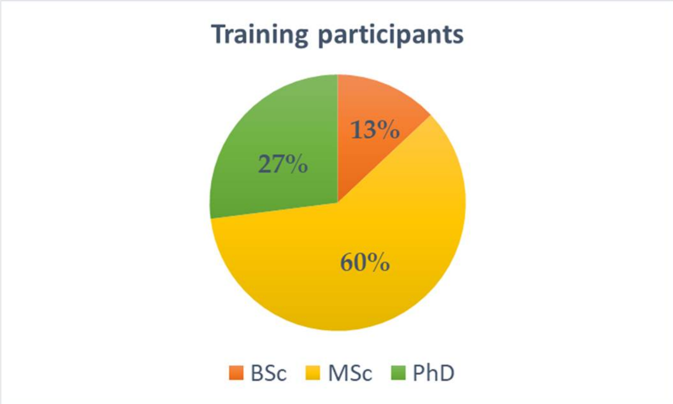

Figure 3. Education of the training participants.

All project and teaching documentation were stored on a computer platform (MyCloud) so that it could be shared among all SUGERE project partners. Due to COVID-19 pandemic restrictions, it has not been possible to carry out the educational trips so far; thus, some of the activities that should have taken place in presence have been transformed into synchronous (and asynchronous) lessons. Staff from the Universities of Salamanca, Torino, and Coimbra transformed the planned lectures described in the SUGERE proposal into online synchronous lectures for students, starting with PhD students from the University of Angola (Table 3).

Table 3. Project activities to carry out within the end of the project.

Project Activities still to Be Carried Out	Period	How	To Whom	Number of Persons
Development of modules of MSC in Geological Resources by UC, USAL and UC.	From December 2021–January 2022		MSc in Geological Resources (UniCV, Cape Verde)	15
Development of the BSc in Geology (UEM, Maputo, Mozambique)	From March 2022		BSc in Geology (UEM, Maputo, Mozambique)	79/80
Development of the BSc in Geological Engineering (ISPT, Lubango, Angola) with the contribution of European teachers.	From March 2022	online and face-to-face lessons	BSc in Geological Engineering (ISPT, Lubango, Angola)	50
BSc in Geological and Mining Engineering (ISCTEM, Maputo, Mozambique) is being finished and it is expected to start with the contribution of European teachers and of mining companies (Kenmare Resources PLC).	From September 2022	online and face-to-face lessons	BSc in Geological and Mining Engineering (ISCTEM, Maputo, Mozambique)	6
Training period UNITO (Torino)				
Frontal lessons, terrain and laboratory activities	From September 2022	in person	ALL AFRICAN PARTNERS (Teachers and researchers)	20
Training period UC (Coimbra)				
Frontal lessons, terrain and laboratory activities	From March 2023	in person	ALL AFRICAN PARTNERS (Teachers and researchers)	20

Other contemporary initiatives, such as the definition of operative protocols for sustainability in mining industry, took place thanks to the interaction between mining companies and academics (teachers and students, e.g., SONANGOL). The lectures covered different aspects of RM characterization activities, focusing on the importance of proper characterization for effective sustainable mining. A very important part of these activities was the tutoring sessions that were carried out at the request of several students. Some of them were interested in learning more about specific topics, such as uranium extraction or the use of stable and radiogenic isotopes to obtain a complete idea of the petrogenesis of important mining environments. This final phase was important to maintain contact with the students in a mentoring way, which is a positive addition to SUGERE's objectives.

The students of the PhD in Geology from UAN are mainly teachers of the institution (49 years old in average, 81% male and 19% female), and they are split into the three areas of the course: Geological Engineering, Energetic Resources, and Solid Mineral Resources. A summary of the profile of the UAN PhD students is reported in Figure 4.

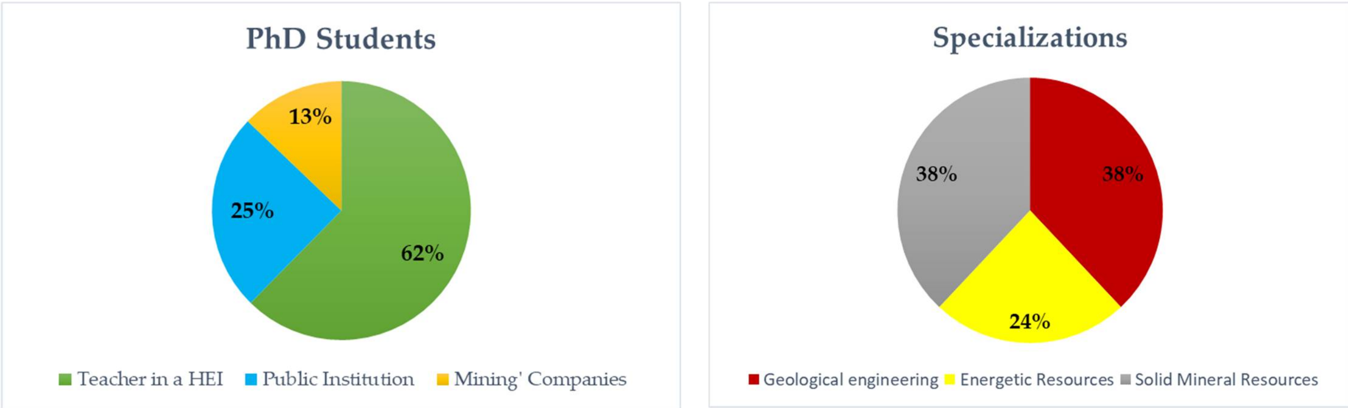

Figure 4. Occupation and specialization of the PhD students.

The training and online sessions took place in parallel with quality control, for which the University of Salamanca was responsible. This quality control was set up in the SUGERE proposal as a project monitoring tool to make sure that the project implementation was successfully achieving its objectives. Quality control was designed as a work package to:

- provide quality in the project structure, processes, and results;
- respond effectively to changes and challenges arising in the project environment;
- ensure the sustainability of the project's outputs/results beyond its lifetime.

Quality control is an essential part of any project, but because of COVID-19, this tool was even more important to maintain the workflow to achieve SUGERE's most important goals. The management of quality control was carried out in two phases:

- A first phase to survey the main results highlighting positive aspects and criticalities. The detection of results was carried out through the compilation of a template, reporting an in-depth analysis of the main results achieved by the different partners. In this way, feedback was given to the other institutions pointing out areas of improvement for the implementation of the project as a whole.
- A discussion and proposal phase in which the heads of each partner institution discussed the developments of the project and proposed recommendations and further steps to achieve the objectives.

The SUGERE project is not yet finished, but future developments have already been planned for MSc and BSc courses. An MSc in Geological Resources (UniCV) has recently been officially approved. A BSc in Geological Engineering (ISPT) awaits approval by the relevant national authorities.

By the end of the project, it is expected that: around 150 new students will be enrolled on the BSc courses, around 30 should be enrolled in the MSc, and some 20 students are expected to be enrolled in the PhD course. These numbers have been revised to take into account the setback created by the pandemic situation that created a delay of about two years in the implementation of the degrees. Despite the difficulties of the period, the part of the project that has been carried out so far has had a positive response. However, there are still some aspects that should be introduced for the complete success of the project. Indeed, thanks to the cooperation of partners in the activities that have been carried out so far, a group of participants joined in a common IGCP (International Geoscience Programme of

UNESCO [93]) proposal with goals similar to the SUGERE ones: the value of raw materials in the context of responsible mining practices (proposal under evaluation).

Mining companies should have been brought into the discussion, and they should have representatives that collaborate with the higher education institutions of Cabo Verde, Angola, and Mozambique in improving the quality of the courses. They should have decided to accommodate some of the graduates of the courses to become active partners and should be the basis of the sequent sustainability of the project. This collaboration is expected to be triggered as soon as the pandemic allows, to generate positive feedback towards the companies engaged; they will become more aware of the importance of LED in mining projects.

A role similar to the mining companies is sought for the Local Professional Institutions: Order of Engineers, Societies of Geologists, Associations of Teachers, etc. These organizations should have nominated representatives for the project and should have brought their ideas for the improvement of the courses. As a side effect, they themselves should become more conscious about LED.

All the partners of the project should have decided to set up joint research projects and the trained lecturers of the African institutions should have become active researchers of joint research projects.

Some of the students enrolled in these courses should have been given the opportunity either to pursue further studies in European Institutions or, at least, to participate in short advanced courses in Europe.

One SUGERE Work Package is devoted to dissemination and communication to tackle the specific objective of ERASMUS+ related to impact, dissemination, and exploitation. The WP targets the educational community to show the results of the project. SUGERE will be presented at the EGU 2022 meeting in Vienna, Austria, with the communication "Linking continents through their educational programs" within the session EOS3.1—Promoting and supporting equality, diversity, and inclusion in the geosciences.

4. Conclusions

Mining development can create new communities and bring wealth to existing ones, but it can also cause considerable disruption. New mining projects can bring jobs, businesses, roads, schools, and health clinics to remote and previously depleted areas, but the benefits can be unequally shared, and for some, it could be an insufficient reward for the loss of livelihoods and damage to their environment and culture. If communities feel they are being treated unfairly or compensated inadequately, mining can lead to social tensions and sometimes violent conflict. At the local level, sustainable development is about meeting locally defined social, environmental, and economic objectives in the long run.

The interaction of the mining industry with local communities has changed over time; such interaction should increase the physical, financial, human, and information resources available.

In many countries, mines have become larger and technically more complex, leading to a decrease in employment and an increase in the skill levels required of workers. In addition, with the emergence of multinational companies as major players, and with the dramatic fall in the cost of transporting materials in bulk, mines can now be located far from where the minerals are processed.

Mining activities must ensure that the basic rights of affected individuals and communities are upheld. Clean water, safe environment, control of land, and fair compensation are just a few basic rights of local communities.

Keeping these in mind, cooperation projects, in particular for the geosciences fields, are promoted with the aim of facilitating the transition to a more sustainable RM/CRM exploitation. To guarantee the transition to sustainable and responsible mining, it is fundamental to train experts able to collaborate and work in an interdisciplinary manner in a sustainable approach to local mining exploitation. Communication and knowledge exchange among scientists, by bringing together complementary interests to improve standards, methods, and techniques for conducting scientific research, are fundamental.

The SUGERE project is designed with the aim of training "smart and responsible" experts in geology and mining engineering who can proceed, hand in hand with the mining sector, towards a more ethical and sustainable mining. It is based on the enhancement of university education with a focus on the economic, environmental, and social sustainability aspects of mineral resource operations. The implementation of five degrees covering the three levels (BSc, MSc, and PhD) have the ultimate aim of fostering local economic development (LED) through the training of competent and aware people. The common denominator LED represents a novelty in the field of Geology/Mining. The implementation of a new European-ACP partnership focused on LED in the context of Geology/Mining engineering will be a key point to be developed.

The SUGERE project seeks to address the issues of sustainability of mineral resources not only from a capacity-building perspective, but also from a LED perspective. SUGERE aims to address the huge gap in terms of necessary infrastructure and critical human resources at all levels to fully realize the potential benefits that would accrue from the sustainable use of mineral resources and to secure local benefits by addressing the root causes of poverty, leveraging inclusive growth and development, and seeking to secure sustainable financing.

To benefit both continents, Europe and Africa, operative partnerships should be based on a clear understanding of respective and mutual interests and responsibilities, which include:

- maximizing the benefits of regional economic integration and trade (SGD1, SDG17);
- ensuring food security and rural development (SDG2, SDG3);
- boosting education, research, and innovation (SDG4);
- engaging together on the global scene to strengthen the multilateral rules-based order, promoting universal values, human rights, democracy, rule of law, and gender equality (SDG5, SDG10);
- the creation of decent jobs and value addition through sustainable investments (SDG8);
- improving the business environment and investment climate (SDG9);
- ensuring access to sustainable energy and protecting biodiversity and natural resources (SDG10, SDG 15);
- developing a green growth model, facing climate change (SDG13);
- promoting peace and security (SDG16);
- ensuring well-governed migration and mobility (SDG17).

Positive developments in one of these areas depend on progress in other areas. Such progress can only be achieved by working together based on shared global commitments, such as the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change and Agenda 2063 [94].

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