EDUCATION RELATED TO MINERAL RAW MATERIALS IN THE EUROPEAN UNION

FINAL REPORT ON SKILL SHORTAGES AND MEANS OF ADDRESSING THEM

Deliverable D3.3

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1 INTRODUCTION

The Strategic Implementation Plan for the European Innovation Partnership (EIP) on Raw Materials, Part I (2013) as well as many mineral strategies on EU Member State national levels (Defra report 2012) have identified skill issues as a prioritised action area as skilled and well trained personnel is decisive for the development and competitiveness of the mineral industry. This refers to improved development by enhanced technologies as well as improved sustainable management and environmental protection. Besides increasing the knowledge and skills of people working in the sector, also improving overall knowledge about raw materials and the minerals industry is necessary in order to change the negative perception of people towards the mining sector.

Work package 3 of the COBALT project has been addressing skills, knowledge and competence issues related to mineral raw materials by a three-step approach: (i) surveying of existing educational offers and identification of skill shortages, (ii) planning of schemes for their mitigation and finally (iii) testing and evaluation.

The first part of the project assumed a matrix approach in the mapping of mineral resource-related educational offers within the European Union (Sand, Rosenkranz 2014a). Differences were surveyed both by taking a geographic perspective and also a cross-value chain approach. The geographic perspective included linking between industrial activity and access to education on national and regional level within the EU, while the value chain approach included mapping the availability of education within various relevant raw material-related value chain constituents. These included disciplines such as applied geology, mining, mineral processing, metallurgy, recycling and mining-related environmental engineering. Furthermore, the educational depth was evaluated by analysing course offers and ranking the level of each educational programme based on the categories; single courses, Bachelor, Master or Doctoral level (third-cycle).

In the second part of the project the identified skill shortages during the mapping phase were briefly summarised and some of these issues were later addressed by proposing educational schemes for their mitigation on various levels (Sand, Rosenkranz 2014c). This included three different concepts for the development of short courses, block courses and a full study programme, thus constituting recommendations for future action plans based on key observations as discussed in the first project report.

The last part of the project was dedicated to the revision and further elaboration of the different courses and programmes, their pilot testing where possible, and an evaluation of the developed concepts based on participant feedback, reviews from technical experts as well as self-assessment and own reflections. The report at hand is the third document in this series that summarises the evaluation phase and also discusses options for utilising and disseminating the course concepts in the future.

2 SUMMARY OF SKILL SHORTAGE MITIGATION SCHEMES

The stocktaking of educational offers was concluded with a discussion of several different approaches for addressing some of the identified skill shortages. Development of full study programmes, short courses or block courses were presented as possible mitigation schemes, depending on region, contents to be covered and intended target audience. Each of these schemes is briefly discussed below.

- Concept I "Short courses for layman persons": The first report (Sand, Rosenkranz 2014a), discussed the need for generalist introductory courses to respond to skill shortages within stakeholder groups with limited technical background competences, such as policymakers and civil society organisations. This need has also been acknowledged by other European expert networks such as ERA-MIN (Vidal et al. 2013). Within the second part of the project, a two-day short course was designed to meet this challenge. The course was structured in a way that it gives participants an introduction to the various processes within the mineral raw material value chain, as well as discussing a number of related key topics. These include, for instance, environmental considerations in minerals and metals production, mine closure and reclamation activities.
- Concept II "Block module extension courses for engineers with other background than mineral and metal production": Several regions within the European Union were found to have limited study offers related to sustainable mineral and metal production and recycling processes. Within the second report (Sand, Rosenkranz 2014c) a block course was presented that had been developed for addressing this issue. The target audience is intended to be either professionals already working in industry or BSc level university students. The course can thus be considered as either a specialist training course or a blueprint for a block course possible to be embedded in a relevant university-level educational programme.
- Concept III "Full study programme for specialisation on master level": During the mapping of educational offers and evaluation of the regional importance of the mineral resource industry, Greenland was identified as a country with strong geological potential that is expected to emerge as an important future mining region. This case was therefore selected as being interesting to work on within the COBALT project. The challenge is twofold: at first, to provide educational opportunities to the Greenlandic population, secondly, to also construct a relevant academic programme giving students from outside the region the appropriate skill set to work in Arctic conditions. This translates into a need for a European-based educational programme devoted to the raw materials sector in the Arctic region, enabling the education of not only the local population but also other nationalities interested to work in Greenland or other parts of the Arctic.

3 REVISION, TESTING AND EVALUATION OF DEVELOPED CONCEPTS

3.1 Full study programme: "Mineral resource management in the Arctic"

3.1.1 Background

The Arctic region, and Greenland in particular, has previously been identified as an area with significant geological potential, but thus far have experienced relatively little mining activity (Sand, Rosenkranz 2014a,c). Greenland as an autonomous country within Denmark has a small population, and, therefore, the educational system does not extend far beyond vocational-level programmes. For higher level education, the country has close ties to Denmark, which does not have any strong educational programmes focused on mineral raw material extraction and processing either. Within COBALT, this region was therefore identified as an interesting candidate for developing a full university-level educational programme devoted to mineral raw materials.

Mining on Greenland is challenging due to the climate conditions as well as infrastructural and economic circumstances related to the relatively high cost of logistics and energy. Additionally the characteristics include a sensitive environment and the need for special societal and cultural considerations. For instance, Greenland does not allow private land ownership which generally puts requirements on locally negotiating and agreeing upon the terms of land usage. Access to skilled workers in sufficient numbers is also a limitation. Due to its small population, it is unlikely that Greenland in a situation with a rapidly expanding extractive sector could meet the demand for mining professionals solely by domestic supply.

Since the Self-Government Act of 2008, Greenland enjoys a high level of autonomy and thus exercises significant self-rule over domestic issues, while Denmark retains control of foreign affairs, defence and monetary policy. With the adaptation of a new structure of the Self-Government Act in 2009, the influence of Greenlandic authorities is expected to gradually increase in issues related to e.g. the judicial system, border control, mineral resource activities and the financial system. The ambition is to eventually move towards full independence. It is also expected that the annual subsidy currently obtained from Denmark will gradually decrease, as Greenland gains more independence and increases its incomes from mineral extraction activities (Statsministeriet 2010).

3.1.2 Mentoring institution

For the development of the full study programme within the COBALT project, the Technical University of Denmark, DTU, and its Arctic Technology Centre (Artek), was identified as a suitable mentoring institution. Artek is responsible for educating university-level engineers with strong focus on the Arctic. The centre is run in collaboration between KTI (Tech College Greenland) in Sisimiut, Greenland and DTU in Lyngby, Denmark.

The current Arctic engineering educational offer includes courses related to construction, infrastructure, logistics, energy and environmental engineering in Arctic conditions. With regard to mineral raw materials, a number of courses are offered in geology, rock physics and rock mechanics, and mining-related environmental engineering (www.artek.byg.dtu.dk). The Arctic Technology study programme is headed by Associate Professor Hans Peter Christensen.

Artek has a strong network of advisors for the planning and execution of their teaching and research activities. The Artek Steering Committee has representatives from Greenlandic ministries and local government, as well as academia. Its Advisory Board has representation from companies, e.g. oil and construction industry, consultancies, government and academia.

3.1.3 Programme development

Two physical meetings were held at DTU (Lyngby, Denmark) to discuss the programme plan and revising it according to issues identified during the evaluation, for instance related to student background requirements, course timing and contents as well as entry requirements for courses.

3.1.3.1 PROGRAMME STRUCTURE

Based on the programme structure described in the previous COBALT report (Sand, Rosenkranz 2014c), revisions were made as result of the feedback during the discussions with the mentoring institution. The previous and revised structures of the programme are presented in Table 1 and 2.

Table 1. Mineral Resource Management in the Arctic – Previously suggested programme structure, within the D3.2 planning phase (Sand, Rosenkranz 2014c)

1st Semester (Autumn), Denmark

First quarter		Second quarter
Engineering and environmental sustainability, 5 ECTS	Engineering in mountains – Soil, Rock and Nature, 5 ECTS	Business Administration 5 ECTS
Mining Project Feasibility Study, 7.5 ECTS (possibly arranged partly as distance education)		Mining and Environmental Laws, 7.5 ECTS (possibly arranged partly as distance education)

2nd Semester (Spring), Greenland

Arctic Mineral Resources, Environmental impacts and Prevention, 7.5 ECTS or The Arctic Nature and Societies, 7.5 ECTS	The Arctic Infrastructure, 7.5 ECTS	Industrial Plants and Infrastructure Constructions in the Arctic, 15 ECTS or Arctic Technology, 15 ECTS (Feb-Dec)

COBALT "COmmunicating, Building of Awareness, Leadership competence and Transferring knowledge on sustainable use of raw materials"	

3rd Semester (Autumn), Denmark or Other University

First quarter	Second quarter
Mineral Processing, 7.5 ECTS	Mine Development Project Course, 7.5 ECTS
Open Pit and Underground Mining, 7.5 ECTS or Fundamentals of Rock Mechanics, 7.5 ECTS	Mining Economy and Risk Evaluation, 7.5 ECTS or Natural Resource Economics, 7.5 ECTS

4th Semester (Spring), Denmark, Greenland or Other University

Master Thesis Project, 30 ECTS

Table 2. Revised programme structure during the implementation phase

1st Semester (Autumn), Denmark

First quarter		Second quarter
Engineering and environmental sustainability, 5 ECTS or Environmental Management and Ethics, 5 ECTS	Engineering in mountains – Soil, Rock and Nature, 5 ECTS	Arctic Mineral Resources, Environmental Impacts and Prevention, 5 ECTS
Rock Physics and Rock Mechanics, 5 ECTS	Management and Organisations, 5 ECTS or New course (e.g. Business Administration 5, ECTS)	Mining Economy and Risk Evaluation, 5 ECTS

2nd Semester (Spring), Greenland

The Arctic Nature and Societies, 7.5 ECTS	The Arctic Infrastructure, 7.5 ECTS	Industrial Plants and Infrastructure Constructions in the Arctic, 15 ECTS

3rd Semester (Autumn), Denmark or Other University

First quarter	Second quarter
Mining and Environmental Laws, and Estimation and Disclosure of Mineral Resources (either one 7.5 ECTS course or two 3.75 ECTS courses)	
Mineral Processing, 7.5 ECTS	
Open Pit and Underground Mining, 7.5 ECTS	Mining Economy and Risk Evaluation, 7.5 ECTS or Natural Resource Economics, 7.5 ECTS

4th Semester (Spring), Denmark, Greenland or Other University

Master Thesis Project, 30 ECTS

3.1.3.2 PROGRAMME REVISIONS

A number of revisions were carried out as result of the further planning of the programme together with the mentoring institution as it is also expressed in the Artek evaluation report (see Appendix section 6.3). The revisions are described in the following:

- The course "Environmental Management and Ethics" was added as an elective in the first semester, possible as an alternative to "Engineering and Environmental Sustainability". The environmental management and ethics course covers many aspects relevant to the programme, such as management and ethics with relation to environmental issues. The course also gives a suitable introduction to contents covered in-depth later in the study programme, for instance considerations related to stakeholder communication and risk management.
- The course "Business Administration" was replaced by "Arctic Mineral Resources: Environmental Impacts and Prevention", which was moved from the 2nd to the 1st semester due to re-planning of the courses to be provided during the semester on Greenland. Also it is not desired to provide elective options during the semester on Greenland as the Arctic semester offered by DTU is already defined as a package. The Business Administration skills will instead be provided through the course "Management and Organizations" or alternatively by moving the course as an elective option during the 1st semester. To suit the revised structure, the "Arctic Mineral Resources" and "Mining Economy and Risk Evaluation" courses were both shortened to 5 ECTS.
- "Mining Project Feasibility Study" was replaced with the course "Rock Physics and Rock Mechanics". This solves the issue of some students being expected to have lacking prerequisites for the later course "Open Pit and Underground Mining". Skills related to planning of mining projects will instead be provided partly through project work in other courses and the theoretical basis will be given in the courses "Mining and Environmental Laws, and Estimation and Disclosure of Mineral Resources" as well as "Mineral Economics and Investment Appraisal" in the 3rd semester.
- In the revised version "Mining and Environmental Laws" will be lectured in the course "Mining and Environmental Laws, and Estimation and Disclosure of Mineral Resources" in the 3rd semester. If this course is found to be framed too broadly, it could be divided into two smaller courses, one focusing on juridical issues and the other on reporting of mineral resources. It is however seen as beneficial if these two aspects could be integrated within the same course, to keep a more practical approach.
- As "Rock Physics and Rock Mechanics" is provided during the 1st semester, all students will have the required background competence for "Open Pit and Underground Mining"

in the 3rd semester. Hence, the elective "Fundamentals of Rock Mechanics" will not be needed.

- As "Mining Economy and Risk Evaluation" was moved to the 1st semester, a new course, "Mineral Economics and Investment Appraisal", was included in its stead. This course is designed to partly compensate for the removal of the two courses "Mining Project Feasibility Study" and "Mine Development Project Course". Natural Resource Economics remains as an elective in the same slot.

3.1.3.3 COURSE DESCRIPTIONS

A number of new courses were included in the study programme as result of the evaluation carried out in collaboration with the mentoring institution. Some of these courses constitute existing or refurbished courses, while some courses need to be developed. Courses which remained unchanged in the revised course structure have been discussed in detail in the previous COBALT report, D3.2 (Sand, Rosenkranz 2014c). The contents of the courses not covered in the D3.2 report are briefly summarised below.

Environmental Management and Ethics

(Existing course within the DTU study offer)

- Basic tools and principles of environmental management
- Ethics with focus on environmental issues
- Stakeholder analysis and technology assessment from environmental perspective
- Technical and chemical risk management
- The role of engineers in social, environmental and ethical issues
- Development of policy recommendations and analysis of regulatory options

Rock Physics and Rock Mechanics

(Existing course within the DTU study offer. Should possibly be modified to put more emphasis on hard rock)

- Physical classification parameters in rock mechanics
- Porous sediments and rocks
- Dynamic and static elasticity measurements and evaluation, test methods
- Modelling of porous rock types and elastic properties
- Modelling of strength and deformation properties
- Evaluation of geotechnical properties of rock

Management and Organisation

(Existing course within the DTU study offer)

- Relation between people in organisations
- Theories of group dynamics, roles and team development
- Communication skills and decision making
- Conflicts, power, participation and leadership
- Organisational efficiency, structure, strategy, management and culture
- Relationship between organisations and environment

Mining and Environmental Laws, and Estimation and Disclosure of Mineral Resources

(Course to be developed)

- Nordic, EU-level and international environmental law
- Requirements on stakeholder participation, human and indigenous peoples rights
- Land and real estate laws, contract negotiation, etc.
- Laws related to land management, physical planning and natural resources
- International standards for resource estimation
- Regulations and principles for disclosure of mineral resources

Mineral Economics and Investment Appraisal

(Course to be developed)

- Basic microeconomics
- Optimal extraction of non-renewable resources
- Mineral markets – supply and demand in mineral industries
- Investment analysis in the mineral industries
- Public policy, pricing institutions and trends in mineral industries

3.1.4 Programme evaluation by DTU/Artek

DTU/Artek has provided a detailed statement defining the background and prerequisites related to the study programme development, as well as an evaluation of the programme development work conducted within the frame of the COBALT project. This statement reviews the outcome of two joint planning meetings and additional communication by e-mail. The full statement is included in Appendix 6.3.

The study programme is pointed out to be suitable and timely in addressing the foreseen need for professionals in the minerals sector in Greenland. The Artek Advisory Board, with representatives from Greenlandic industry and government is also clearly stating that there is a need for experts in Mineral Resource Management in Greenland.

In the evaluation it is further mentioned that Greenland has a limited student potential due to the low population. A programme with a broader recruitment basis than Greenland can therefore be considered a benefit. This is in line with the existing "Artek model", where both Greenlandic students and students of other nationalities study together, thereby spending at least one semester in Greenland. The specialisation in "Geology – Constructions & Raw Materials", which is currently part of the Artek study offer, requires students to spend half a year at a foreign university to acquire skills related to minerals production, as the expertise within this field is limited in Denmark. The proposed study programme could also be a complement to the Greenlandic Mining School that offers vocational training with relation to the mining industry.

Despite the potential, Greenland has only had a few operational mines and at the moment there are none. Most workers with vocational training are therefore employed in other fields, e.g. construction and infrastructure projects. There is also a risk that students within the proposed programme will not find jobs within the mining industry after graduation. Thus, it is suggested that the students should acquire knowledge on exploration and the mining industry in general, combined with an understanding of Arctic conditions and the legal framework for mineral exploration and production that applies to this region. It is also pointed out that the expertise of the Greenland Government in this field is limited, which indicates that graduates of this programme could act as experts in evaluating exploration and mining permissions and either for preparing or evaluating documentation such as for instance environmental and social impact assessments. The graduates could also act as consultants to mining companies, contributing with their knowledge on Greenlandic and Arctic conditions, any specific regional issues related to permitting procedures, etc.

The courses suggested as part of the programme are found to be relevant, but further adjustments will be needed due to practical considerations on course planning at DTU. Furthermore, the Artek Advisory Board would also like to see more focus on HSE health, safety and environmental issues. The suggested student background may constitute a risk due to the required pre-knowledge on mineral or mechanical process technology, as students from civil or environmental engineering will not have this background. A course on basic process technology should therefore be included in the programme. The programme may have to be designed from the start with mostly using existing courses or courses provided from third parties. One such party could be Luleå University of Technology, LTU, which has a complementary study offer to DTU. From this starting point, resources and competences could gradually be built up.

3.1.5 Risk mitigation

A significant risk identified during the development stage involved the capacity to receive programme students for the Arctic semester at Artek's facilities in Sisimiut. With the current size of facilities and student dormitories, a maximum of about 10 students can feasibly be accommodated at any given time. A study programme with an intake of only 10 students per year will bear a high cost on a per student basis both in terms of teacher resources, and due to the high degree of practical work projected within the educational programme. It is deemed unlikely that the establishment of such a programme, based on the low student planning numbers, would be approved by DTU or LTU university administration unless additional financing of the programme can be secured from external sources or by some alternative arrangement. One suggestion for such an arrangement could therefore be to expand the study programme collaboration with one or several additional university partners having a similar profile as either DTU/Artek or LTU. This would enable several study tracks to be developed or incorporated within the same programme, where the Mineral Resource Management would constitute one of the study tracks. The lowest threshold would in that case be to merge one or several existing collaborative programmes with the concept developed during the COBALT project. One option for this could be the ongoing Nordic Mining School collaboration between LTU and University of Oulu in Finland (Sand 2013a;b), which includes an exchange study agreement and two double degree agreements on Master level, a general Master in Geosciences and the other in Chemical Engineering. If including the Mineral Resource Management programme as an additional study track within this larger concept, and finding synergies in running some of the offered courses between the different tracks, the critical mass in number of students could probably be achieved.

3.1.6 Discussion and lessons learned

The proposed master programme in "Mineral Resource Management in the Arctic" appears promising with the alterations to the programme structure made within the evaluation phase. The head of the Arctic Technology programme has in a written statement expressed and delineated the need for a cross-disciplinary educational programme in the Arctic, with focus on mineral raw materials.

The concept has also been presented and discussed within the Artek Steering Committee and Advisory Board, who were both positive to the development of an educational programme in raw materials management. The programme is also deemed relevant for the EIP Strategic Implementation Plan on Raw Materials (2013) in terms of providing education and skill provision that can promote the security of supply and self-sufficiency of mineral-based resources of the European Union.

The development of a study programme with a stronger emphasis on non-technical skills related to the minerals sector appears relevant and is also perceived to be in demand by other stakeholders (see section 3.1.2). It was also found possible to identify a suitable set

of existing courses that could be included in the study programme, however in some cases with minor alterations. A number of new courses need to be developed, mostly for providing skills related to business, economics, and social sciences. The programme, in case it is instated, will need continuous development and evaluation based on feedback from potential employers and other stakeholders. The already existing Artek Steering Committee and Advisory Board would represent a good forum for continuous programme review and evaluation.

As stated in the evaluation, DTU and LTU will continue with the planning of the programme developed and revised within the COBALT project. Issues mentioned in the evaluation, for instance related to course structure and student background can likely be overcome through a more detailed programme planning.

3.2 Short course: "Introduction to minerals and metals production"

3.2.1 Background

The discussion of technical aspects of minerals and metallurgical production among non-experts or between specialists and non-experts is typically hampered by the differences in information level and terminology. This frequently results in misled interpretations of the environmental risks from mining and processing or in unrealistic expectations about what is technically feasible in primary production or metal recycling.

As already stated in the second report (Sand, Rosenkranz 2014c), this situation can be overcome by adequately educating lay persons not having the necessary technical background, i.e. policy makers, representatives from consumer organisations, members of non-governmental organisations and other stakeholders from civil society, in order to fill the knowledge gaps in process technology and by conveying general awareness of existing technical constraints with regard to both material and process. Interdependencies occurring between individual processing steps make it usually necessary to take a more holistic view on the entire value chain of minerals and metallurgical production, in order to give layman persons an insight into technical alternatives and their constraints.

The challenge in designing such a course is that the scope has to be broad enough in order to give an insight into the areas of exploration, extraction, ore dressing and metal refining. The level of detail in describing these steps, on the other hand, needs to be limited in order to meet the level of aspiration defined by the target audience. I.e. lectures should not overwhelm the listeners but instead be given in a popular science way, in order to meet the needs of the non-technical target audience.

3.2.2 Conceptual design of the course

Course aim and expected outcome

The developed short course "Introduction to minerals and metal production" is intended for a broad target audience of various stakeholder groups that are not familiar with the

technical background of minerals and metal production and want to improve their knowledge in this field. As lay persons are addressed, there are no formal prerequisites that the participants need to fulfil before entering the course. The course is designed for anyone that is interested in this field, be it in the professional or personal context.

The course aims at providing a common understanding of mineral and metal production under a holistic value chain perspective and by considering the different periods of time of a mine's life cycle. The intended learning outcomes can be summarized as follows. After completion of the course the participants should be able to:

- Describe different mineral resources (ore types, occurring minerals)
- Explain the different steps in developing a mine project
- Describe the major unit operations that are used within ore dressing and metal extraction
- Discuss the environmental, social and economic dimensions of sustainable mineral and metal production

There is no examination or grading provided. Only the attendance of the course can be acknowledged.

Course content and format

The short course is designed as a 2-day seminar. Teaching comprises in total 7 lectures (duration 1 hour each, including questions and answers) as well as three interactive workshop formats for initiating discussion and contemplation after every second lecture (duration 1 hour each including wrap-up). The course concludes with a discussion exercise of approximately 1 hour on the second day where the course participants are requested to take up the position of other stakeholder groups within a certain topic area.

Lectures are given in the areas of:

1. Ore geology and mineralogy (emphasis may vary with location and group of people)
2. Mineral exploration and mining project development
3. Mining methods – Production technology (underground mining, open pit mining)
4. Mineral processing – Principles of ore dressing, selected unit operations and processing flow sheets
5. Metallurgical processing – Principles of metal production, selected processing flow sheets
6. Metal recycling from residues and end-of-life products
7. Environmental aspects of mine production (waste rock and tailings, energy, emissions, mine closure)

Workshops and panel discussions are dedicated to:

- Mineralogy, geology, resource management in the EU
- Impacts from mining operations: economic-environmental-social

- Sustainable metal production
- Environmental aspects of mining

In this introduction-type course no particular course book is assigned. Hand-outs of the presentation material are provided by the course authors.

3.2.3 Pilot testing of the concept

3.2.3.1 COURSE PLANNING

During the course of the COBALT project the short course has been pilot-tested as a joint event for the COBALT-regions "Eastern Europe" and "Iberian Peninsula". Being a central and easy to reach location, Vienna was selected as the location for conducting the pilot implementation.

Course invitations (compare Appendix 6.4.1) were sent out based on corresponding parts of the COBALT contact data base and with the support of the COBALT partners from Austria, Romania and Spain. In order to facilitate the organisational part, Vienna University of Business and Economics was chosen as the hosting institution. The short course was conducted as a two-day meeting in the facilities of the Institute for Managing Sustainability at Vienna University of Business and Economics on the 25th and 26th of February, 2015. Teachers (AS Anders Sand, JR Jan Rosenkranz, CL Cecilia Lund) were all coming from Luleå University of Technology. Table 3 shows the course agenda.

Table 3: Agenda for the short course given in Vienna

Time	1. Day (February 25th)	2. Day (February 26th)
09:00 – 11:00	Welcome and introduction LECTURE 1 (CL) Ore geology and mineralogy	LECTURE 5 (AS) Metallurgical processing
	LECTURE 2 (CL) Mineral exploration and mining project	LECTURE 6 (AS) Metal recycling
	Break	Break
11:15 – 12:15	WORKSHOP 1 (CL) Resource management in the EU	WORKSHOP 3 (AS) Sustainable metal production
	Lunch	Lunch
13:00 – 15:00	LECTURE 3 (JR) Mining methods	LECTURE 7 (CL, JR) Environmental aspects of mine production, and mine closure
	LECTURE 4 (JR) Mineral processing	CLOSING DISCUSSION Environmental aspects of mining – the long-term perspective Course wrap-up and evaluation
	Break	End of course
15:15 – 16:00	WORKSHOP 2 (JR) Impacts from mining operations	

In total 10 persons from different affiliations and countries attended the short course. The group of participants represented various stakeholder groups, covering NGOs, government agencies and consulting companies, compare Figure 1 for the distribution between

stakeholders. Additionally, several staff members of the RIMAS attended selected parts of the course program as lookers-on.

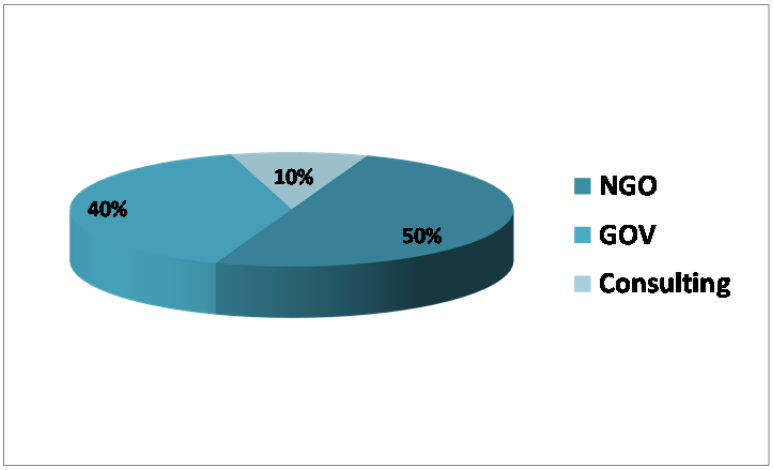

Figure 1: Participants' affiliation

Most of the participants had little to no previous knowledge of mineral and metallurgical production while a few individuals had some prior knowledge. The degree to which the participants were already faced with raw material related issues in their job varied quite broadly.

3.2.3.2 PREPARATION OF THE COURSE MATERIAL

The course material was put together following the concepts developed within D3.2 (Sand, Rosenkranz 2014c). Preparation included the selection and compilation of the lecture material (provided to the attendants as PowerPoint presentations), the design of the workshop assignments as well as the preparation of a hands-on exercise within mineralogy and ore geology (Sand, Rosenkranz, Lund 2015).

The lecture material followed a basic structure that was kept identical for the different topic areas (i.e. geology, mining, mineral and metallurgical processing, recycling). Using the same logotypes, the following sections were defined:

- Objectives: Definition of objectives for the respective topic area.
- Basic terms and definitions: Small collection of definitions and recurring terms used in the respective topic are, frequently used in technical discussions.
- Techniques and technology: The main content section, including facts, explaining technical processes and relationships related to the respective topic area.
- Environmental issues: Description of environmental impact and emissions related to the respective technical processes.
- Summary: Some major statements/conclusions to take with.

In terms of level of aspiration, much attention was paid on presenting the subject in a comprehensible and easy way in order to not overwhelm the participants with too many technical details but also not demand too little. Particular attention was also paid to explain

and illustrate interrelations between different parts of the mineral production chain. Concrete technical examples were mainly taken from Northern Europe where mining is still an active industry. Based on the PowerPoint slides, handouts were produced and distributed to the participants.

Topics for three workshop exercises and the concluding discussion were selected with the aim to let the participants reflect on the topic area taught prior to the workshop session and initiate fruitful discussion between the participants and with the teachers. The following questions/tasks were set to the participants:

a) Hands-on exercise "Minerals and mineral resources in the EU":
    - What are minerals? How are they defined?
    - Identification of ore minerals? What mineral properties can be used for that? What are the metals you can extract?
    - Important ore deposits in Scandinavia? What is mined where?
b) Workshop "Impacts from mining operations": Mining and mineral processing plants are affecting local communities and nature in several ways. Please discuss in your group:
    - What are the potential environmental impacts?
    - What are expected social impacts? Think of negative and positive impacts.
    - What is your vision of the mine of the future?
c) Workshop "Sustainable metal production":
    - The EU directive on Restriction of use of Hazardous Substances (RoHS) severely restricts the usage of some metals:
        - Discuss the relevance and consequences of this directive from the virgin and secondary raw material perspective.
        - Which implications does the directive have in terms of mined ore (virgin raw material)?
    - Accomplishing a transition to a circular economy:
        - Discuss the secondary raw material potential in terms of replacing mined (primary) resources.
        - How does dissipation, collection rate, and recycling efficiency (recovery) come into the picture?
    - Establishment of compact fluorescent lamps (CFL) containing small amounts of mercury, classifying them as a hazardous waste. The more complex composition and requirements for safe handling also makes them more difficult to recycle.
        - Discuss the trade-off between energy saving, recycling potential and environmental risk (e.g. heavy metal emission).
d) Closing discussion "Environmental aspects of mining" (role playing involving different stakeholder point of views):
    - 1. Question

- Industry: Your company running a copper mine is planning to increase the production. As part of the permitting procedure you shall justify the extension of your tailings dam capacity.
- Authorities: You as the local government of the region where the mine is in operation shall request information about the expected impacts.
- Civil society: You as the interest group of the nearby residential area shall formulate your concerns and the impact you expect.

o 2. Question

- The company shall reply to the concerns of the interest group.
- The local government shall weigh the industry needs with the concerns of the interest group (also including the local government's own concerns).
- The interest group shall develop ideas for an appropriate compensation.

3.2.3.3 COURSE EVALUATION

The evaluation of the short course was done by means of a printed questionnaire distributed to the course participants directly after the course. The questionnaire comprised several groups of inquiries, involving some open questions but mostly scaling questions (questions with ordinal scale response). For the latter, a Likert-type scale with six levels (ranging from "strongly disagree" to "strongly agree") was used as a rating scale for measuring either positive or negative responses to several statements around the course.

The filled in questionnaires can be found in section 6.4.2. The results from evaluating the questionnaire are summarized in the following sections.

Course aims and content

"The aims of the course are clear." This statement aimed at analysing how the scope and the objectives of the course had been announced prior to the course. The evaluation shows that the pre-information from the invitation letter and the explanations within the course introduction were well received by the participants, see Figure 2 a).

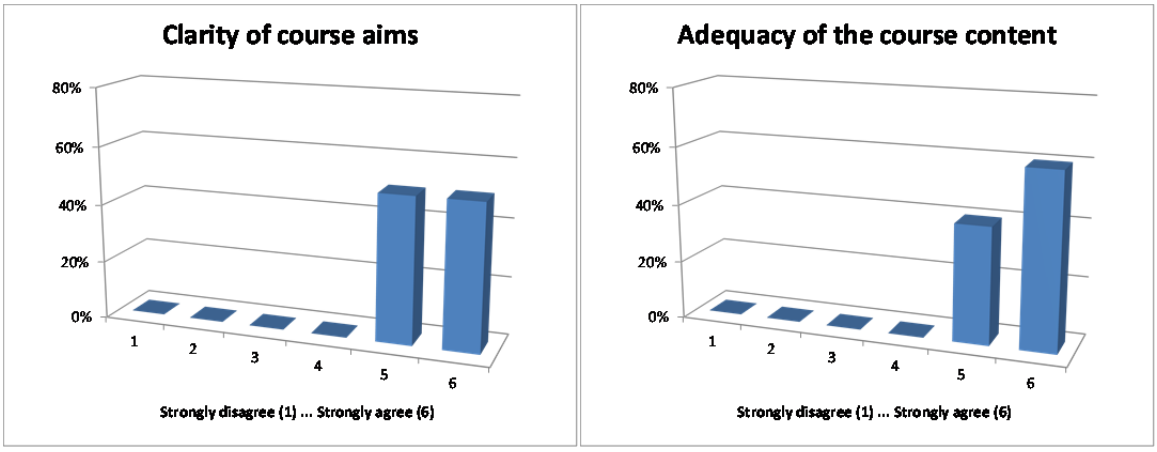

Figure 2: a) The aims of the course are clear, b) The course contents were adequate

"The contents of the course help to achieve/meet the course's aims." Here the alignment between the compiled course content and the targeted course output was inquired. The evaluation by the participants showed that the selected content was considered to be adequate to support the course aims, compare Figure 2 b).

"The course planning and supervision are structured and easy to follow." Besides the adequacy of the course content also planning of the course and the supervision during the course conduct were asked for. Here a similar picture was obtained, i.e. the way the course was structured and provided was generally appreciated by the participants (Figure 3).

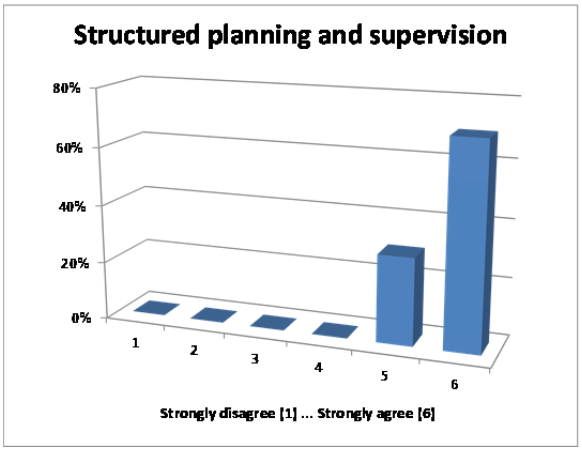

Figure 3: Structured planning and supervision

Quality of teaching

"It has been worthwhile attending the lectures". One very important question was whether the lectures, being the essential channel for transferring knowledge towards understanding of technical issues, were experienced as rewarding by the participants. As in the case of planning and conceptual design, the lectures were generally appreciated by the participants and classed valuable, see Figure 4 a). In the comments from the participants (compare section below) it was noted that even more attention should be dedicated to the environmental impact of the different parts of the mineral production chain.

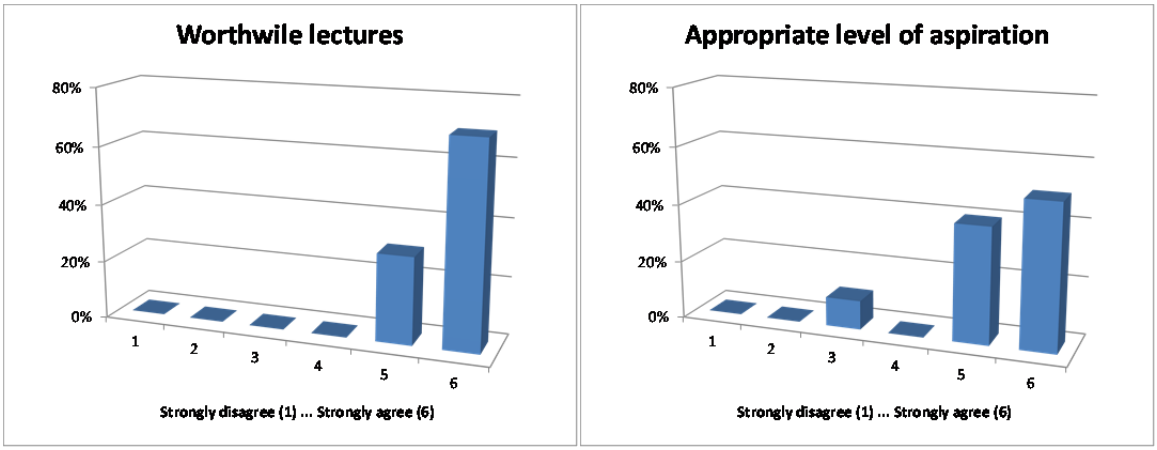

Figure 4: a) Worthwhile lectures, b) Appropriate level of aspiration

"Given the aims of the course the aspiration level of the lectures was appropriate." Another feedback was inquired in order to find out whether the level of aspiration of the lectures was too ambitious for this target audience. For most of the participants, the level was found to be generally appropriate, see Figure 4 b). Only in an individual case some but not all of the lectures the content has been considered as too detailed (see also the free comments below).

"The workshop exercises were rewarding." Besides the lectures also the exercises were evaluated. The participants mostly had a positive impression of the workshop exercises, see Figure 5 a). Particularly the practical assignment, where mineral samples from different origin were examined in a hands-on exercise, was appreciated and emphasized in the free comments.

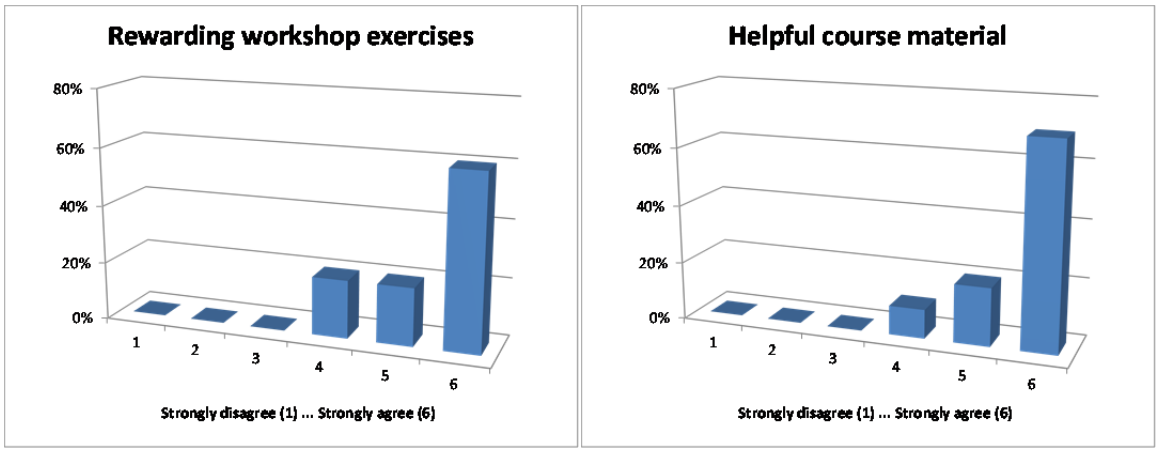

Figure 5: a) Rewarding workshop exercises, b) Helpful course material

"The course material was helpful". The provided course material received mainly a good evaluation from the participants, compare Figure 5 b). A minor point of criticism was related to the size of the hard copy printouts, an issue that can easily be solved for future course conducts.

General evaluation

"The course design content matched with my expectations." The course description sent with the invitation obviously raised the right expectations among the participants. Accordingly, the matching between course and the participant's anticipation was considered adequate, see Figure 6 a).

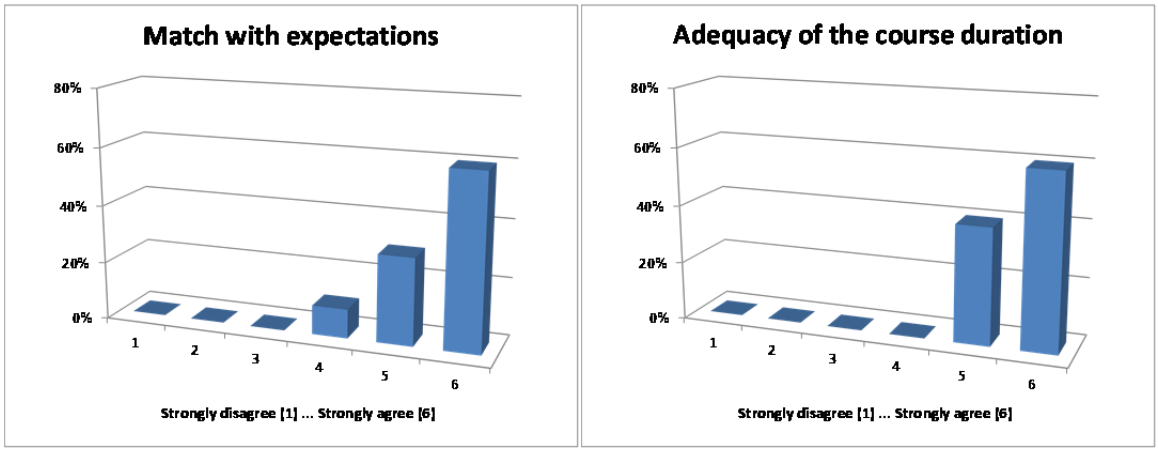

Figure 6: a) Match with expectations, b) Adequacy of the course duration

"The course duration is adequate for this course." A further important issue was whether the time scheduled for the course had been adequate for the participants, or in other words whether the course planning was useful or inadequate. As it can be seen from Figure 6 b the participants experienced the duration as suitable for this type of education.

"My overall impression is that this was a good course." Finally the overall evaluation of the course quality was inquired, compare Figure 7. The feedback was positive throughout and can be seen a verification of the concept.

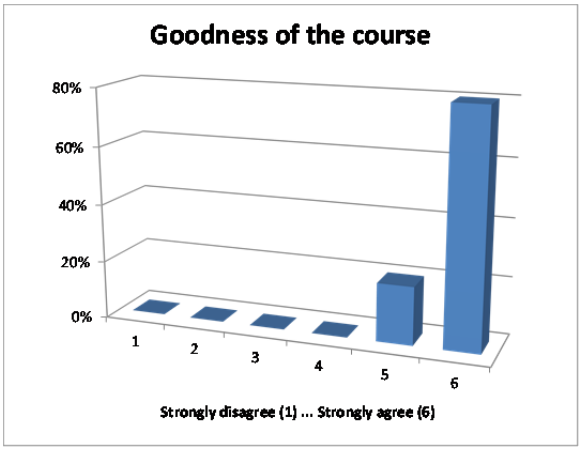

Figure 7: Goodness of the course

Free comments

"Some lecture maybe a little too technical and detailed, details not that relevant compared to other topics, but of course that's just from my personal pretensions"

"Only one question I expect more information about is impact environmental in all phases of the production, p.e. [sic!] in the beginning about ground water impact…"

"It was a good course, I don't have any comments."

"Very creative and interesting, even {though] the [my] job profile wasn't the same with the topic of the course. Thank you!"

"Use of practical exercises is good to learn the lessons, especially the rocks!"

"The copies in paper should be in a bigger size. We couldn't read it, that's the only problem. I am very satisfied with the whole organization. Thanks to everyone! Excellent teachers and materials"

3.2.4 Discussion and lessons learned

The conduct of the short course "Introduction to minerals and metals production" proceeded without any deviations from the initial course plan. The developed concept, the schedule as well as the elaborated course material turned out to be suitable for this course format. This subjective impression of the team of teachers was confirmed by the evaluation of the questionnaires that were handed out at the end.

It has to be pointed out that the friendly and collaborative atmosphere during the course had much to do with the size and the constitution of the group of participants. Interesting discussion arose subsequent to nearly all the lectures and was even livelier during the workshop exercises and the concluding discussion associated with the role play.

The comment from one of the participants wishing to emphasize more on the environmental impact from mining was an individual opinion at this point but can be considered as representative for the attending stakeholder groups. However, the authors consider this as a helpful and important suggestion that needs to be considered in future runs.

3.3 Block module course: "Sustainable minerals and metal production"

3.3.1 Background

Some EU Member States where mining and metal production is taking place do not offer suitable study programmes. Furthermore, in EU Member States where such mining-related engineering programmes exist, the number of vacant positions in industry cannot be filled by local graduates (Sand, Rosenkranz 2014a).

In addition to hiring personnel from abroad companies often choose the option of employing engineers with a different background, for instance in process engineering or chemical engineering. As some studies have pointed out, this is not necessarily a drawback since these professionals provide alternative skill sets to the industry (McDivitt 2002). However, in order to improve process understanding and alleviate communication with other parts of the workforce, there is a need for time-condensed training schemes. This would allow engineers with other background to level up their competences with respect to understanding the characteristics of natural mineral resources and the particular process technology used for ore dressing and refining.

Besides various on-site opportunities offered by the company such as "training-on-the-job" type apprentice systems, there is also a need for more formalised approaches. This can for instance include either specialised courses giving an overview on relevant process technology to young professionals, or even specified training related to a particular process. As previously mentioned, a course that addresses participants in preparation to, or already working in industry, will be subject to time restrictions. The setup of this type of specialist course should therefore consider that it is often not possible to teach a course over a long time period like a university term. Instead a block module course taught intensively over a time frame of maximum a few weeks should be the preferred format.

3.3.2 Conceptual design of the course

Course aim and expected outcome

The COBALT block module course "Sustainable minerals and metal production" has been developed for persons with at least a Bachelor level degree in engineering, preferably addressing graduates from process, chemical or mechanical engineering programmes, who either have plans to work or have already stated working in the minerals and metallurgical industry and who need to build up or improve their competences in the field of minerals beneficiation and metal extraction including recycling processes. Accordingly, the educational level of the course is of advanced level (second cycle, after completion of a bachelor) (The Bologna Declaration 1999).

The course aims at providing knowledge on mineral and metallurgical processing of metal ores and metal recycling. The intended learning outcomes can be summarized as follows. After completion of the course the participants should be able to:

- Describe the concept of sustainable development
- Describe different types of metal ores and their mineralogy
- Describe and explain the unit operations and flow sheets used in metal ore dressing
- Understand different metallurgical unit processes and their specific reaction processes
- Describe and explain material and energy flows related to extraction of metals and alloys
- Understand the life cycle of metals
- Describe and explain the techniques usually used in recycling
- Describe the important limitations for recycling

General entry requirements for the second cycle apply. This means a Bachelor or 180 ECTS in a relevant engineering field or equivalent knowledge from practical work experience (minimum 5 years work experience for instance as a process or development engineer) is required for entering the course. Additionally, documented skills in English language are a prerequisite as the course is given in English.

Course content and format

Lectures will be given in the areas:

1. Introduction: metal life cycle, design for recycling
2. Mineral processing
3. Metallurgical processing
4. Metal recycling – Pre-treatment
5. Metal recycling – Metallurgical processing

Laboratory exercises comprise:

- Comminution tests
- Separation tests
- Smelting experiment and mass balancing
- Leaching experiment

Exercises will cover:

- Calculation of grades/ recovery/ selectivity
- Material balancing for a concentrator
- Technical-economic analysis of process alternatives
- Simulation of a copper converter

3.3.3 Tailored pilot course for sulphide ore processing

3.3.3.1 MENTORING INSTITUTIONS

A number of mentoring institutions, both companies active in the mineral industry and academic institutions, were contacted for the evaluation of the block module course concept. These institutions are briefly described below:

- *Wardell Armstrong International* is a multidisciplinary engineering, environmental and mining consultancy service provider. The company has over 400 employees and is primarily based in the UK, Russia and Kazakhstan. Wardell Armstrong is experienced in education through its graduate training and staff development programmes.
- *Boliden* is an international raw materials company with activities in base and precious metal mining, metallurgy and secondary raw material recycling. The company has mining operations in Sweden, Finland and Ireland and smelters in Sweden, Norway and Finland. The total number of employees exceeds 5,000.
- The *University of Lorraine* (Nancy, France) is a university with about 55,000 students and over 6,000 staff members. The university's "Laboratory GeoResources" has a staff of 150 and is active in education and research in geosciences, exploration, mineral processing, etc.

- *University of Oulu* (Oulu, Finland) is a university with 16,000 students and about 3,000 staff. In the area of raw materials, the university offers education and research in geosciences, process engineering including mineral processing, mining engineering, process metallurgy, and environmental engineering.
- The *Escuela Superior de Comercio Internacional (ESCI)* is a business school at the University Pompeu Fabra in Barcelona, Spain, working in the fields of sustainable development and life cycle management.

3.3.3.2 REVISION OF COURSE CONTENT AND SCHEDULE

The initial course concept (Sand, Rosenkranz 2014c) was revised in order to focus on the important area of base metal production with sulphide mineral ores as the raw material base. This was introduced in order not to let the course become too broad in scope and too detailed.

The original course plan was, therefore, revised in terms of content and by tightening the schedule, i.e. by distributing the teaching over a period of two weeks in two block modules of 3-day meetings each. Teaching now comprises 18 lectures in total (duration 60 min. each) plus the introduction, as well as practical and theoretical exercises. Table 4 and Table 5 show the course schedule for the two weeks.

Table 4: Agenda – Mineral processing (week 1)

Time	1. Day	2. Day	3. Day
08.30-09.30	Introduction	6. Copper ore dressing	Lab Comminution/ Flotation
09.30-10.30	1. Geology	7. Lead-zinc ore dressing	Lab Comminution/ Flotation
10.30-10.45	Break	Break	Break
10.45-11.45	2. Mineralogy	Lab Comminution/ Flotation	Analyses and test data evaluation
11.45-12.45	Calculation exercise Grades/selectivity	Lab Comminution/ Flotation	Calculation exercise Separation curves
12.45-13.30	Break	Break	Break
13.30-14.30	3. Comminution	Analyses and test data evaluation	Calc exercise Process statistics
14.30-15.30	4. Flotation	Calculation exercise Balancing	Questions and answers
15.30-16.00	Break	Break	
16.00-17.00	5. Physical separation	8. Precious metals from sulphide ore dressing	

Table 5: Agenda – Metallurgical processing and recycling (week 2)

Time	1. Day	2. Day	3. Day
08.30-09.30	9. Introduction to pyrometallurgy	Lab Leaching experiment	Calc exercise Mass balancing of copper converting
09.30-10.30	10. Pyrometallurgical extraction of nonferrous metals I	Lab Leaching experiment	Calc exercise Mass balancing of copper converting
10.30-10.45	Break	Break	Break
10.45-11.45	11. Introduction to hydrometallurgy	13. Pyrometallurgical extraction of nonferrous metals II	17. Pre-treatment of metal-bearing waste
11.45-12.45	12. Hydrometallurgical extraction of zinc and copper	14. Pyrometallurgical extraction of nonferrous metals III	18. Metal recycling
12.45-13.30	Break	Break	Break
13.30-14.30	Lab Leaching experiment	Calc exercise	Questions and answers
14.30-15.30	Lab Leaching experiment	15. Hydrometallurgical extraction of precious metals I	
15.30-16.00	Break	Break	
16.00-17.00	Lab Leaching experiment	16. Hydrometallurgical extraction of precious metals II	

Examination and credits

Attendance of all teaching elements except for the lectures, i.e. calculation exercises and practical lab exercises, is compulsory.

The course is valued with 5 ECTS credits, split into 2 credits for two home assignments, 1 credit for writing a course portfolio and 2 credits for the lab exercises. The assignments are graded and determine the grand grade of the course.

Course literature

- Wills, B.; Napier-Munn, T.J. (2006). Mineral Processing Technology: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery, 7th ed., Butterworth-Heinemann, ISBN 978-0-7506-4450-1
- Schlesinger, Mark E. (2011). Extractive Metallurgy of Copper, 5th ed., Elsevier Ltd., ISBN 978-0-08-096789-9.
- Biswas, A. K. (1999). Principles of Blast Furnace Iron Making, SBA Publications, Calcutta, 1999
- Worrell, E.; Reuter, M. (2014). Handbook of Recycling: State-of-the-art for practitioners, Analysts and Scientists, 1st ed., Elsevier, ISBN 978-0-12-396459-5.

- Material from the Division of Minerals and Metallurgical Engineering, Luleå University of Technology.

Content of the revised lectures

- Geology: The geology lectures will give an introduction to ore types and their formation as well as to mineralogy / process mineralogy. This part is intended to provide basic knowledge to students not having a background in these fields.
    - Ore geology
        - Mining areas in Europe
        - Rock types and ore minerals
        - Ore types and formation processes with emphasis on sulphide ores
        - Exploration and resource estimation
    - Mineralogy
        - Mineral properties
        - Mineral identification
        - Methods in quantitative mineralogy
- Mineral processing: The mineral processing lectures mainly focus on the unit operations and machine types used within sulphide ore processing, i.e. crushing and grinding for mineral liberation, separation processes for concentrating the ore minerals and phase separation, as well as on ore beneficiation processes for copper, lead, zinc:
    - Mineral processing – Comminution:
        - Mechanisms of breakage
        - Mineral liberation
        - Energy for size reduction
        - Crushing and sizing
        - Grinding mills including autogenous grinding
        - Classification and circuit design
    - Mineral processing – Separation processes:

      Froth flotation:
        - Mechanisms of flotation
        - Flotation reagents: collectors, frothers, activators and depressants, modifiers
        - Laboratory scale equipment
        - Industrial flotation cells

Physical separation methods:

- Gravity separation, principles and equipment
- Magnetic separation, principles and equipment
- Dewatering in thickeners and filters

- Mineral processing – Particular ore beneficiation processes:
  - Copper ore dressing
  - Lead-zinc ore dressing
  - Precious metals from sulphide ore dressing

- Pyrometallurgy – This part gives an introduction to general metallurgical methods for extraction of metals from primary and secondary raw materials with special focus on pyrometallurgical methods for extraction of metals from ore concentrates. The lectures cover:
  - General overview of pyrometallurgy
  - General overview of pyrometallurgical unit processes to extract copper and lead
    - Roasting
    - Smelting
    - Converting
    - Refining
  - Introduction to thermodynamic and phased diagrams relevant to pyrometallurgical processing

- Hydrometallurgy: This part gives an introduction to hydrometallurgical methods used for metal production. Special attention is paid on the production of zinc, copper and precious metals. The lectures cover:
  - Overview of hydrometallurgical unit operations
  - Hydrometallurgical phase diagrams (solubility, complexes, E-pH)
  - Leaching methods
    - In situ-leaching
    - Heap leaching
    - Vat leaching
    - Stirred tank leaching
    - Pressure leaching
  - Solution purification and concentration methods
    - Precipitation
    - Crystallisation
    - Adsorption
    - Cementation
    - Solvent extraction

        - Ion exchange
    - Zinc production through the Roast-Leach-Electrowinning (RLE) method
    - Copper production through leaching, solvent extraction and electrowinning
    - Bioleaching of refractory gold concentrates
    - Cyanide leaching for gold and silver extraction

- Metal recycling – Pre-treatment: The unit operations used in primary resource extraction can mostly be used for treating recycling material. Besides, specific equipment and processes are applied that are introduced in the lectures:
    - Dismantling
    - Comminution equipment (shredders, cutting mills)
    - Physical separation methods
        - Magnetic separation
        - Eddy-current separation
        - Dense-media separation)
- Metal recycling – Metallurgical processing: Metallurgical processing of secondary materials can be done integrated with processing of primary materials but also in process units or plants dedicated to treating secondary materials. This lecture covers examples of
    - Treatment routes for copper bearing scrap, including electronic scrap, using pyrometallurgical methods.

Lab and calculation exercises

Laboratory and calculation exercises comprise:

- Mineral processing:
    - Comminution test (ball mill grinding and sieve analysis)
    - Separation test (batch flotation test)
    - Calculation of grades/ recovery/ selectivity
    - Calculation of a separation curve from test data
    - Process statistics (material balancing for a concentrator plant)
- Metallurgical processing:
    - Exercise covering mass and heat balance for a chosen unit process
    - Exercise based on a student lab (a film will be shown on the practical part) simulating a copper converting process. Mass and heat balance for the process based on data from the student lab.
    - Leaching experiment to recover zinc from an electric arc furnace dust from scrap based steel production. Recovery calculations and determination of zinc distribution between zinc oxide and zinc ferrite in the dust.

3.3.3.3 PREPARATION OF THE COURSE MATERIAL

For the theoretical part, Powerpoint presentation material was compiled to be distributed to the course participants as hand-outs (Sand, Rosenkranz, Sandström, Samuelsson 2015). The listed course books are complementary to the hand-outs and were selected to provide more in-depth information on concepts covered in the course as well as a support for the exercises and the development of the course portfolio. The distributed material as well as the course literature is also intended to be a useful source of future reference to the students in their ordinary work.

Calculation exercises and laboratory exercises were developed to give the students a hands-on experience both in terms of carrying out basic calculations, conducting laboratory scale experiments and for the interpretation and analysis of real experimental results.

According to the course planning, laboratory work carried out by the students was considered as an important element for acquiring practical technical skills related to mineral and metallurgical processing. A problem identified, however, was that only institutions with well-equipped laboratory facilities could act as host institutions for conducting the course. This is a clear drawback in terms of skill shortage mitigation, as this has the consequence that weakly equipped institutions that have the strongest need for skill development will not be able to support the conduct of the full course concept. For this reason, a toolbox of lab instructional videos was developed in the form of virtual "demo labs" (Sand, Rosenkranz, Sandström, Samuelsson 2015). These demonstrational videos could function as a classroom aid, providing practical input to the presentation of theoretical concepts and as an introduction to laboratory exercises, or can in some cases make up the lack of appropriate equipment at the site the course is given.

3.3.3.4 COURSE EVALUATION

A course evaluation was conducted by collecting the opinion from several experts from industry and academia. In total four reviews were received and evaluated for this report. Without any rank order the following summary can be made:

- There is a need for this type of comprehensive course that serves as an introduction to extractive metallurgy and minerals beneficiation.
- The course is considered to be useful, well structured and in good alignment with the aims.
- Particularly for industry, the compact schedule is of advantage and adapted to the particular needs in terms of content.
- The combination of theoretical lectures with practical laboratory exercises is highly appreciated. The well balanced mixture of theory and practice probably has positive effects on the learning curve.

- The utilisation of a particular production chain throughout the course is considered as a good idea.
- Having a view on the entire chain involving deposit description, concentration processes and metallurgical processing is in line with modern holistic concepts as for instance geometallurgy.

Apart from that, the following recommendations have been given by the reviewers:

- The focus on the technical implementation of metal production rather than on principles of phenomena should be more emphasized in the description of learning outcomes.
- Industrial case studies should be integrated in order to support understanding and knowledge.
- Involvement of industrial speakers in the lecturing is seen as a benefit.
- A more distinct consideration of environmental impacts from different technologies as well as health and safety issues should be included. This includes also the principles of sustainable development.
- An outlook on novel, emerging technologies, e.g. sensor-based sorting, should be included.
- While specialist course are appreciated, there is a need to align this type of course offer with regular teaching.

3.3.4 Discussion and lessons learned

From the expert evaluation but also from the discussions the authors led with various attendees of the COBALT dialogue meetings, it can be confirmed that the concept of educating engineers that have a different technical background but want to enter the minerals industry (by "lateral entry") is highly relevant. There is a gap existing between a full master level specialization in minerals processing or extractive metallurgy and the standard process engineering education. The developed block course is suited to fill this gap and to introduce students to the sector. The more holistic approach that describes large parts of the value chain is also useful when introducing for instance mine geologists or quality engineers to processing topics.

From the teachers' side, this course concept requires a multidisciplinary team of lecturers in order to provide knowledge from the different areas (geology, exploration and mining as well as processing and recycling) with the necessary quality. Involving industry people in certain parts of the teaching, as suggested by one of the reviewers, would certainly be of additional value.

While the block course at hand has been designed with a distinct focus on process technology, the authors agree with the reviewers and see the necessity to address sustainable development and the environmental issues in a more comprehensive way. In the context of minerals processing and metallurgy, this refers to responsible mining and resource efficiency. Taking up sustainability in minerals education means that technical competence needs to be integrated with competence in environmental and also social sciences. The objective has to be to educate environmentally literate engineers in mining and minerals engineering, with the challenge to increase the environmental content while maintaining high standards in the core disciplines.

When planning the elaboration of the revised course concept also a conduct of the block course was pursued. Contact was made with two academic institutions, the Universidad Politécnica de Madrid, Spain, and the School of Chemistry at Trinity College Dublin, Ireland. Both institutions are based in regions that were identified within the COBALT survey as having a limited educational offer in the area of mineral raw materials. While the initial interest in the course was large, the opportunities for a concrete implementation were very constrained in the end. This was mainly related to lacking access to the necessary lab equipment (laboratory facilities not equipped with the processing unit operations relevant to the course subject) and the tedious administrative procedures for establishing entirely new courses in the university curricula, in order to make it possible for the students to receive credits for their participation. The latter had called for a much longer time to prepare.

4 CONCLUDING REMARKS AND FUTURE DEVELOPMENT

This report summarises the implementation and evaluation phase of the skill shortage mitigation concepts developed within the COBALT project for the European Union mineral raw materials sector. The implementation involved concept evaluation and, in the case of the short course, pilot testing and evaluation.

The testing and evaluation phase involved all parts of the European Union, as well as all three regions defined within the COBALT project. The short course involved participants from Eastern Europe and the Iberian Peninsula, the block course module was evaluated by experts from the mineral industry and academia in Northern Europe and the full study programme concept was developed for Northern Europe with special focus on Greenland.

In addition to reporting of experiences from the testing and evaluation phase, as well as a summary of the feedback and evaluations obtained, measures have been taken to continue the dissemination and formalisation of the developed concepts. The aim is to create a Europe-wide network for continuing information spreading and skill shortage mitigation also after the ending of the COBALT project. This work is further described in the sections below.

Full study programme

Based on the outcomes of the COBALT project, DTU and LTU will further explore the possibilities for establishing a Mineral Resource Management study programme with focus on the Arctic. The mutual interest of continuing this work between DTU and LTU is also expressed by the mentoring institution in the evaluation in Appendix 6.3.

The further work will include negotiating the participation of a third partner for the educational programme in order to meet the requirements for labelling within the EIT KIC Raw Materials programme (EIT Raw Materials Factsheet 2014). In order to fulfil the eligibility criteria for financial support through the EIT Raw Materials programme, a third partner needs to be attached to the consortium. DTU is not part of the consortium, but can be included as an external partner. The increased mobility offered within the programme through DTU, part of the studies in Denmark and a possibility for a study semester on Greenland, would probably be seen as a unique selling point for the programme and also be viewed positively in the application process.

Short course

There seem to be a clear need for the tested type of short course for layman persons, addressing different stakeholder groups and also different European regions. The authors are now in the act of pursuing the short course concept within the recently launched EIT KIC – Knowledge and Innovation Community on Raw Materials. The idea is to continue via a KIC Added Value Activity (KAVA) using the recently opened first call for "Wider society learning" for developing a suite of short courses with different emphases.

This type of course could be offered in collaboration with public agencies, e.g. geological surveys, as potential mentoring institutions, doing the marketing and the organising. For a wider dissemination other academic partners from universities with a broad profile within mineral raw materials are needed. Compared to courses given in academic education the language will most probably be an issue. Thus, based on the original English version the course should be translated into the local language for appropriate implementation.

Block module course

Also the block course is a candidate for future dissemination. Similarly as the short course, the EIT KIC on Raw Materials will be an interesting funding option as the first KAVA-call is also supporting activities aiming at "Life-long learning". A suite of block courses could be promoted via e.g. branch organisations, as tailored courses for employees from certain companies or companies in certain industrial areas, or alternatively as summer schools for engineering students. With regard to teaching methods, it should be examined whether this type of courses is suitable for online teaching, at least in the case of lectures.

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6 Appendices

6.1 List of figures

6.2 List of tables

6.3 Attachments to full study programme evaluation

Center for ARKTISK TEKNOLOGI

Comments on the COBALT proposal for a study programme in Mineral Resource Management

The proposed study programme matches a need for professionals to the mineral sector in Greenland, and the suggested study structure is suitable for such a programme.

Greenland has a limited student potential for higher education. The small Greenlandic University Ilisimatusarfik does not have programmes in Natural Sciences or Technology.

The Arctic Technology Centre (ARTEK) was established in 2000 by the Technical University of Denmark (DTU), the Building & Construction School in Sisimiut (now Tech College Greenland – KTI) and the Greenlandic Home Government (now the Greenlandic Government). The Professional Bachelor programme in Arctic Engineering was established in 2001, and has been a success by so far producing approximately 25 Greenlandic candidates now working in Greenland. Both Greenlandic and Danish students are enrolled in the programme, and they study both in Greenland and in Denmark. This is the "ARTEK model" now recommend by the Greenlandic Government for new Greenlandic programmes in higher Education.

Since 2006 there has been a specialisation in Geology – Constructions & Raw Materials, where students due to the limited knowledge of mineral production in Denmark is required to spend half a year in a foreign university. Most of these students go to Luleå Technical University (LTU) in Sweden or Norwegian University of Science and Technology (NTNU) in Trondheim.

At approximately at the same time the Greenlandic Mining School (now School of Minerals and Petroleum) was established at KTI to educate the blue-colour workforce to the mining industry.

A few years ago it was decided to expand ARTEK's presence in Greenland. This included establishing education in Arctic Engineering at a master level. The first implementation of this is an 'Arctic Semester', which will lead to full master programmes in Arctic Engineering. To fulfil the Greenlandic needs with respect to raw materials this will include international Master programmes in collaboration with Universities outside Denmark.

There have been very few operational mines in Greenland, and for the moment there are none. A small ruby-mine will probably soon open, and some larger mines could open in the coming year depending on world market prices. However, there are many mineral exploration projects going on. Most graduates from the School of Minerals and Petroleum therefore today works with construction not related to mining or mineral exploration.

Due to this uncertainty is it not suitable to educate specialised Greenlandic mining engineers, since the jobs may not be there, and if they are, they are likely to be filled with foreign specialist. But there is a need for professionals with a general knowledge of mineral exploitation combined with knowledge of Arctic conditions and the Greenlandic framework for mineral exploration and production.

The Department of Raw Materials of the Greenland Government is very small, so there is a need for experts to evaluate permissions to explore and extract minerals. There is also a need for consulting engineering to prepare all the EIA, SIA, and IBA reports there have to be written in relation to min-

Arctic Technology Centre
Technical University of Denmark
KTI Tech College Greenland, Sisimiut, Greenland

cobalt review.doc • 09-02-2015 • hpc
Page 1 of 2

eral licensing. And the mineral companies need people with knowledge of the Greenlandic conditions. All three stakeholders need people, who can talk to each other and to the public based on relevant engineering knowledge.

Therefore there is a need for specialist in Mineral Resource Management even if large mining projects are not coming to Greenland in the near future. The ARTEK Advisory Board of Greenlandic industrial and government experts is clearly stating the need for professionals in Mineral Resource Management in Greenland.

The proposed study programme in Mineral Resource Management is there very timely. The proposed competences of the graduates are in line with the suggestions from the advisory board, which has added that they would like more focus on health, safety and environmental issues.

The programme structure is closely aligned with the ARTEK model, which states that education of Greenland specialist cannot be done alone in Greenland and cannot focus only on Greenlandic students due to the limited number. So the students must spend time in Greenland, to experience the Greenlandic conditions, but they must also spend time outside Greenland, since they ned competences not possible to give them in Greenland – and in this case they need to go to a university outside Denmark, since the necessary competences is not at present available neither in Greenland nor Denmark. And the programme has to have international appeal, since the low number of potential Greenlandic students makes it necessary to attract international students.

The suggested courses are relevant, but adjustments have to be made due to practical considerations on course planning at DTU.

The suggested student background may pose a problem with respect to pre-knowledge on mineral or mechanical process technology, since likely applicants from civil or environment engineering probably don't have this knowledge. Basic process technology should therefore be included in the programme.

As indicated in the suggestions, the programme may have to be designed with from the start primarily using existing courses and courses from third parties to allow resources and competences to be build.

Based on the suggestions from the COBALT programme a real master programme in Mineral Resource Management is under development in cooperation between LTU and DTU.

2015.02.09
Hans Peter Christensen
Associate Professor
Director Arctic Study Programmes
DTU, Sisimiut

6.4 Attachments to short course evaluation

6.4.1 Invitation

INVITATION

TO THE SHORT COURSE

Introduction to Minerals and Metal Production

February 25-26th 2015

at

Vienna University of Economics and Business, Institute for Managing Sustainability

Meeting room D 2.088, Welthandelsplatz 1, Building D1 (2nd floor), A-1020 Vienna, Austria

Are you concerned with the supply of minerals and metals? Are you interested in sustainable raw material production? Do you want to learn about the impact of mining? – This short course provides you with basic knowledge on where minerals and metals are produced, the technology behind and the related environmental, social and economic aspects.

The course is developed within the COBALT project (www.cobalt-fp7.eu). COBALT is supporting the work and objectives of the European Innovation Partnership of Raw Materials (EIP) and aims at building awareness, facilitate learning and knowledge transfer on the sustainable use of raw materials. The work is receiving funding from the European Union FP7 ENV.2013.6.5-2 grant agreement no 603509.

Co-funded by the 7th Framework Programme of the European Union

Introduction to Minerals and Metal Production

SCOPE OF COURSE

The course aims at providing a common understanding of mineral and metal production under a holistic value chain perspective and by considering the different periods of time of a mine's life cycle. It is meant to give an introduction to process technology and by conveying general awareness of existing technical constraints with regard to both material and process. The level of detail in describing technical coherences has been adapted to the needs also of a non-technical target audience.

Intended learning outcomes: After completion of the course the participants should be able to:

- Describe different mineral resources (ore types, occurring minerals)
- Explain the different steps in developing a mine project
- Describe the major unit operations that are used within ore dressing and metal extraction
- Discuss the environmental, social and economic dimensions of sustainable mineral and metal production

The course is conducted by teachers from Luleå University of Technology in Sweden, Europe's northernmost technical university and a leading research and education institution in mining, mineral processing and metallurgy.

TARGET AUDIENCE

The course is targeted towards an audience with interest in, but without prior background in technical fields related to mineral raw material extraction or production. This can include policy makers, governmental or NGO employees, representatives from companies not directly involved in raw material production, and civil society. The course is designed for anyone interested in the field, either in the professional or personal context.

MODES OF EDUCATION

The course includes lectures, discussions and workshop exercises. Course material will be distributed during the lectures. The course will be held in English.

PRACTICALITIES

The number of participants is limited to 12. The course, including refreshments and light meals is provided free of charge. Participants are kindly asked to do travel and accommodation arrangements on their own expense. Maps and suggested hotels near the course venue are listed in a separate document.

REGISTRATION

Registration or inquiries by e-mail to Anders Sand, anders.sand@ltu.se by February 16th. With your registration, please also inform of any dietary constraints.

COURSE SCHEDULE

Time	1. Day (February 25th)	2. Day (February 26th)
09:00 – 11:00	Welcome and introduction LECTURE 1 Ore geology and mineralogy	LECTURE 5 Metallurgical processing
	LECTURE 2 Mineral exploration and mining project	LECTURE 6 Metal recycling
	Break	Break
11:15 – 12:15	WORKSHOP 1 Resource management in the EU	WORKSHOP 3 Sustainable metal production
	Lunch	Lunch
13:00 – 15:00	LECTURE 3 Mining methods	LECTURE 7 Environmental aspects of mine production, and mine closure
	LECTURE 4 Mineral processing	CLOSING DISCUSSION Environmental aspects of mining – the long-term perspective Course wrap-up and evaluation
	Break	End of course
15:15 – 16:00	WORKSHOP 2 Impacts from mining operations	

6.4.2 Evaluation questionnaire

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area			X			
In my work I am faced with raw material issues				X		
I am working for (GOV, NGO, Industry, Research, University, other)	NGO					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.					X	
The contents of the course help to achieve/meet the course's aims.					X	
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.					X	
Given the aims of the course the aspiration level of the lectures was appropriate.			X			
The workshop exercises were rewarding.				X		
The course material was helpful.					X	

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.				X		
The course duration is adequate for this course.					X	
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)	Some lectures maybe a little too technical and detailed, details not that relevant compared to other topics, but of course that's just from my personal preferences					

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area					X	
In my work I am faced with raw material issues		X				
I am working for (GOV, NGO, Industry, Research, University, other)	GOV					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.						X
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.						X
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.					X	
The course duration is adequate for this course.						X
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)	Only one question I expect more information about impact enviromental in all phases of the prodution p.e. in the begining about ground water impact ...					

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area		X				
In my work I am faced with raw material issues	X					
I am working for (GOV, NGO, Industry, Research, University, other)	NGO					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.						X
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.						✓
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.					X	
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)	it was a good course, I don't have any comments					

Thank you for helping to improve this course.

cobalt

Short course

"Introduction to Minerals and Metal Production"

February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area		X				
In my work I am faced with raw material issues	X					
I am working for (GOV, NGO, Industry, Research, University, other)	NGO					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.						X
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.						X
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.						X
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)	very creative and interesting even the job profile doesn't the same with the topic of the course. Thank you.!					

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area					X	
In my work I am faced with raw material issues						X
I am working for (GOV, NGO, Industry, Research, University, other)	GOV					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.						X
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.					X	

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.					X	
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.						X
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)	Use of practical exercises is good to learn the lessons. Especially the rocks!					

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area	X					
In my work I am faced with raw material issues				X		
I am working for (GOV, NGO, Industry, Research, University, other)	CONSULTANCY					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.					X	
The contents of the course help to achieve/meet the course's aims.					X	
The course planning and supervision are structured and easy to follow.					X	

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.					X	
Given the aims of the course the aspiration level of the lectures was appropriate.					X	
The workshop exercises were rewarding.					X	
The course material was helpful.					X	

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.					X	
The course duration is adequate for this course.					X	
My overall impression is that this was a good course.					X	
My comments (use also the backside if necessary)						

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area						X
In my work I am faced with raw material issues						X
I am working for (GOV, NGO, Industry, Research, University, other)						

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.						X
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.						X
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.						X
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary) Bravo!						

Thank you for helping to improve this course.

cobalt

awareness learning dialogue

Short course

"Introduction to Minerals and Metal Production"

February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area		✓				
In my work I am faced with raw material issues	✓					
I am working for (GOV, NGO, Industry, Research, University, other)	GOV (REGIONAL, MADRID)					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.					✓	
The contents of the course help to achieve/meet the course's aims.					✓	
The course planning and supervision are structured and easy to follow.						✓

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.					✓	
Given the aims of the course the aspiration level of the lectures was appropriate.					✓	
The workshop exercises were rewarding.				✓		
The course material was helpful.				✓		

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.					✓	
The course duration is adequate for this course.						✓
My overall impression is that this was a good course.						✓
My comments (use also the backside if necessary)						

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area			X			
In my work I am faced with raw material issues					X	
I am working for (GOV, NGO, Industry, Research, University, other)	NGO					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.					X	
The contents of the course help to achieve/meet the course's aims.						X
The course planning and supervision are structured and easy to follow.						X

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.						X
The workshop exercises were rewarding.						X
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.						X
My overall impression is that this was a good course.						X
My comments (use also the backside if necessary)						

Thank you for helping to improve this course.

cobalt
awareness learning dialogue

Short course
"Introduction to Minerals and Metal Production"
February 25th and 26th, 2015

Personal background

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
I already had previous knowledge of the topic area		X				
In my work I am faced with raw material issues		X				
I am working for (GOV, NGO, Industry, Research, University, other)	GoV					

Course aims and content

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The aims of the course are clear.					X	
The contents of the course help to achieve/meet the course's aims.					X	
The course planning and supervision are structured and easy to follow.					X	

Quality of Teaching

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
It has been worthwhile attending the lectures.						X
Given the aims of the course the aspiration level of the lectures was appropriate.					X	
The workshop exercises were rewarding.					X	
The course material was helpful.						X

General evaluation

Strongly disagree / Strongly agree (1-6)

	1	2	3	4	5	6
The course design and content matched with my expectations.						X
The course duration is adequate for this course.					X	
My overall impression is that this was a good course.					X	
My comments (use also the backside if necessary)	→ the copies in paper should be in a bigger size. We couldn't read it! ← that's the only problem!					

Thank you for helping to improve this course.

I am very satisfied with the whole organisation. Thanks to everyone!
Excellent teachers and materials

6.5 Attachments to block module course evaluation

6.5.1 Wardell Armstrong International, London, UK

Wardell Armstrong International
Third Floor, 46 Chancery Lane, London, WC2A 1JE, United Kingdom
Telephone: +44 (0) 20 7242 3243 www.wardell-armstrong.com

wardell armstrong
your earth our world

Our ref: ZL611158/J009/CPB/KO.
Digital ref:
Your ref:

Date: 01 May 2015

Professor J Rosenkranz
Dept. of Civil, Environmental & Natural Resource Engineering
MiMeR Minerals and Metals Research Laboratory
Luleå University of Technology
SE-971 87 Luleå, Sweden

Dear Professor Rosenkranz

Masters Level, Sustainable Minerals and Metals Production Course

Thank you for sending me the syllabus for the Master Level, Sustainable Minerals and Metals Production course developed recently at Luleå University as part of the COBALT Programme. I would like to commend you for devising a most interesting comprehensive and useful course in an area which is, sadly, generally lacking throughout Europe (i.e., Extractive Metallurgy and Minerals beneficiation). I consider that the course provides a good basis for developing understanding of the subject and will assist the European minerals and mining industry. I also consider that the course will be well received by employers in the industry, indeed, as Director of an Engineering Consultancy with a Minerals Processing Laboratory and Pilot Plant I would certainly consider employing graduates of this course.

Theoretical considerations are nicely supported by practical laboratory sessions, something that is essential to develop understanding and knowledge. It might be useful to consider the introduction of industrial cast studies within the course to help put the 'theory' in to context. It would be invaluable if any external, industrial speakers could be invited to give presentations on aspects of Minerals Processing and/or Extractive Metallurgy at their operational sites. Other than this, the only enhancement to the course I would consider is the integration of the HSE into the course (it may well be the intention to do this but HSE does not seem to be mentioned in the syllabus). In particular, the

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ZL611210/E001

impacts associated with different technologies (social as well as environmental) should be examined together with consideration of occupational health and safety risks and ways to mitigate these.

As stated previously, I believe this is a well organised, useful course in a specialism that has been largely ignored for too long within Europe. As such, it is a welcome addition to the European teaching of sustainable minerals processing and I have no hesitation in commending the course.

Yours sincerely

for Wardell Armstrong International

Dr C P Broadbent

DIRECTOR

cbroadbent@wardell-armstrong.com

ZL611158/J010/CPB/KO 1 May 2015

6.5.2 Boliden Mineral AB, Boliden, Sweden

BOLIDEN

May 8, 2015

To whom it may concern

Regarding proposed course called COBALT

Boliden have been asked to give its point of view on the course called COBALT.

Boliden have sent employees that have not had mineral processing background in their previous studies for basic courses at the University of Luleå. The proposed course COBALT is more adapted to the need for this purpose than the ordinary courses that have been used.

The COBALT course is comprehensive and covers most of the need regarding knowledge about mineralogy and mineral processing. The only gap is that ore-sorting is not included. Ore-sorting is not common in mineral processing, but should be mentioned at least.

It is an advantage that the course is compressed in time since that will be more efficient when people from industry will participate. Travelling time and other "lost time" will be minimized this way.

It is an intensive course and the mixture between lectures and lab exercises is good since that most probably will have a positive effect on the learning curve.

Yours faithfully,

BOLIDEN MINERAL AB
Boliden Mines
Process Technology

Nils Johan Bolin

Boliden Mineral AB
Boliden Mines
SE-936 81 Boliden, Sweden
Telephone +46 910 77 40 00, Fax +46 910 77 41 10, Registration No. 556231-8850, Registered Office Skellefteå, www.boliden.com

6.5.3 University of Lorraine, Nancy, France

Comments on the course program
"Education related to mineral raw materials in the European union"

Most of the ores that will be discovered in the near future will certainly contain values elements in very low grades, typically 1% or less[1, 2]. Furthermore, these values elements are finely disseminated among several minerals in the ores and will require new techniques to recover and separate them from the gangues minerals. In this situation, the knowledge of the ore concentration processes and the description of mineral composition and associations will define the choice of mineral processing routes to increase to maximize the economic efficiency parameters of mining projects. In fact the processing of low-grade ores involve a combination of deposit description (mineral cartography), (pre)concentration methods and (hydro)metallurgical steps. Thus, the mining industry requires the project engineers with multiples competencies covering all aspects of mineral formation and transformation processes.

The courses proposed by the LTU corroborate perfectly with attempts of the industry and research institutions and fit well with geometallurgical approach (or metal life cycle) which is expected by the partners for modern engineers.

The courses are very well balanced and comprises as essential elements the lectures, practical works and exercises. The students will have the knowledge at various levels of ore processing and recycling, starting from ore mineralogy description, principle of processing methods, description and calculation of energy and materials flows for unit operations.

In my opinion the program can be completed by the exercises to calculate the material and water balance for a flowsheet with reduced number of operation with references to the existing softwares.

The block courses present a very dense set of matters in the field of mineral and metallurgical processing and can be used as short courses for the training of students and/or process engineers from industry.

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PROCESS AND
ENVIRONMENTAL ENGINEERING
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UNIVERSITY of OULU
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EVALUATION
4.5.2015

In ref.: Request for an evaluation by Åke Sandström (29.4.2015)

AN EVALUATION ON THE COURSE SYLLABUS OF "SUSTAINABLE MINERALS AND METAL PRODUCTION"

This commentary aims to give a short overview and evaluation on the course syllabus of "Sustainable minerals and metal production" (5.0 ECTS) created by Anders Sand, Jan Rosenkranz, Caisa Samuelsson and Åke Sandström at the Luleå University of Technology. The course is aimed for students with a bachelor's degree in engineering or with at least five years of work experience,

Aims and outcomes The course aims to provide knowledge on mineral and metallurgical processes as well as metal recycling. The aims are described in more detail as seven learning outcomes that are clearly expressed. The area of expertise covered by these learning outcomes includes the whole production chain from minerals and mineral processing to the production and recycling of metals. The focus of the learning outcomes (as well as the contents of the course, *cf.* below) seem to be more on the technical implementation of metal production (*i.e.* processes and unit operations, *etc.*) than on the phenomena taking place in these processes (*i.e.* chemical reactions, transport phenomena, *etc.*). This is a very reasonable approach on an intensive course such as this, but it could be mentioned more explicitly on the description of the learning outcomes.

Contents The contents of the course are in good alignment with the aims and they cover extensively the whole production chain from mineral processing to metal production and recycling. Both pyro- and hydrometallurgical processes are included in the syllabus. Since the covered area of contents is relatively large for a single course, it is a good idea to use a certain production chain (*e.g.* production of copper from sulphide ores and recycling of copper scrap) as an example throughout the course, even if the aims are on a more general level.

Realisation The course is to be implemented as two 3-day meeting blocks during two weeks. The schedule in which the first three days focus on the mineralogy and mineral processing whereas the last three days focus on process metallurgy and metal recycling is well-structured and in good alignment with the course aims and contents. Use of calculation and laboratory experiments among the lectures is a pedagogically wise desicion.

Examination Students are required to do two home assignments, a course portfolio and laboratory exercises. Since the attendance on two 3-day meeting blocks only covers approximately one fifth or one fourth of the course credits, it may be assumed that a major part of the students' work is connected to these assignments. Considering their large role in the course, their description on the course syllabus is quite limited.

Course literature Four books covering the whole course content from mineral processing to metal production and recycling are presented in the course syllabus. In addition to these books, material from the Division of Minerals and Metallurgical Engineering at the Luleå University of Technology is mentioned as supplementary material. The material is up-to-date and focuses on the topics relevant in this course. The supplementary materials enable the use of the most recent research results as a part of education.

Conclusions Based on the syllabus, the course of "Sustainable minerals and metal production" seems to be a well-defined and clearly constructed entity in which the knowledge on mineral and metallurgical processes is provided for the students with a basic engineering background from other areas of engineering. The aims, contents, realisation, examination and course literature are in good alignment with each other. Since the assignments required from the students are a major part of the course, a more detailed description of these assignments would have improved the syllabus, but nevertheless the syllabus affords a very good basis to implement the course.

Oulu, 4.5.2015

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EDUCATION RELATED TO MINERAL RAW MATERIALS IN THE EUROPEAN UNION

BLOCK COURSE PILOT

Review of Deliverable D3.3

AUTHOR

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Escola Superior de Comerç Internacional – Pompeu Fabra University

Barcelona, 2015-05-10

1. Entry requirements
   - Not clear if the work experience is related to the engineering studies or to the specific field.
   - English skills not specified (first, advanced, proficiency..., personal interview...).
2. Course aim
   - "Understand sustainability in minerals and metal production and the life cycle of metals". I would rephrase as: "Understand sustainability throughout the life cycle of minerals and metal production".
3. Course content
   - It would be fair to state which minerals and metals will be studied.
   - Environmental impacts due to collection and recycling are not treated in 3.4, while the course title implies sustainability is key. All in all, it doesn't seem that sustainability is such a key issue when you go through the contents. To me, it shows a classical engineering course with an hour or two of sustainability small talking.
   - Nothing on resource depletion?
4. Schedule
   - This type of Schedule is not easy to combine with the typical master shcedule, in which the different subjects are tought 1-2 hours a day at the most. For a student to follow it, it would mean not to go to his other lessons. For people working in industry, leaving their job three days might be too much. Could it be also performed as a Friday-Saturday type?
   - Not clear what the home assignments are and how long does it take to finish them.
5. Examination
   - Not clear if attendance to lectures is not compulsory. Shouldn't a minimum of, say, 80% be stated? Or a statement that the host university rules shall be followed?
   - Not clear how the overall grade will be calculated out of the three individual grades.

OVERALL COMMENTS

All in all, the course seems interesting, useful and well planned.

Specialized seminars/courses are welcome in Spanish universities. However, good attention must be given to make sure schedules are compatible with normal teaching. In Spanish universities, in this moment, there is a clear overoffer of subjects with few students attending and an extreme lack of financial resources to pay for them. It is essential that a market study is done.

The course is well described and scheduled but the home assignments are unclear. Proportion between university time and home time according to the Bologna process is not ensured. Balance between conceptual and practical lessons is fine.

In relation to improvements, please be guided by my comments above on each chapter of the course description.