ENVIHEI

Title of the PBL challenge: **Digging Deeper: Sustainability Challenges in the Raw Materials Sector**

Name of the responsible lecturer

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University / Department / Degree program

Technical University of Leoben / Chair of Mining Engineering and Mineral Economics / International Master's Degree in Advanced Mineral Resources Development

Course / Subject in which implemented

1st / Mineral Economics and Project Management

Implementation period (dates)

October 26, 2025 – January 30, 2026

Total duration (weeks/hours)

16 weeks / 150 hours

Number of students involved

38 students

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1. Project Design

1.1 Brief description of the project and the challenge proposed

The class provides a basic introduction to the multiple conceptual bases of Sustainable Development and Sustainability as well as their current applications across different real-world raw material case studies. The class is based on an innovative Problem Based Learning (PBL) - Artificial Intelligence (AI) approach. The active participation of students in the activities below is strongly encouraged. The lecture is organized as follows:

1. The students will be provided with a knowledge base on the complex topics of Sustainability and Sustainable Developments such as basic history, key concepts, theory (Passarella) and mining and raw materials-specific current applications (Tost). This includes frontal lectures, recorded lectures, videos, readings (selected scientific literature and textbooks), etc.
2. A number of wicked sustainable development problems based on real-world mineral raw material case studies will be presented. The students will be divided into groups and they will be working on a certain problem/case study, applying the knowledge base and using AI as one team member.
3. Every group will prepare a final report of the group work and every student a learning log (details will be announced separately) and will present to the whole group (modality of presentation will be announced separately). In this occasion, the lecturers will moderate a wrap-up session.

The knowledge base includes the concepts of sustainable development and sustainability with special regard to their application to non-renewable raw materials. Those concepts are traced briefly to their origins (key UN processes

such as Brundtland Commission, UN MDGs, SDGs, etc.). An overview of underlying fundamental concepts (e.g. well-being, weak vs. strong sustainability formulations, decent living standards, planetary boundaries, etc.) and frameworks (e.g. doughnuts economics, MCA, etc.) will be presented from a multidisciplinary perspective, including ethics, economics, social and environmental sciences. The class also reviews current applications of sustainable development concepts and principles in mining and raw materials industries, in particular the UN Sustainable Development Goals (SDGs) and ongoing extensions (e.g. The World in 2050 Initiative); proposed policy (sectorial vs. integrative) frameworks for implementation are also critically evaluated. Special focus will be devoted to discussing the case of extractive industries.

Both the course structure and material are organized with supervised support of AI. Additionally, students will need to include AI as a member of the group and (critically) use AI-powered tools to support their group work throughout the lecture duration.

The lecture is organized to ensure that key capacities needed to foster sustainability will be covered by the course (e.g. capacities for sustainable development by Harly and Clark-Harvard).

The class will partly be held online. At least one week before each class, as specified in the Syllabus, all relevant class materials (slides, literature) as well as a video of the lecture will be posted online. At the designated class date and time, a Webex call will bring together lecturers and students for discussions and a questions/answers session. Students are expected to have watched the respective lecture video and have studied posted class material prior to each online class discussion session. The students will be supported through group work and interaction through Moodle for discussion, and Q&A interaction is

encouraged. Specific weblinks and online discussion software tools will be announced separately.

***Table 1**. Proposed challenges, lecturers in charge, and number of students in each group.*

Group	Title	Lecturer	N° students
1	The Jadar Project - Team 1	Marinella Passarella	5
2	The Jadar Project - Team 2	Marinella Passarella	5
3	The Salar de Atacama Challenge - Team 1	Michael Tost	4
4	The Salar de Atacama Challenge - Team 2	Michael Tost	4
5	The Simandou Gambit	Michael Tost	4
6	The Glencore Coal Controversy	Michael Tost	4
7	The Fen Complex Investment	Michael Tost	4
8	Planetary Boundaries - Team 1 (Europe)	Marinella Passarella	4
9	Planetary Boundaries - Team 2 (Dubai)	Marinella Passarella	4

1.2 Expected learning outcomes (academic and transversal competences)

Understand and start developing system thinking

- Define and explain key sustainability concepts (Sustainable Development Goals, Planetary Boundaries, Decent Living Standards, different forms of capital and weak vs. strong sustainability, etc.).
- Explain key sustainability principles and their relevance to renewable vs. non-renewable resources.
- Explain the sustainability concepts in examples from the raw materials/ mining context.
- Explain the interconnectedness of systems (systems thinking).

Apply/analyse and develop system thinking

- Examine/analyse real-world complex sustainability problems in the raw materials/mining context.
- Contrast different aspects of sustainability of complex real-world raw materials/mining problems.

- Select and apply the right sustainability framework/definition /concept/method for analysing complex real-world raw materials/mining problems.
- Compare different settings in complex real-world raw materials/ mining problems in relation to sustainable development (e.g. Equity consideration: global south vs. global north, benefits vs. cost/externalities of extraction).
- Understand and compare the different viewpoints of different stakeholders (e.g. company vs. community; local vs. national vs. global).
- Analyse complex sustainability problems in the raw materials sector by identifying systemic interdependencies across environmental, economic, and social dimensions.

Create/evaluate

- Argue and defend their own (and the group) positions on their scientific/engineering sustainability solution proposed in front of other peers.
- Critique peers´ sustainability solutions and methods selected for approaching complex real-world raw materials/mining problems.
- Prepare a scientific and/or technical report on the sustainability issues in complex real-world raw materials/mining project treated.
- Propose innovative solutions to one or more sustainability issues of complex real-world raw materials/mining problems.

Develop Critical thinking, responsibility, foresight and collaboration:

- Evaluate the sustainability impact of mining strategies by comparing alternatives based on ethical, environmental, social, and economic criteria, using structured decision-making tools.

- Co-create viable solutions for sustainability challenges in the raw materials and mining sector through interdisciplinary collaboration and stakeholder analysis.

Develop a shift in mindset, agency and empowerment

- Develop a critical mindset to transform unsustainable development pathways into sustainable ones.
- Link knowledge with action for sustainability.
- Consider equity both within and among generations in decision making when developing innovative solutions to one or more sustainability issues of complex real-world raw materials/mining problems.
- Reflect on your role as an active change agent and formulate a personal or group-based action plan to promote sustainable practices for your career.

Soft skills/Process

- Work effectively in teams, including group decision-making and conflict management.
- Work effectively in multicultural environments and consider different perspectives.
- Develop multicultural awareness.
- Manage one-semester-long projects.
- Manage multiple deadlines.
- Communicate and present ideas effectively in different formats (e.g., oral presentations, posters).
- Critically and reflectively use AI for information searching, evaluating sources and research results, and collaborative group work, including assigning AI appropriate roles and evaluating its contributions.

1.3 Targeted sustainability competences

The responsible lecture aimed at integrating in the expected learning outcomes (where possible) the sustainability competences from the researchers of Harvard (Clark and Harley, 2020):

1. Capacity to measure progress toward sustainable development.
2. Capacity to adapt development pathways to protect human well-being in the face of shocks.
3. Capacity to transform unsustainable development pathways into sustainable ones.
4. Capacity to advance equity both within and among generations.
5. Capacity to govern, i.e., to build and maintain collaborative relationships in pursuit of sustainable development.
6. Capacity to link knowledge with action for sustainability.

1.4 Sustainability approach and how it is integrated into the project

A knowledge base on main sustainability and sustainable development aspect is provided to students in form of video lectures (e.g. SDGs, Planetary Boundaries, Sustainability Framework from MCA, and their applications to mineral raw materials and mining sector such as Social License to Operate).

1.5 Methodologies and tools used (PBL structure, facilitation techniques, etc.)

Every group had assigned a mentor. The work was organized following the 7 jump processes (Maastricht model):

1. Clarify unfamiliar terms.
2. Define problem.
3. Brainstorm (prior knowledge, ideas).

4. Analyse the problem (Discuss explanations + hypotheses).
5. Formulate learning goals.
6. Self-study.
7. Report findings.

Iteration and additional loops can be repeated with complex problems.

1.6 Organization of the project (group formation, timeline, milestones)

At the beginning of the lecture the students were informed about the operational working rules of the PBL-class including deliverables, evaluation criteria, timelines and milestones to assure their smooth workflow (each deliverables had mandatory interim milestones e.g. submit a draft and get feedback from both mentors and peers). Challenges where illustrated, students were divided into groups following the criteria of optimizing diversity in terms of gender (at least 1 woman in each group), nationality and international vs. local students.

1.7 Deliverables requested from students (type, format, deadlines)

Deliverables (see Table 2):

Portfolio of students´ learning path

- Learning log: follow the 7 jumps steps and report regularly on your learnings (e.g. Group formation, Midterm collaborations, learning goals, End, Reflection)
- Technical Report
    - System map
    - Literature review
    - First draft report

- Final report

- Scientific Poster
  - Scientific Poster draft – presentation
  - Scientific Poster presentation

***Table 2**. Schedule of lectures and deliverables. The mandatory in-person meetings are highlighted in red, while the consultation group mentoring slots Q&A (online or in person) are highlighted in black.*

Date	Lecture time		Deliverable
6th October (Marinella + Michael)	14:00-15:30		
9th October (Marinella + Michael)	14:30-16:00		(Start Learning Log)
13th October (Marinella + Michael)	14:00-15:30		By 15th October • Group Contract
20th October (Marinella + Michael)	13:00-15:30		• System Map • Update Learning Log
27th October (Michael)	15:30-17:00		
30th October (Marinella)	14:00-15:30		
3rd November (Michael)	15:30-17:00		• Learning objectives • Update Learning Log
6th November (Marinella)	14:00-15:30		
10th November (Michael)	15:30-17:00		
13th November (Marinella)	14:00-15:30		
17th November (optional)			
20th November (Marinella)	14:00-15:30		
24th November (Michael + Marinella)	13:00-15:30	2.5h	• Literature review • Update Learning Log
1st December (Michael)	14:00-15:30		
1st December (Marinella)	15:30-17:00		
9th December (Marinella)	15:30-17:00		
10th December (Michael)	15:30-17:00		
15th December (Michael + Marinella)	13:00-15:30	2.5h	• First Draft Report • Update Learning Log
12th January (Marinella)	13:00-14:30		
12th January (Michael)	14:30-16:00		
19th January (Michael + Marinella)	14:00-15:30		• Final Report • Draft Poster in PPT • Update Learning Log
26th January (Michael + Marinella)	13:00-15:30	2.5h	• Scientific Poster • Update Learning Log
30th January (Michael + Marinella)	13:00-15:30	2.5h	• Final Learning Log

1.8 External collaborators involved (mentors, companies, experts...) and their role

The lecturers served as specialized mentors for the sector investigated. Each group was assigned one mentor to support them on technical and organizational question during the whole duration of the course. The challenges assigned are real-life case studies.

2. Project Evaluation

2.1 Assessment criteria and methods used

The assessment criteria and weighting are shown below (Figure 1).

% of the overall grade	Deliverable	Group	Individual	Results	Process	AI	Grade / accomplished	Who is the grader?
25%	Portfolio of your learning path		X		X	X	Accomplishment	Teachers
35%	Technical Report	X		X		X	Grade (track where AI was used and include it in an appendix of the report)	Teachers
15%	Scientific Poster	X		X		X		Peer assessment
10%	Overall Participation		X		X		Level of participation? (minus or red flags + neutral)	Teachers
15%	Group Participation / collaboration		X		X		Grade	Peers verified by the teacher

Figure 1. *Evaluation criteria and methods used for the PBL.*

2.2 Evidence of student learning (examples, outputs, results)

Evidence of student learning includes completed deliverables, attendance at in-person lectures and meetings, and active participation and collaboration in group activities.

3. Reflections and Recommendations

3.1 Main achievements and strengths of the project

Students felt empowered and demonstrated a high level of engagement and involvement in the group work. Their feedback highlighted that working in an international environment, using English, and addressing complex real-world challenges was a valuable and enriching experience.

Students developed their ability to manage a several-month-long project within a group. They particularly appreciated the milestones established for each deliverable, including the interim submissions, which helped them structure their work and monitor their progress throughout the project.

The project also fostered strong connections among group members and helped students develop strategies to overcome challenges collaboratively. Through the learning log, students were encouraged to reflect on their learning process, challenges, progress, and personal development throughout the project.

The connection between mentors/lecturers and each student group was another important strength. From the mentors' perspective, it was a rewarding experience to accompany the students throughout their PBL journey, providing support, advice, and suggestions while allowing them to progressively take responsibility for their work.

From the lecturers' perspective, the project required a significant initial investment of time, resources, and preparation. However, once the materials and structure were developed, the approach can be readily replicated in future years with new students.

The project also helped students recognise the complexity and importance of sustainability. They developed an understanding of key sustainability concepts and frameworks and learned to apply them to environmental sustainability challenges while considering their connections with social and economic dimensions.

Overall, the project was a highly rewarding and enriching experience for both students and lecturers, combining collaborative learning, real-world challenges, sustainability, and personal development.

3.2 Challenges faced and how they were addressed

At the beginning of the course, having the Moodle platform fully prepared with all the necessary materials was a challenge. This was addressed by prioritising and preparing the most essential materials needed at the start of the course, such as the descriptions of the challenges. The remaining materials were developed during the first month of the course, in parallel with the implementation.

Preparing all the videos for the flipped classroom approach was also a challenge. This was addressed by recording the final video after the course had started, as students would not need to access it until November.

Another challenge was that one mentor had to support several groups at the same time. To address this, more time was allocated to mentoring activities than initially planned.

3.3 Lessons learned for future implementations

The students highlighted in their feedback that they would have wished more formal lectures in class about the sustainability and sustainable development

theories, framework and concepts. Students had access to video lectures in a flipped classroom format, but they would have preferred live lectures, as they felt they learned much more from the few sessions delivered in person.

Distribute the deliverables more evenly throughout the course, with more deadlines towards the end. Students felt that the pace was too fast during the first part of the course, until mid-November, and that they did not have enough time to understand the key concepts from the knowledge base before applying them to their projects.

4. Supporting Material

4.1 Lecturers' materials and project documentation

Lecturers' materials and project documentation are available in the following link:
https://drive.google.com/drive/folders/1zVf8NVo86EeKvQcYep1lPMmSW-Xk62Wu?usp=drive_link

4.2 Deliverables produced by students, final presentations or pitch materials

Some students expressed an interest in publishing the content of their technical reports and posters. Therefore, the technical reports, posters, and other related deliverables will not be made openly available until the students have had the opportunity to publish their work. Finally, the learning logs will not be made publicly available, as they contain personal reflections from individual students.

An example of deliverables produced by students are available in the following link:
https://drive.google.com/drive/folders/1_4iWAocbkoPuXH_EG7PbjyFltRCEoY4r?usp=drive_link

Students' final presentations are available in the following link:

https://drive.google.com/drive/folders/1nIbrHmMgMMF_3HQIqHF1Z_j_jeiWlw3m?usp=drive_link

4.3 Images/videos (with consent)

Photographic and video records were captured with the explicit consent of the participating students, and are available in the following link:

https://drive.google.com/drive/folders/18x19T8k4bCjGAmB50MobbuXbP9OVj4Py?usp=drive_link

4.4 Any other relevant material

All the materials, including this report, are available in the following link:

https://drive.google.com/drive/folders/1nKjMkwkTf7BZCzWY40b7798mHpfyM3um?usp=drive_link