

# Transforming a Problem-based learning course into a Challenge-based learning course: UT M-EEM “Challenge-based Sustainability Case projects”

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## Executive Summary

From the academic year 2021/2022, all M-EEM group work courses in quartile 3 have served for a pilot process to become challenge-based, adopting tailored Engage-Investigate-Act phases. Traditionally, these have been a problem-based course, i.e. teachers provided research problems including external partners/clients. The alignment of challenge-based learning (CBL) in the three applied case courses within M-EEM is desirable not only in terms of programme cohesion, but also in terms of experimenting with new forms of educational methods. As such, we would like to position these courses as an occasion to find out:

1. How does challenge-based learning contribute to the development, formulation and execution of profound, original, and integrated sustainability research in a student group setting?
2. How does the use of a combined self- and peer-assessment procedure contribute to formative student learning about their personal development and group participation in a challenge-based learning setting? (Section 1)

The case project courses are embedded in a 1-year master programme at University of Twente that trains students to become professionals in environmental, energy or water management. The courses are specifically meant for students to implement the knowledge and skills they have acquired in the previous quartiles in a dedicated group work setting and also prepare them for their individual thesis research work, by putting into practice their research skills before they have to do this on their own. The learning objectives are the same for all three courses and are structured according to content-related and process-related skills. These have been overhauled for the specific purpose of aligning with a CBL approach, as have the teaching activities. These involve a not too rigid pre-structuring of the quartile into the three CBL phases Engage-Investigate-Act. Progress is assessed through progress reports, self- and peer assessment sessions, as well as a mid-term report and a final report. (Section 2)

To answer our research questions, we have used three sources, including dedicated teacher reflections elicited after the courses ended; the forms students submitted for their self- and peer assessment sessions, which detailed their progress on 21<sup>st</sup>-century skills; and the alignment of the content reporting with principles of CBL. These were analysed with qualitative thematic analysis, and counting (a) how often certain skills were mentioned by students, and (b) how many skills students cited in their reflections. (Section 3)

In general, teachers felt that the Engage phase was executed best in the first run of the courses. This led to satisfactory challenges for all groups. Unfortunately, from the Investigate phase on, the course became more of a 'regular' research course, also owing to the kind of rubrics used for the summative assessment of the courses. Teachers thought the self- and peer assessment sessions were a welcome and useful addition to the course. Talking about their divergent group work performances helped students individually and in the group.

The analysis of the self- and peer assessment forms brought to light that students reported more on the criteria of 'critical thinking' and 'communication' than on 'creativity' and 'collaboration' (the latter were lower down on the form). The skills that were mentioned often in all three courses included systems thinking, confidence about collaboration, and taking initiative/finding ways to make the project run better. These are all skills that are encouraged by the challenge-based learning approach. However the micro-level differences in how the courses were taught make it slightly difficult to come up with clear conclusions as to the differences between the courses.

Summative assessments had pre-defined contributions to CBL by including specific sections on how students worked on their challenge. They had to describe how they implemented the CBL approach in their methods, as well as derive conclusions for the stakeholders in their final chapter. However, due to the time restraints for the course, the action phase of CBL is sometimes only reached as part of the discussion/conclusion sections in which students make action proposals or plans to address the challenges they researched. (Section 4)

The teaching team has made several suggestions for improving the courses for the second run and aligning them even more with the CBL philosophy. Some of these have already been implemented in the second run of the courses executed in quartile 3 of academic year 2022/2023. In the self- and peer assessment forms, we have found issues regarding

- the number of assessment sessions, which should be reduced to two,
- the single-point rubric, which now includes generic 21<sup>st</sup>-century skills criteria that could be aligned better with CBL,
- how students fill out the self-assessment forms, for which teachers need to safeguard that a similar level of immersive reflection is achieved for all criteria,
- the 21<sup>st</sup>-century skills that students thought they learned about; these included, for example, low-hanging fruit skills related to project management in a group setting.

For the summative assessments, the role of describing the CBL process and infusing the academic research reports with a stronger CBL influence was highlighted. It is suggested to change the prescribed report structures and assessment rubrics to reflect the CBL 'learning journey' that students navigate through. (Section 5)

We conclude that the challenge-based learning approach has definitely had its influence on the outcomes, albeit mixed. Regarding research question 1, it has in the first run been difficult to deviate from a traditional academic research report, in which the engagement with stakeholders could have been emphasised more. Regarding research question 2, we found that we might have overshot the mark with the three formative self- and peer assessment approach we implemented, and that two should suffice. Although the variables contributing to how students fill out their forms do not allow for a specific answer, we are fairly confident that our self- and peer assessment procedure has contributed to students personal development. (Section 6)

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# 1 Introduction

The Master programme in Energy and Environmental Management (M-EEM) already has group-work-based courses in each specialisation track in quartile 3 for many years. Traditionally, these have been a problem-based course, i.e. teachers provided research problems including external partners/clients. In the recent past, the courses have already opened up to a more challenge-based structure, especially in the Case Project Water Management, with specific a ‘scoping phase’ at the beginning of the course for students to develop and formulate their own research problems.

From the academic year 2021/2022, all three courses have served for a pilot process to become challenge-based, adopting tailored Engage-Investigate-Act phases. While the precise temporal segmentation of the available learning time is left to each course coordinator, both the summative and formative assessment have been aligned to include mid-term reports, e.g. proposals (formative), final reports (formative/summative), and a combination of self- and peer-assessment applied at three moments during the quartile (beginning, middle, end). The latter is mainly meant for formative assessment, but we also want to experiment with it to see whether and how it can be used to inform two of the criteria in the final assessment rubric (“personal development” and “group participation”).

The alignment of challenge-based learning in the three applied case courses within M-EEM is desirable not only in terms of programme cohesion, but also in terms of experimenting with new forms of educational methods. As such, we would like to position these courses as an occasion to find out:

3. How does challenge-based learning contribute to the development, formulation and execution of profound, original, and integrated sustainability research in a student group setting?
4. How does the use of a combined self- and peer-assessment procedure contribute to formative student learning about their personal development and group participation in a challenge-based learning setting?

The report continues with an overview of the constructive alignment applied to the courses, including their embedding in the larger M-EEM programme (section 2). In section 3, we briefly detail the methods by which we generated and analysed the data. We describe our findings based on teacher reflections, self- and peer assessment forms, and the summative assessments (section 4). Section 5 discusses a few points of attention, and we conclude by answering our research questions (section 6).

## 2 Constructive alignment

The various elements of a course have to be balanced with each other as well as with the programme curriculum at large. This process of coordinating the learning objectives, teaching activities, and assessment methods (and its outcome) is what Biggs (1999, as cited in Stefani, 2009) termed 'constructive alignment'. In the following we describe the role of the three case project courses, in which challenge-based learning has been integrated, in the M-EEM programme, how the programme ILOs relate to those on course level, and what the various course components are.

### 2.1 Programme level

The M-EEM programme has the following final qualifications, which outline the programme-level intended learning outcomes (PILOs) in terms of the knowledge and skills that the students gain throughout the four quartiles<sup>1</sup>:

1. Expertise within and across MEEM domains
2. Competence in doing research
3. Competence in designing solutions
4. Demonstration of a scientific approach
5. Demonstration of basic intellectual skills
6. Competence in cooperating and communicating
7. Awareness of the temporal and social context

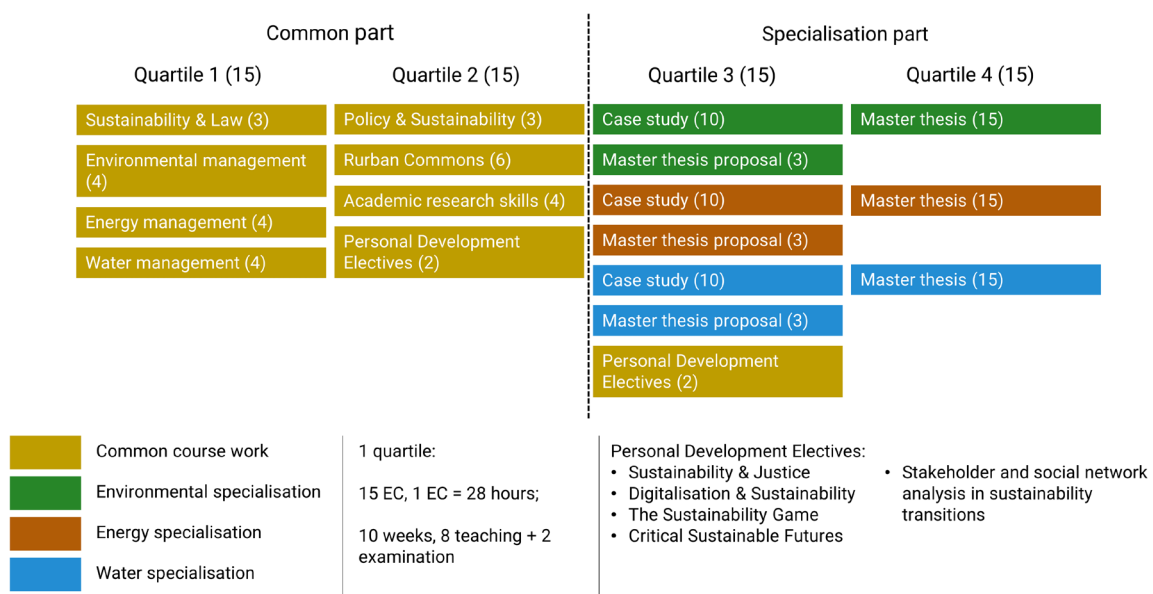


Figure 1 Overview of M-EEM curriculum; case projects in quartile 3.

Courses offered in quartiles 1 and 2 mostly focus on the knowledge-oriented ILOs, particularly those under the final qualifications 1-3, and provide a basic level of certain skills, such as academic writing and working in a team (Figure 1). In several courses, the students also learn about societal challenges, such as climate change and biodiversity loss, and complete individual or group assignments, which are

<sup>1</sup> Programme-specific appendix to the Education and Examination Regulations for MEEM <https://www.utwente.nl/en/bms/education/regulations/2022-2023-eng/eer-master-2022-2023/11087-eer-psa-meem-24.pdf>

based on literature review or secondary data from documents. The Case Project course builds on these knowledge and skills, covering each and every PILO under the seven final qualifications, and advance the learning experience of students by exposing them to a real-life challenges through CBL. In quartile 3, students also take the Research Proposal course, which focuses on the knowledge and skills towards designing and conducting a research project independently. Together with the Research Proposal Course, the knowledge and skills gained through the Case Project are essential for the students' successful completion of the Master Thesis in quartile 4.

## 2.2 Course level

The course level is an intermediary level of constructive alignment. Here, we describe the revision of the ILOs to incorporate challenge-based aspects, how this translates into relevant teaching activities, and the methods applied to assess how and what students have learnt during the case projects.

### 2.2.1 Intended Learning Outcomes

The intended learning outcomes (ILOs) of any course reflect the specific qualities regarding the knowledge, insight and skills that students are expected to gain after accomplishment of the course program (Article 7.13, paragraph 2c of the WHW). As introduced in section 2, the ILOs of a course should be in alignment with the PILOs of the program, to which it belongs. On course level, the ILO's frame the content, methods, activities and evaluation formats deployed during the course. Coherence of those aspects is the bottom line of the course quality assessment. Hence, ILOs play a crucial role in the design and execution of any course. In the context of the effort to integrate a challenge-based learning approach into the case project courses, the ILOs have been formulated as follows for all three courses:

- 1) By means of a group proposal, group report and a group presentation, students will demonstrate that they are able to:
  - a) Examine a multidisciplinary and complex research challenge of their own definition by applying knowledge and insights acquired in the study programme.
  - b) Design or create a potential solution or solutions to the research challenge.
  - c) Report on and present the outcomes of their group work activities according to academic standards.
- 2) In terms of the group work process, students will demonstrate that they are able to:
  - a) Focus on a relevant challenge in society, scope the topic into a research project, conduct the research, report and present findings (students select and describe the challenge themselves, consent needed from supervisors and from external partners when required).
  - b) Lead the research process from proposal to completed report within time constraints, while working in a multi-disciplinary, multicultural team.
  - c) Apply the acquired social, communication and research skills in a complex research project.
  - d) Work in a research team according to a (diversity of) team role(s).

These learning outcomes are constructively aligned with the assessment framework and the teaching activities (Biggs and Tang 2011). Learning outcome 1) is assessed with the deliverables of a mid-term report or proposal, the final report and a presentation at the end. Learning outcome 2) is monitored and assessed by means of a self-assessment immediately followed by a peer-assessment under teacher guidance at three points in the quartile. Each of those sessions is concluded with the completion of a single-point rubric per student. This rubric is envisioned to be used for the student to tackle weak points or expanding strengths, but also for the teacher to track personal development and group participation. In this way, self- and peer-assessment is used formatively to prevent power games and

other negative effects common to summative peer assessment (Norton 2009). We also want to explore the possibility to use this process as a means to prevent free-riding behaviour. The use of self- and peer assessment has been an issue of interest for some time, especially in international, culturally diverse classrooms. All summative assessments involve a rubric tailored to the assignment.

### 2.2.2 Teaching/learning activities

CBL provided the fundamentals for the case projects water, environment and energy in the MEEM program (2021-2022). The case project is an important component of the MEEM program. In short, for 10 weeks students work in a team on a real-life challenge and with actual stakeholders. The case project allows students to integrate their knowledge gained during the first half of the master program, and to apply and practice professional skills and competences.

The following CBL fundamentals were used for the design of the three case projects:

- (1) **Solving real-world challenge:** instead of teachers dictating the learning activities, students were in charge of selecting a challenge to study. The only requirement was that the challenge needed to be related to water, environment or energy. Departing from a big abstract idea, the students had to define a concrete and actionable challenge. For example, one team of students started off with a general idea of energy storage and ended up studying the role of home batteries in making Ameland more energy independent.
- (2) **Multidisciplinary teams:** the students worked in teams on their selected challenge, and as they come from different disciplinary bachelor programs, they learned both how to work in multidisciplinary teams and how to approach their selected challenge from multiple disciplines. Since most MEEM students have a technical background, they were particularly encouraged to delve into social science perspectives. For example, one team of students studied the issue of net congestion from four perspectives: political, technical, spatial planning and business development.
- (3) **Collaboration with stakeholders:** while working in teams on the challenge, the students were encouraged to actively interact with stakeholders. This implies, not only during the process of data gathering (e.g. interviews or surveys) but also by involving them in the starting and closing phases of the case project. The students ended up interacting with a variety of stakeholders: from policy officers and business owners, to citizens and project developers.
- (4) **Preparing professionals:** while working in teams, the students simultaneously developed skills and competences they needed for their future careers. Thereby the focus was on developing 21<sup>st</sup> century skills: critical thinking, communication, creativity and collaboration.
- (5) **Sharing and reflecting:** students were regularly asked to share and reflect throughout the entire case project. For this purpose, there were sessions dedicated for supervision of and peer-to-peer feedback. In these sessions, the students discussed with each other and their coaches progress in terms of the assignments as well as their personal development of skills.

By applying these fundamentals of CBL, the students learned and developed while they were making an actual difference in the real-world. More specifics on the assignments and assessments of the case project can be read in the next section.

### 2.2.3 Assessment

Every week there are formative progress presentations, Q+A session, on-demand mini lectures, and on-demand guidance by mail exchange. The core elements of the test-plan and included tests are:

The Mid-term Report assignment (Test 3, ASS5) is a pass/fail test, in which students have to integrate three aspects of their work in a concise report: (a) a research plan (including challenge, problem



statement, questions, methodology), (b) a literature review, and (c) other engaging endeavours towards clients/stakeholders. The research plan contains at least a descriptive, an exploratory and a prospective question by which the students show their understanding of the relationships between CBL and conventional research approaches. We provide guidance regarding the assignment, various possible report structures and length; a single point formative rubric is used and shared. This test is linked to the "Mid-term report and Q + A session" (Test 1, PRS), also a pass/fail.

In the Final Report assignment (Test 5, ASS6), students have to deliver a report in which they integrate their further iterations regarding engaging, investigating and acting. This calls for integrating and synthesizing their research activities (data collection and data analysis by various methods) and design efforts, envisioning possible improvements and responsible solutions by design thinking, based upon data, reasoning and creativity, into a well-structured and well written report. Again, we provide guidance regarding the assignment, various possible report structures and length; an analytic rubric is used and shared, it is a numeric test. The report is assessed by multiple criteria. 50% of the final mark of a student, individual performance of a student is assessed by other criterions, also 50% of the final grade. A presentation of the findings precedes the submission of the final report, and Q + A and (final formative) feedback session", (Test 4, PRS), a pass/fail.

Finally three self- and peer assessments on 21<sup>st</sup>-century skills had to be participated in (Test 2, ASS1). Students first reflect on their 21<sup>st</sup>-century skills in four categories in a single point rubric. The self-assessment is followed by a peer-to-peer session, in which students share their self-assessment with their group members and reflect on it, ultimately developing ways forward to develop the skills.

In comparison to preceding years, the self- and peer assessment (Test 2) has been added. Other tests have been reworked with regard to the details, in order to bridge the CBL approach and the more conventional research approach. There does not seem to be a fundamental tension between the CBL approach and more conventional research approaches that advocate research questions related typologies (i.e. "descriptive", "explanatory/exploratory", "evaluative", "prospective/design").

### 3 Research Methods

We briefly describe the methods that we used to assess student learning and answer our research questions. Furthermore, we describe how we analysed the data and provide a brief statement about our positionality as a teaching team vis-à-vis the students.

#### 3.1 Data generation

The methods were partly pre-existent and the data associated with them would have been generated anyway, such as the mid-term reports (section 4.3). New data were generated by asking teachers for reflections upon their experience of implementing our challenge-based approach for the first time (section 4.1) and processing the self- and peer assessment forms for each session (section 4.2).

Teacher reflections: After the course ended, all teachers involved in the three courses answered a pre-given set of questions about how they experienced the course. See the list of questions in Appendix II.

Self- and peer assessment forms: For each peer assessment session, students have been asked to fill out a single-point rubric with 21<sup>st</sup>-century skills as criteria (a “pre-form” in our terms). This is the self-assessment part of the procedure. This single-point rubric was then discussed in the peer assessment session, in which students could compare their own perception of their performance with that of their fellow group members and think about ways to develop further in any of the criteria. After the session, students were asked to update the submitted “pre-form” and resubmit (the “post-form” in our terms). Given that we organised these sessions at the beginning, middle, and end of the quartile, this yielded a total of six forms (3x pre-form, and 3x post-form) per student; as not every student submitted each form, we had a total of approximately 150 forms.

Mid-term reports: We did not use the reports as such as a data source, but we qualitatively reflected on their value for and role in our CBL process.

#### 3.2 Data analysis

The teacher reflections were analysed with a qualitative thematic analysis, summarising the topics, issues, problems, and suggestions, that teachers perceived in their experiencing of the courses. These were also verified with a discussion session involving most of the teachers.

The self- and peer assessment forms were analysed by first condensing them into a spreadsheet with all details.<sup>2</sup> Due to time and space limitations for this analysis we looked at the post-session forms of the first peer assessment session at the beginning of the course and at the post-session form of the third and final session. Although the data would have allowed a closer look at the specific changes in the course of the case project, we only analysed which of the 21<sup>st</sup>-century skills and subskills were mentioned by the students (see Appendices III-V). Even with good guidance, which we think we provided, filling out the forms for reliable specific analysis, depends on so many factors, that it does not make sense to look into that kind of detail. Students could (a) not be in the mood, (b) think about the criteria in different ways both between students and over time, (c) want to feint more engagement than has actually occurred, etc. In the end, we approached this self- and peer assessment on 21<sup>st</sup>-century skills as something that requires intrinsic motivation. Although it seems that some students may have approached the process in terms of option (c), we have the impression that the majority of students has tried to engage with their personal development in an earnest manner. We summarised the individual post-session forms into a general form by interpreting which skill within each of the 21<sup>st</sup>-

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<sup>2</sup> While we only analysed the post-forms of the first and third session (see above), we all six pre- and post-session forms were included in the spreadsheet to allow for further analysis in the future.

century skill criteria the student was referring to. As a next step in the analysis, we constructed what could be called 'frequency tables' showing which skills were mentioned by which student and counting both how often the skill was mentioned, and how many skills a student mentioned. These tables were first ranked according to the number of times a skill was mentioned, and then according to how many skills were mentioned by the students (see Appendices VI-VIII). In the frequency tables, we omitted whether students referred to the skill as below or exceeding expectation, which is still visible in appendices III-V.

## 4 Findings

In this section, we describe the outcomes of our evaluation of how we introduced challenge-based learning in the M-EEM case projects. We first describe all outcomes per method of data generation and conclude with a summarising paragraph.

### 4.1 Teacher reflections

In the following, we report the more specific findings from the teacher reflections on the implementation of the CBL phases, the self- and peer assessment, some new requirements that CBL supervision emphasises, and end with a list of concrete implications mentioned by the teachers to be taken into the revision process for the next edition. Most teachers agreed that the Engage phase was executed best. Although students did not all have the scoping skills at the level required, they learned swiftly. The challenges selected by all student groups were satisfactory. Unfortunately, into the Investigate phase, the course turned into a 'normal' more research-focused/academic group project. According to the teachers, the reasons for this can be found in the time constraint of the ten week course, but also in the unclarity of what a CBL product could or should look like and teachers' inexperience with facilitating CBL. Also owing to the assessment rubric used, the products resembled academic research reports more than anything else.

The self- and peer assessment which we designed specifically for the course was generally welcomed very much. With the three reflection sessions at the beginning, middle, and end of the course, students gained a frequent opportunity to reflect on their group process as well as their individual learning in terms of 21st century skills. Teachers report sessions with constructive feedback and advice. They observed that students learned to appreciate their differences instead of perceiving them as obstructions, which resulted in better working environment and prevented issues related to teamwork. One teacher expanded the potential usefulness of this assessment format to all kinds of team work. Although one teacher observed that the kick-off and mid-term session were more constructive and the end-of-term one felt more like a formality, another appreciated all sessions for their function of increasing insight into group processes and enabling a differentiation of individual efforts in the group effort. This is, of course, helpful in the assessment of group work and giving individual grades.

There were two concrete requirements for teaching skills different from 'normal' academic research group supervision that the teachers reported. In CBL teachers need to restrain themselves not to pre-define too much content and encourage self-learning. Similarly, it is important not to pre-determine for the students how the challenge should be addressed but encourage an open reflection, brainstorm, or search for the appropriate methods to do so.

### 4.2 Self- and peer assessments

In this section, we analyse the form the students filled out in the context of the self- and peer assessments. We first discuss each course separately and then compare any differences or similarities across the courses. The results are ordered according to the frequency that each (sub-)skill was mentioned by students.<sup>3</sup> A general observation that held for all three courses is that the change in the discussed skills was so small between the first and third peer assessment session that it did not make sense to include the second session in the analysis.

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<sup>3</sup> In the conclusion, we also present an outlook to more fine-grained analyses of the data.

#### 4.2.1 Water track

The skills reported by water track students were diverse. There was not one general skill that all students reported to have improved or planned to improve. On average, 2,0 out of the 7 students mentioned the respective skill in question, amounting to 29% of the whole water track group. Some patterns could be discerned. No skill was mentioned more than three times. Those mentioned three times were time management, systems thinking, confidence in group collaboration, open mindedness and flexibility, and improvements in written communication. The two skills mentioned twice were speaking up, and practicing to let go of perfectionism as expressed in wanting to control the process and a perceived need to know everything about the group topic. Finally, there were a few topics that were only mentioned by one student each, such as using writing as a means to focus; strengthening organisational skills; suspending the 'writing mode' to elaborate the topic thoroughly, first; taking more initiative; focusing on main issues and not getting lost in side issues; listening; and giving and receiving feedback.

We have observed that most students in the water track project commented on several skills across the four criteria of critical thinking, communication, creativity, and collaboration. Six out of seven students discussed at least four subskills, with two students discussing five. Only one student was either very focused on specific subskills or did not spend too much time thinking about it; they mentioned two subskills. On average, students mentioned 4,0 out of 14 skills as below or exceeding expectations.

#### 4.2.2 Environment track

The self- and peer assessment data of the environmental track show a different pattern. None of the skills is mentioned ten or more times, in fact the highest frequency of mentioning is 8, which holds for one skill only (Confidence about peers and own contribution and participating in discussions). Many skills are not mentioned once (n=12). This distribution leads to an average of merely 2,6 students out of 12 mentioning any given skill, amounting to 21% of the whole environment track group.

Ranking the students according to the number of skills they mentioned, shows that students mentioned fewer skills in their post-session forms (7,1 out of 33 skills). Only two students mentioned ten or more skills (12 and 13, resp.). One student did not submit the post-session forms.

#### 4.2.3 Energy track

Among energy track students, five subskills reached ten or more mentions, including taking initiative (14x), expressing thoughts coherently and appropriately (11x), being open minded and flexible (11x), systems thinking (10x), and confidence about being able to contribute and participate (10x). Owing to the higher number of students there are also more skills that are mentioned merely once, including knowing when to stop ideating, letting go of perfectionism, being satisfied rather quickly, and speaking up. None of these were explicitly mentioned in the examples of the single-point rubric, but were formulated by students individually. The remainder of 24 skills were mentioned in a range of 2-9 times. Any given skill was mentioned by 5,2 out of 16 students in the energy track, amounting to 32% of the whole energy track group.

If we rank the students according to how many skills they mentioned, we can see that most students have taken the time to fill out the self- and peer assessment form. Most mention ten or more skills in their reflections. There is also a small group that does not seem to have engaged with the purpose of the self-assessments sufficiently; one student has mentioned as little as three skills to have improved or to be in need of improvement. On average, students mentioned 10,6 out of 33 skills.

#### 4.2.4 Comparison

Most of the observed changes in all three courses occurred in the domains of 'critical thinking' or 'communication' and hardly in 'creativity' and 'collaboration'. Coaches observed that it helped the team to openly bring up critical thinking and communication issues that were mentioned in the forms during the self- and peer assessment sessions. This made students more aware of their communication issues and different perspectives on 'critical thinking'. Discussing their issues also functioned as a (claimed) incentive to work on these (e.g. relations between argumentation and processing new information, and systems thinking versus details). But it was also true for the domain of collaboration. Nonetheless, one student observed to be 'locked' into their own ideas and thinking in some situations, while quickly jumping on the next idea in others, seemingly wishing for more flexibility in this. Finally, some students were critical about their time management, including thoroughly preparing for meetings and being on time, which influenced their collaboration capacities, too. Several students explicitly expressed the value of the peer assessment sessions, especially since they also helped a group that initially risked becoming dysfunctional.

The skills that were mentioned often in all three courses included systems thinking, confidence about collaboration, and taking initiative/finding ways to make the project run better. These are all skills that are encouraged by the challenge-based learning approach, both conceptually and practically. Conceptually, because the idea of 'challenges' implies to take on the complexity of societal problems and including as many system elements as possible. Practically, the temporal scope of a CBL project in a UT quartile of 10 weeks requires project management skills and learning to rely on group members to do their work, because one cannot do everything on one's own. Waiting for things to happen also does not fit the course's time plan, so taking initiative is appreciated. Another skill that ranked high in the energy and environment courses was that of expressing themselves, which could relate to a lowering or remaining language barrier, or to feeling safe enough to voice their concerns. The language barrier should not be a big problem as students are accepted to the programme based on evidenced language levels, but in practice this is in some cases a paper reality. Furthermore, the diversity of the cultural classroom in M-EEM adds to the already generally present threshold of sharing feelings such as concerns or confidence with peers, especially peers who one does not know that well. In relation to this, the skill of open mindedness towards other's perspectives and being flexible towards other's behaviour in terms of responsibilities, tasks, and patience, was mentioned often in both the water track course and the energy track course. Other than in the water track case project, where listening and feedback were ranked relatively low, both skills featured as a higher middle segment of the ranks in the energy and environment courses. Perhaps this has to do with the specific sizes of the groups or specific composition of the groups. Finally, it is difficult to compare all three case projects into nitty-gritty details for two reasons. First, the analysis of the skills has not yet been done as extensively for the water track data. Second, it seems that forms have been filled out less diligently in the environment case project. The reasons for this are yet to be established.

#### 4.3 Summative assessments

Summative assessments in the Case Study courses are two-fold: a mid-term and final report. Both the mid-term and final reports follow a typical academic IMRAD structure. The mid-term report is essentially the first draft of the first half of the final report, including introduction, conceptual framework, literature and references, research strategy and methods, and a preview of the analysis, discussion, and possible conclusions. The mid-term report rubric is also typical for a research report assignment, focusing on the quality and academic rigor demonstrated. However, we do include a criterion specifically targeting CBL. Teachers assess student groups' ability to successfully shift between the challenge-based learning mode of work to achieving the academic goals and standards associated

with a Master's level research project. The final report is assessed primarily on the academic quality and rigor, but we encourage student groups to write about their CBL process as part of the methods section and conclusion. In the methods section, the goal is to illustrate the logical steps taken as they moved through the engage-investigate-act phases; in the conclusion, to reflect on the limitations or influential dimensions of CBL and interaction with stakeholders on the research results. Due to the time restraints for the course, the action phase of CBL is sometimes only reached as part of the discussion/conclusion sections in which students make action proposals or plans to address the challenges they researched.

## 5 Discussion

### 5.1 The teacher perspective

In general, teachers were cautiously positive about the implementation of challenge-based learning. They reported that the format motivated students to look at the big picture and had them act more engaged and curious – partly because they were allowed to pick their own challenge. This led to more dynamic, slightly more creative coursework featuring active discussions about learning needs. Executing the course in challenge-based manner resulted in both content and skills learning and raised students' awareness of the complexity of real-life challenges. However, some teachers also reported the difficulty of navigating the thin line between learning for a challenge of a challenge provider and doing contract research for a consultancy client.

Finally, teachers reported a set of six relatively concrete suggestions to take away from the previous experience:

- Decide what role the second and third phase should play, how these should be understood
- Present alternatives of structuring a CBL process right from the start
- Share burden of (pre-)structuring the three phases among teachers and students, not only students responsibility
- Add more explicit role assignment process in the groups
- Use the single-point rubric for presentations and final report
- Reassess the format of the final product and the assessment criteria; encourage more creative forms of products instead of an 'academic' report

### 5.2 Self- and peer assessment

#### 5.2.1 Number of peer assessment sessions

The setup of having three self- and peer assessment sessions might be considered overdoing things in a 10 weeks IOEC course. Scanning the results of all three self- and peer assessment sessions in terms of what students wrote down in their forms, for about half the students the forms looked identical. For the other half some change is reported upon how they reflect upon their 21<sup>st</sup>- century skills. The peer assessment sessions were sometimes lively, though not always. Some sessions helped students considerably, especially in the situation of students seeking for confirmation and actively asked questions to fellow students. In one case, wherein a group of students found it hard to collaborate, the sessions helped students to connect by reflecting upon each other's behaviour, their ways of working and their contributions. In this group opposing ideas upon how to approach the assignment were observed.

Having three self- and peer assessment sessions in a 10 weeks course is a lot, and reducing the number of sessions to two might be closer to optimal.<sup>4</sup> In such a period, it is more about drawing a personal agenda for development of 21<sup>st</sup>-century skills and getting some feedback (and inspiration) by the peers than to expect that significant progress is made by dedicated actions. For coaches, this requires a more conscious development of the facilitation skills required for the peer assessment sessions.

#### 5.2.2 Single-point rubric

Among the teaching team, there has been some discussion about whether the single-point rubric of 21<sup>st</sup>-century skills was optimal. First of all, the forms of the water track students indicated that most learning occurred in the areas of 'critical thinking' and 'communication'. Perhaps, reflecting on

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<sup>4</sup> This has been adapted in the next run of the courses during the academic year 2022/2023.



‘creativity’ and ‘collaboration’ can better be done in another manner, by starting reflecting upon groupwork and progress, and then reflect upon individual roles in the team. This could also be a short self-assessment followed by a group progress meeting.

Nevertheless, the approach we implemented was a good start for the moment. We could consider restructuring the rubric such that the criteria have a better fit with the three phases of CBL.<sup>5</sup> In doing so, CBL and 21<sup>st</sup>-century skills would become intertwined in a reflective scheme for self- and peer assessment of skills to become a change agent in the spirit of UT’s Shaping 2030 mission, vision, and strategy.

### 5.2.3 Filling out reflexion forms

There are two points we want to raise regarding how students filled out the self- and peer assessment forms. First, the depth of reflection as evidenced by student’s writings is a point of attention. Some students report seriously and in a detailed fashion; they diligently self-report and try to take up feedback from their peers. Others seem to copy paste from one to the next form. Similar variations are observable in terms of how students engage during the peer assessment sessions. We have to encourage students to engage actively in their self-assessment and the subsequent peer assessment sessions. If a student engages actively, the process can have beneficial effects on personal development. If a student does not, it immediately feels like a useless thing to be done besides the ‘interesting’ process of elaborating the challenge. Thus, teachers acting as CBL coaches have to positively stimulate students to engage in reflection of their own skills and lead the peer assessment sessions in a constructive and productive manner.

A second point of attention in the way students fill out the forms is the hunch several of the teachers had that students became fatigued while filling out the form. The fact that ‘critical thinking’ and ‘communication’ have been filled out consistently relatively well by students might indicate that they can relate better to those categories. However, it may just as well be the case that they become fatigued of thinking about instances with which they can prove whether they performed below or above expectations on a certain 21<sup>st</sup>-century skill or subskill. This can be tackled by encouraging students to reflect on all four criteria in a balanced way, but perhaps other avenues to deal with this need to be explored. For the analysis of the data in this report, this also means that a next step would be to order the skills within each criterion and see whether not reporting on the criteria lower down on the form is coincidental or a pattern throughout all three courses.

### 5.2.4 21<sup>st</sup>-century skills

Several issues stand out when looking at the peer assessment data. First, in and of itself, the fact that there are skills that are referred to by most students is not necessarily significant, as students may simply state some change (a) without giving relevant examples, or (b) to mention as many skills as possible and feint intensive engagement. However, a more positive reading is that these are ‘low-hanging fruit’ skills that improve quickly once a student is forced to work in a group setting, in general. Across the courses, this holds for confidence in contribution and organising the project well. Another possibility is that the challenge-based learning setting invites improvements in these areas. Across the courses, this holds for the skills systems thinking, open mindedness and flexibility, listening, or working creatively with others. Second, it does not make sense to look at specific students individually. The fact

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<sup>5</sup> NB: “Engage (in which the Learners move from an abstract big idea to a concrete and actionable challenge), Investigate (in which Learners conduct research to create a foundation for actionable and sustainable solutions) and Act (in which evidence-based solutions are developed and implemented with an authentic audience and the results evaluated)” ([www.utwente.nl/en/cbl/what-is-cbl/](http://www.utwente.nl/en/cbl/what-is-cbl/)).

that some refer to many skills and some refer to few can, in principle, relate to the simple fact that people are different and have different perceptions of what they want to work on in terms of personal development. For both issues holds that students need to be coached in a flexible and student-centred way, not prioritising any skills. Which skills to prioritise needs to be decided upon by students themselves. As coaches, teachers can emphasise that authentic engagement is more important than keeping up appearances.<sup>6</sup> Doing the latter would actually be shooting themselves in the foot, as they would spend a lot of time filling out forms without actually developing personally.

### 5.3 Summative assessments

CBL is still only included in a limited way within the summative assessments of the Case Study courses. With CBL, we ask students to be active learners, struggling with diverse perspectives, contexts, and sources of information to understand and intervene in a challenge. Better capturing this CBL process within the summative assessments might include...

- Requiring a specific section within the reports (perhaps in the methods section) to record the learning journey between engagement and investigation phases. This might include previous versions of research questions that have since been modified, key insights/feedback derived from engaging directly with stakeholders that changed the direction of the research, or an explanation of how a systems representation has evolved over time due to the activities in engage and investigate phases.
- Modifying the rubrics of both the mid-term and final reports to specifically assess this “learning journey”

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<sup>6</sup> This is also visible in the fact that the self- and peer assessment process does not contain a summative assessment.

## 6 Conclusions

In this report, we have described and analysed the changes the UT M-EEM programme teaching team has made to the case project courses in quartile 3 of the academic year. The overarching idea was to implement a challenge-based learning approach into the formerly more problem/project based courses. We have shown the new constructive alignment of the courses, including revised learning objectives, the teaching activities and how the learning was assessed. The results of these changes are evidenced with an analysis of participating teacher reflections, the forms submitted by students for the self- and peer assessments, and the impact on summative course assessments that challenge-based learning in the pilot run had.

The most original element from our perspective in our implementation of the CBL approach is an elaborate form of formative assessment of personal development skills exemplified by a set of four criteria of 21<sup>st</sup>-century skills. The guiding questions for this report were, thus,

1. How does challenge-based learning contribute to the development, formulation and execution of profound, original, and integrated sustainability research in a student group setting?
2. How does the use of a combined self- and peer-assessment procedure contribute to formative student learning about their personal development and group participation in a challenge-based learning setting?

Based on the results of our findings, we can conclude that the challenge-based learning approach has definitely had its influence on the outcomes, albeit mixed. Regarding research question 1, it has in the first run been difficult to deviate from a traditional academic research report. Although in academic terms, the reports had their merit, the engagement with stakeholders could have been emphasised more. This is something we have taken up for the current second run of the CBL case project courses. One of the suggestions we make here, is to align the rubrics for the summative assessments better with CBL-type criteria. Regarding research question 2, we found that we might have overshot the mark with the formative self- and peer assessment approach we implemented. Three sessions with preparation and reflexion forms was a little too much. However, students have indicated that the peer assessment sessions have helped them both develop individually and getting closer together in the functioning of the group. Although the variables contributing to how students fill out their forms do not allow for a specific answer, we are fairly confident that our self- and peer assessment procedure has contributed to students personal development.

While we have already mentioned some further improvements of the course setup which we have already implemented, there are a few more recommendations to make, both for further course development, and for analysis of the results. For the execution of peer assessment sessions, it suffices in the time given in one UT quartile to organise two sessions. And it makes sense to provide specific training or guidance for teachers acting as coaches to facilitate this kind of skills-based sessions in a constructive and productive manner. Furthermore, we are considering to adapt the structure of the single-point rubric used for the self- and peer assessments to align more with challenge-based learning skills, instead of containing 21<sup>st</sup>-century skills on a generic level. There is also a need for specific, positive, instructions for students as to how they should fill out their assessment forms, such that students do not get fatigued and engage with all criteria in a similar way. For final reports, the alignment of academic research reports with CBL could entail the addition of a specific 'learning journey' section detailing the navigation through the three CBL phases. In any case, we have just started our journey to implement CBL in the M-EEM case project courses and have plenty of starting points for further refining the M-EEM CBL approach.

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# Appendix

## Appendix I: Progress report and self- and P2P assessment form

>>> **ATTENTION: additions to the procedure added in Red** <<<

### **Progress report and self- and P2P assessment**

#### *MEEM Case project*

An important pillar of challenge-based learning is the ongoing process of feedback and reflection. This does not follow the traditional way of teachers assessing students, but instead focuses on constructive feedback coming as well from fellow students. This is not exclusively targeted at the quality and quantity of the students' work, but mostly at the students' abilities and skills to contribute to the overall case project. Think of social and communication skills, and fulfillment of a specific role within the team, next to more general research skills.

Therefore, in the case project Energy Management the students have to upload three progress reports, including self-assessment forms that are discussed in P2P assessment sessions, throughout the entire quartile<sup>1</sup>. This is for both the supervisor, the teams and the students themselves to monitor the progress they make; in terms of both the course's assignments as well as personal development. These progress reports, including self-assessment forms, are compulsory. They are assessed on a pass/fail basis, however, please note that the overall self- and P2P assessment process will be taken into account to differentiate among students' grades for the final report. If a student actively participated in the process and shows clear progress on personal development or vice versa, this may affect his/her grade.

#### **Progress report**

The first component is the progress report, which is a group effort and thus written in collaboration. There is no fixed format for the progress report, except that it should be limited to one page (A4). Guiding questions to report on the teams' progress are for example:

1. What activities did you perform the past weeks; and how do these relate to the CBL phase(s)?
2. How did it go; did it run smoothly or rather difficult, and why?
3. Are you satisfied with the result and why?
4. What did you learn so far; what will you do the same or differently in the next weeks?
5. What will the next steps look like?

The progress reports will be discussed during the team sessions dedicated to weekly progress. Both the students and teacher play an active role in these sessions.

#### **Self- and P2P assessment**

The second component is the self- and P2P assessment, which is both an individual and group effort. It consists of three components:

1. The students evaluate
  - a. their own performance within the team by filling out and submitting the self-assessment form before the P2P assessment session;
  - b. **what they learned in the previous work period and what they intend to work on to improve/learn in the coming work period; this can be added to the table at the end of the form (p.4).**

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<sup>1</sup> *Deadline first progress report, incl. self- & P2P assessment: Thursday 17 February (23:59); Deadline mid-term progress report, incl. self- & P2P assessment: Thursday 17 March (23:59); Deadline final progress report, incl. self- & P2P assessment: Thursday 20 April (23:59).*

- c. their group members' performance by reflecting on the criteria in the self-assessment form before the P2P assessment session (This does not have to be submitted!!! It's about giving well-founded, constructive feedback to your peers.);
2. The students actively participate in the 45 to 60 minutes session dedicated to P2P assessment, which implies discussing and reflecting on each other's self-assessment to see what needs improvement and/or how work exceeds expectations (the students' self-assessment forms will be shown on screen). During this session the students have the opportunity to adapt their self-assessment form based on the reflections of fellow students;
3. After the P2P assessment session, the students resubmit their revised self-assessment form attached to the team's progress report the same day by 23:59.

The self- and P2P assessment focuses on "21<sup>st</sup> century skills" and particularly on four learning qualities. These are four commonly argued abilities that students need to succeed in their future career, more specifically to adapt and improve in a modern (21<sup>st</sup> century) working environment.<sup>2</sup> The four qualities can be further specified in concrete criteria (see below). The assessment involves a single point rubric, which is a simple format but allows for higher-quality feedback. The students assess themselves by reflecting on whether they perform below expectation or exceed expectations with regards to the four qualities and more specific criteria. Please note that students can perform below expectation and exceed expectations with regard to one quality at the same time, as students may need improvement when it comes to one criterion and be excellent already at another criterion. In practice, this means that for each quality, the form can be filled out on both left (below expectation) and right side (exceeds expectations). Where students perform below expectation, please specify what needs improvement and provide concrete actions on how to address this. Where students exceed expectations, please write notes on how the work exceeds expectations (evidence). During the dedicated P2P assessment sessions, you might receive concrete tips and tops to update or add to your self-assessment form. Please find the self-assessment form below.

**In sum:** the students submit their filled-out self-assessment forms before each P2P assessment session. After the P2P assessment session, the students adapt their self-assessment form and resubmit it, attached to the progress report. Since the progress report is a group effort and the self-assessment form an individual effort, each student of the group must submit the overall report individually. It includes maximum one page for the progress report (written collectively) and remaining pages for the self-assessment (written individually complemented by reflections of fellow students).

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<sup>2</sup> If you want to know more about this, see for example Rotherham & Willingham (2010) "[21<sup>st</sup>-Century" skills – Not new, but a worthy challenge](#)"; or read this blog [What Are 21st Century Skills? \(aeseducation.com\)](#).

<b>Quality</b>	<b>Below expectations</b> <i>Notes on what needs improvement</i>	<b>Criteria</b> <i>Standard indicators for this performance</i>	<b>Exceeds expectations</b> <i>Notes on how the work exceeds the standard</i>
<i>Critical thinking</i>		Is able to discover, interpret and analyze information; sufficiently reasons and constructs arguments; is capable to look at the bigger picture and finer details at the same time; applies a holistic view and systems thinking.	
<i>Communication</i>		Is able to make him/herself understood in clear and unambiguous fashion; listens attentively to others' concerns with consideration; is able to present ideas in a variety of formats; engages actively in discussions and brainstorming; expresses concerns in a coherent and appropriate manner; offers and takes feedback constructively.	
<i>Creativity</i>		Is keen and eager to provide input; asks relevant questions and makes connections between ideas; has courage to explore; works creatively with others, synergizing for maximum impact; is able to solve complex problems and finds interesting ways to approach tasks.	
<i>Collaboration</i>		Takes initiative and finds way to make the project run better; keen to take on new responsibilities or tasks; actively helps team members; actively shares knowledge and progress; has an open mind and is flexible to adjusting to others; makes fair contributions; steers activity according to the agreed course of action.	

**Learning**

Looking back:  
what did you learn/improve?

Looking forward:  
what do you want to  
learn/improve?



## Appendix II: Questions teacher reflections

- Course elements:
  - How well would you say the various elements of the course (e.g. introduction to CBL, peer review sessions, CBL phases, assessment) worked in your course?
- Difficulties:
  - Which difficulties did you encounter in the implementation of challenge-based learning in the M-EEM case study?
  - Where did those difficulties come from in your opinion?
- Overall:
  - What is your overall experience with introducing (or strengthening) challenge-based learning in the M-EEM case study?
  - How, from your perspective, were the outcomes of the course influenced by the challenge-based structure we/you applied?

## Appendix III: Data table water track

Quality	<b>Below expectations</b> <i>Notes on what needs improvement</i>	<b>Criteria</b> <i>Standard indicators for this performance</i>	<b>Exceeds expectations</b> <i>Notes on how the work exceeds the standard</i>
<i>Critical thinking</i>	(s1) system thinking, processing abundant information (get distracted easily) (s2) system thinking (improved over time), overload goes on account of concentration; at the end still issues with finer details (s3) formulating arguments based on information. (s4) Looking at cases and data without connecting 'to big picture' (improved over time) (s5) Looking at the big picture and details at the same time, getting lost in not crucial details. (s6) Analytical thinking and constructing arguments (s7). Data analysis (statistical), exploring the big picture	<ul style="list-style-type: none"> <li>• Is able to discover, interpret and analyze information;</li> <li>• Sufficiently reasons and constructs arguments;</li> <li>• Is capable to look at the bigger picture and finer details at the same time;</li> <li>• Applies a holistic view and systems thinking.</li> </ul>	(s1) if I have time I can analyze the information round 1, in round 3 acknowledging the time is restricting. (s2) able to construct arguments, if abundant time. (s3) able to connect big picture to steps and details. (s4) Able to connect dots. (s5) Able to deal with information and deriving reasoning from it. (s6) Big picture and small details connections, interpreting information. (s7) Data gathering/scraping, reviewing cases
<i>Communication</i>	(s1) presenting thoughts in a clear manner, prefer to be silent and listen (got the feeling I confuse people), reacting too late. (s2) Problem with concentration and focus in meetings. (s3) Should be more patient listening to others (s4) Struggling technical side of communication, contributing to work supervised by others. (s5) Verbal communication, too ambiguous and sometimes repeating, writings sometimes also overly complex and too detailed. (s6) Clear presentation of my ideas (s7) Academic writing and data presentation skills, too critical annoying verbal inputs, too lengthy, too complex, not flexible.	<ul style="list-style-type: none"> <li>• Is able to make him/herself understood in clear and unambiguous fashion;</li> <li>• Listens attentively to others' concerns with consideration;</li> <li>• Is able to present ideas in a variety of formats;</li> <li>• Engages actively in discussions and brainstorm;</li> <li>• Expresses concerns in a coherent and appropriate manner;</li> <li>• Offers and takes feedback constructively.</li> </ul>	(s1) Open to feedback, learned (round 3) to react earlier and more frequent in meetings, feedback learned to relate inputs to themes on the agenda. (s2) Clear communications and contributions to meetings (learned , round 3, able to think along with peers). (s3) presenting my ideas, taking others input seriously (learned, round 3, to take feedback serious and communicating less direct, efficient, dealing with cultural differences, related to feedback from others) (s4) able to talk about concerns is a straightforward positive manner (round3 learned to deal with technical side of communication by taking longer for discussions, follow up upon feedback peers) . (s5) able to engage in discussions more actively(learned by peers feedback to be more self-confident). (s6) Listening to others, dealing with concerns, feedback (giving an taking) (s7) summarizing, innovative presentation style, some understanding of professional communication and

Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
			presentation techniques (learned to become better listener, more open for feedback).
Creativity	<p>(s1) Sometimes too detailed thinking and get locked, sometimes too easily to the next topic.</p> <p>(s2) It is hard to be creative at the beginning. I get stuck taking the first step.</p> <p>(s3) If something is not logic to me right away, I have the tendency to shut it down, too efficiency driven to explore possible dead ends.</p> <p>(s4) Find myself wanting to get to action points rather than looking at the different options, find that discussions on different sides of the topic to be a waste of time, which it isn't necessarily.</p> <p>(s5) Connections between ideas are still sometimes vague, taking care of the feasibility of ideas/solutions.</p> <p>(s6) Need to improve on providing diverse ways to approach tasks.</p> <p>(s7) Being over-ambitious may undermine little creativity to be appreciated, need to make things easy and smooth.</p>	<ul style="list-style-type: none"> <li>• Is keen and eager to provide input;</li> <li>• Asks relevant questions and makes connections between ideas;</li> <li>• Has courage to explore; works creatively with others, synergizing for maximum impact;</li> <li>• Is able to solve complex problems and finds interesting ways to approach tasks.</li> </ul>	<p>(s1) Flexible connecting to team mates ideas and thinking, good in finding related sources of information.</p> <p>(s2) Can think creatively very easily once the problem has been laid out and there is a base where to build upon. .</p> <p>(s3) Able to "mind map " projects, which allows me to make connections, which sometimes result in creative solutions which solve multiple problems.</p> <p>(s4) Able to ask relevant question about cases / how we can analyze them in different ways.</p> <p>(s5) Eager to provide input, able to work with others and synergize, come up with solutions.</p> <p>(s6) Eager to provide input and work creatively with others, synergizing for maximum impact. I ask relevant questions.</p> <p>(s7) Good in learning and connecting ideas – how to apply theories to the context. Good in exploring and shaping a new way of thinking and to adjust to changes.</p>

<b>Quality</b>	<b>Below expectations</b> <i>Notes on what needs improvement</i>	<b>Criteria</b> <i>Standard indicators for this performance</i>	<b>Exceeds expectations</b> <i>Notes on how the work exceeds the standard</i>
<i>Collaboration</i>	<p>(s1) n.a.</p> <p>(s2) Have a problem with organization and time management, and sometimes I want to make one part of the job just alone because I feel like no one else will be able to do it as I expect.</p> <p>(s3) Getting really frustrated if something other team members say makes no sense to me, should give an Idea more time when considering it before disregarding it.</p> <p>(s4) Being emphatic to how team members are doing individually.</p> <p>(s5) Problems with keeping track on progress and time management. Should take more care about task management, learn to share the work and provide results in time.</p> <p>(s6) Sometimes scared of taking on new tasks especially one that could affect initial schedules.</p> <p>(s7) Have to work on improving my collaboration skills by helping others and making progress, though the group believes that I am good in collaborations.</p>	<ul style="list-style-type: none"> <li>• Takes initiative and finds way to make the project run better;</li> <li>• Keen to take on new responsibilities or tasks;</li> <li>• Actively helps team members;</li> <li>• Actively shares knowledge and progress;</li> <li>• Has an open mind and is flexible to adjusting to others;</li> <li>• Makes fair contributions;</li> <li>• Steers activity according to the agreed course of action.</li> </ul>	<p>(s1) Being open about others' suggestions though considering different perspectives on the issue and not just accept one version.</p> <p>(s2) Been more on time for the online meetings, and dedicated steady time to work on it. I am always willing to help my teammate.</p> <p>(s3) Have the tendency to become the project manager. Therefore, I enjoy taking over tasks which are not content related. This is especially useful when sticking to deadlines.</p> <p>(s4) Keeping deadlines and action points in mind for my groups and peers, process management. feeling better in participating, and staying focused on actions where required.</p> <p>(s5) Not afraid of taking on new tasks. Open mind to adjust ideas to fit with others.</p> <p>(s6) Good at actively helping my team members and flexible to adjust to others with an open mind. I work well in teams"</p> <p>(s7) Learned well to be flexible, take responsibilities, and steer technical issues.</p>

Appendix IV: Data table environment track

Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
<i>Critical thinking</i>	(s1) reasoning and arguing; systems thinking (s2) n/a (no form) (s3) too critical (s4) n/a (self-reported) (s5) too critical (s6) n/a (self-reported) (s7) looking at finer details (s8) n/a (self-reported) (s9) n/a (self-reported) (s10) discovering information (s11) n/a (no form) (s12) discovering information	<ul style="list-style-type: none"> <li>• Is able to discover, interpret and analyze information;</li> <li>• Sufficiently reasons and constructs arguments;</li> <li>• Is capable to look at the bigger picture and finer details at the same time;</li> <li>• Applies a holistic view and systems thinking.</li> </ul>	(s1) n/a (self-reported) (s2) n/a (no form) (s3) systems thinking (s4) unclear (s5) interpret/analyse information (s6) systems thinking (s7) interpret/analyse information (s8) systems thinking; processing new information (s9) interpret/analyse information (s10) systems thinking; processing new information (s11) n/a (no form) (s12) systems thinking
<i>Communication</i>	(s1) making themselves understood (s2) n/a (no form) (s3) n/a (self-reported) (s4) contribution to discussion (s5) contribution to discussion (s6) making themselves understood (s7) making themselves understood (s8) n/a (self-reported) (s9) n/a (self-reported) (s10) making themselves understood (s11) n/a (no form) (s12) listening	<ul style="list-style-type: none"> <li>• Is able to make him/herself understood in clear and unambiguous fashion;</li> <li>• Listens attentively to others' concerns with consideration;</li> <li>• Is able to present ideas in a variety of formats;</li> <li>• Engages actively in discussions and brainstorming;</li> <li>• Expresses concerns in a coherent and appropriate manner;</li> <li>• Offers and takes feedback constructively.</li> </ul>	(s1) listening (s2) n/a (no form) (s3) receiving feedback; contribution to discussion (s4) giving and receiving feedback; presenting (s5) giving and receiving feedback; making themselves understood (s6) n/a (self-reported) (s7) contribution to discussion (s8) listening; contribution to discussion; giving and receiving feedback; expressing concerns (s9) listening; contribution to discussion (s10) listening; giving and receiving feedback; expressing concerns (s11) n/a (no form) (s12) contribution to discussion

Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
<i>Creativity</i>	(s1) synergising for maximum impact (s2) n/a (no form) (s3) n/a (self-reported) (s4) eager to contribute (s5) unclear (s6) n/a (self-reported) (s7) courage to explore (s8) n/a (self-reported) (s9) n/a (self-reported) (s10) unclear (s11) n/a (no form) (s12) n/a (self-reported)	<ul style="list-style-type: none"> <li>• Is keen and eager to provide input;</li> <li>• Asks relevant questions and makes connections between ideas;</li> <li>• Has courage to explore; works creatively with others, synergizing for maximum impact;</li> <li>• Is able to solve complex problems and finds interesting ways to approach tasks.</li> </ul>	(s1) working creatively (s2) n/a (no form) (s3) eager to contribute (s4) find interesting ways to approach tasks (s5) working creatively (s6) working creatively (s7) working creatively (s8) eager to provide input; asking relevant questions connecting ideas (s9) asks relevant questions and makes connections between ideas (s10) keen and eager to provide input; asks relevant questions and makes connections between ideas; has courage to explore; works creatively with others, synergizing for maximum impact (s11) n/a (no form) (s12) find interesting ways to approach tasks
<i>Collaboration</i>	(s1) take initiative; actively helping team members; taking on new responsibilities (s2) n/a (no form) (s3) n/a (self-reported) (s4) n/a (self-reported) (s5) actively shares knowledge and progress (s6) n/a (self-reported) (s7) make fair contribution (s8) keen on taking on new responsibilities; take initiative (s9) make fair contribution; take initiative (s10) n/a (self-reported) (s11) n/a (no form) (s12) unclear	<ul style="list-style-type: none"> <li>• Takes initiative and finds way to make the project run better;</li> <li>• Keen to take on new responsibilities or tasks;</li> <li>• Actively helps team members;</li> <li>• Actively shares knowledge and progress;</li> <li>• Has an open mind and is flexible to adjusting to others;</li> <li>• Makes fair contributions;</li> <li>• Steers activity according to the agreed course of action.</li> </ul>	(s1) n/a (self-reported) (s2) n/a (no form) (s3) taking on new responsibilities; actively shares knowledge and progress (s4) take initiative and find ways to make project run better; makes fair contribution; steers activity according to agreed course of action (s5) Takes initiative and finds way to make the project run better; Steers activity according to the agreed course of action; Actively shares knowledge and progress; Makes fair contributions (s6) unclear (s7) collaborative in general (s8) Takes initiative and finds way to make the project run better; Keen to take on new responsibilities or tasks; Actively helps team members; Actively shares knowledge and progress (s9) Takes initiative and finds way to make the project run better; Steers activity according to the agreed

<b>Quality</b>	<b>Below expectations</b> <i>Notes on what needs improvement</i>	<b>Criteria</b> <i>Standard indicators for this performance</i>	<b>Exceeds expectations</b> <i>Notes on how the work exceeds the standard</i>
			<p>course of action; Actively shares knowledge and progress; make fair contributions</p> <p>(s10) Takes initiative and finds way to make the project run better; Keen to take on new responsibilities or tasks; Actively helps team members; Actively shares knowledge and progress; Has an open mind and is flexible to adjusting to others; Makes fair contributions; Steers activity according to the agreed course of action</p> <p>(s11) n/a (no form)</p> <p>(s12) Actively shares knowledge and progress; Takes initiative and finds way to make the project run better; Actively helps team members; Makes fair contributions</p>

## Appendix V: Data table energy track

Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
<i>Critical thinking</i>	(s1) difficult to be open-minded, mind set on own perception/opinion (s2) system thinking; distinguish main from side issues; data analysis (s3) agreeing on common scope; getting from theory to practice (s4) uncritical (s5) perfectionism; low confidence about own contribution; detail-oriented (s6) impatience; need an overview before being confident about contribution (s7) processing new information; uncritical (s8) finding information; writing structure (s9) insecurity about contribution; content integration (s10) detail-oriented; distinguish main from side issues (s11) n/a (no form) (s12) writing; looking at details (s13) Breaking out of argumentation deadlock (s14) looking at details; rather quickly satisfied (s15) systems thinking; processing new information (s16) distinguish main from side issues	<ul style="list-style-type: none"> <li>• Is able to discover, interpret and analyze information;</li> <li>• Sufficiently reasons and constructs arguments;</li> <li>• Is capable to look at the bigger picture and finer details at the same time;</li> </ul> Applies a holistic view and systems thinking.	(s1) systems thinking with attention for details; processing new information (s2) n/a (self-reported) (s3) processing new information; writing structure (s4) processing new information; data analysis (s5) logical thinking (s6) Easily get overview (s7) developed critical information processing (s8) systems thinking with attention for details; can handle criticism (s9) processing new information; systems thinking (s10) systems thinking; data analysis (s11) n/a (no form) (s12) systems thinking; overview (s13) agreeing on common scope (s14) systems thinking; processing new information (s15) detail-orientation; systematic work process; developed systems thinking (s16) agreeing on common scope; data analysis
<i>Communication</i>	(s1) presenting; giving feedback (s2) express thoughts coherently (s3) express thoughts coherently; give others space in discussions (s4) receiving feedback; express thoughts coherently (s5) presenting	<ul style="list-style-type: none"> <li>• Is able to make him/herself understood in clear and unambiguous fashion;</li> <li>• Listens attentively to others' concerns with consideration;</li> <li>• Is able to present ideas in a variety of formats;</li> <li>• Engages actively in discussions and brainstorming;</li> <li>• Expresses concerns in a coherent and appropriate manner;</li> <li>• Offers and takes feedback constructively.</li> </ul>	(s1) receiving feedback; active involvement in discussion (s2) receiving feedback; open mindedness; organizational skills (s3) Listening (s4) active participation (s5) giving and receiving feedback (s6) developed making themselves understood



Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
Creativity	(s6) making themselves understood; express thoughts appropriately (s7) giving feedback; active participation (s8) express thoughts appropriately (s9) making themselves understood in writing and presenting (s10) assumptions about others' perspective ( <i>listening?</i> ); communicating diversely under pressure (s11) n/a (no form) (s12) listening; asking for help (s13) making themselves understood (s14) express thoughts coherently (s15) active participation; doubts about contribution; organizational skills (s16) making themselves understood		(s7) developed giving feedback; listening (s8) Listening; receiving feedback; writing (s9) Listening (s10) making themselves understood (s11) n/a (no form) (s12) eager to contribute; developed receiving feedback (s13) speak up (s14) giving and receiving feedback; active participation; (s15) listening; expressing thoughts (s16) active participation
	(s1) problem solving in difficult challenges (s2) courage to explore; systematic work process (s3) courage to explore; finding interesting ways to approach tasks (s4) connecting ideas; problem solving (s5) asking relevant questions (s6) n/a (no form) (s7) courage to explore (s8) knowing when to stop ideating (s9) n/a (self-reported) (s10) connecting ideas (s11) n/a (no form) (s12) asking relevant questions; finding interesting ways to approach tasks (s13) asking relevant questions (s14) n/a (self-reported) (s15) courage to explore	<ul style="list-style-type: none"> <li>• Is keen and eager to provide input;</li> <li>• Asks relevant questions and makes connections between ideas;</li> <li>• Has courage to explore; works creatively with others, synergizing for maximum impact;</li> <li>• Is able to solve complex problems and finds interesting ways to approach tasks.</li> </ul>	(s1) Eagerness to help; general problem solving (s2) working creatively (s3) synergizing for maximum impact (s4) eagerness to help (s5) eagerness to provide input (s6) asking relevant questions (s7) developed courage to explore (s8) eagerness to provide input; courage to explore; connecting ideas (s9) eager to provide input; finding interesting ways to approach tasks (s10) working creatively; open mindedness (s11) n/a (no form) (s12) working creatively (s13) eagerness to provide input

Quality	Below expectations <i>Notes on what needs improvement</i>	Criteria <i>Standard indicators for this performance</i>	Exceeds expectations <i>Notes on how the work exceeds the standard</i>
Collaboration	(s16) general doubts about contribution		(s14) courage to explore; synergise for maximum impact; connecting ideas; asking relevant questions (s15) problem solving; asking relevant questions; eagerness to provide input; connecting ideas (s16) n/a (self-reported)
	(s1) taking initiative when busy (s2) time management (s3) flexible (s4) finding ways to make the project run better; time management (s5) n/a (self-reported) (s6) taking initiative; open minded (s7) taking on new tasks (s8) finding ways to make the project run better; time management (s9) actively shares knowledge and progress (s10) take initiative; keen on taking new responsibilities (s11) make fair contribution (s12) actively help team members; steers activity according to the agreed course of action; time management; finding ways to make the project run better (s13) make fair contributions (s14) n/a (self-reported) (s15) asking for help; (s16) n/a (self-reported)	<ul style="list-style-type: none"> <li>• Takes initiative and finds way to make the project run better;</li> <li>• Keen to take on new responsibilities or tasks;</li> <li>• Actively helps team members;</li> <li>• Actively shares knowledge and progress;</li> <li>• Has an open mind and is flexible to adjusting to others;</li> <li>• Makes fair contributions;</li> <li>• Steers activity according to the agreed course of action.</li> </ul>	(s1) Take initiative; flexible; keen on taking on new responsibilities; actively sharing knowledge and progress (s2) open-minded; listening; comply with agreed course of action; flexible; actively helps team members (s3) take initiative; finding ways to make the project run better (s4) actively help team members; actively share knowledge and progress; finding ways to make the project run better; keen to take on new tasks; flexible (s5) finding ways to make the project run better; flexible (s6) actively help team members (s7) actively shares knowledge and progress; open mind (s8) make fair contributions (s9) make fair contributions; actively shares knowledge and progress; taking initiative (s10) open minded; finding ways to make the project run better; make fair contribution; actively helps team members (s11) take initiative; steer activity according to the agreed course of action

<b>Quality</b>	<b>Below expectations</b> <i>Notes on what needs improvement</i>	<b>Criteria</b> <i>Standard indicators for this performance</i>	<b>Exceeds expectations</b> <i>Notes on how the work exceeds the standard</i>
			(s12) open minded; flexible; actively helps team members; time management (s13) actively helps team members (s14) open minded; flexible; keen on taking responsibilities; finding ways to make the project run better (s15) flexible; finding ways to make the project run better; actively shares knowledge and progress; make fair contributions (s16) finding ways to make the project run better

Appendix VI: Frequency table water track

<b>Skills mentioned</b>	<b>Wat-S5</b>	<b>Wat-S7</b>	<b>Wat-S2</b>	<b>Wat-S3</b>	<b>Wat-S4</b>	<b>Wat-S6</b>	<b>Wat-S1</b>	<i>Total</i>
<i>Time management (individual and group influence)</i>	x		x	x				3
<i>Systems thinking</i>		x	x			x		3
<i>Collaboration (confidence about peer and own contribution)</i>		x			x	x		3
<i>Open mindedness (e.g. culture, perspectives)</i>				x	x	x		3
<i>Flexibility (e.g. responsibility, tasks, patience)</i>	x	x		x				3
<i>Writing</i>				x		x	x	3
<i>Speak up</i>	x						x	2
<i>Letting go of perfectionism (e.g. wanting to do everything, pressure to know everything)</i>			x		x			2
<i>Organisational skills and creativity</i>			x					1
<i>Systematic work process</i>					x			1
<i>Take initiative</i>	x							1
<i>Focus on main issues and not get lost in side issues</i>	x							1
<i>Listening</i>		x						1
<i>Feedback (asking and giving)</i>		x						1
<i>Total</i>	5	5	4	4	4	4	2	

Appendix VII: Frequency table environment track

Skills mentioned	Env-S8	Env-S10	Env-S5	Env-S12	Env-S1	Env-S4	Env-S9	Env-S7	Env-S3	Env-S6	Env-S11	Env-S2	Total
<i>Contribution (confidence about peers and own; participating in discussions)</i>	x	x	x	x		x	x	x	x				8
<i>Systems thinking</i>	x			x	x			x	x	x	x		7
<i>Take initiative and finds way to make the project run better</i>	x	x	x	x	x	x	x						7
<i>Actively share knowledge and progress</i>	x	x	x	x			x		x				6
<i>Make fair contributions</i>		x	x	x		x	x	x					6
<i>Expressing thoughts (coherence, appropriateness, concerns)</i>	x		x		x	x		x		x			6
<i>Working creatively with others, synergizing for maximum impact</i>		x	x		x			x		x			5
<i>Processing new information</i>	x		x	x				x			x		5
<i>Listening</i>	x			x	x		x						4
<i>Feedback (receiving and giving)</i>	x		x			x			x				4
<i>Keen to take on new responsibilities or tasks</i>	x	x			x				x				4
<i>Actively help team members</i>	x	x		x	x								4
<i>Steer activity according to the agreed course of action</i>		x	x			x	x						4
<i>Eagerness to help/provide input</i>	x	x							x				3
<i>Asks relevant questions and makes connections between ideas</i>	x	x					x						3
<i>21Data analysis</i>	x						x						2
<i>Courage to explore</i>		x						x					2
<i>Finding interesting ways to approach tasks</i>				x		x							2
<i>Being open minded (e.g. culture, perspective, criticism) and flexible (e.g. responsibility, tasks, patience)</i>		x											1

<b>Skills mentioned</b>	<b>Env-S8</b>	<b>Env-S10</b>	<b>Env-S5</b>	<b>Env-S12</b>	<b>Env-S1</b>	<b>Env-S4</b>	<b>Env-S9</b>	<b>Env-S7</b>	<b>Env-S3</b>	<b>Env-S6</b>	<b>Env-S11</b>	<b>Env-S2</b>	<b>Total</b>
<i>Presenting</i>						x							1
<i>Argumentation</i>					x								1
<i>Time management (individual and group influence)</i>													0
<i>Speak up</i>													0
<i>Writing</i>													0
<i>Letting go of perfectionism (e.g. wanting to do everything, pressure to know everything)</i>													0
<i>Organisational skills and creativity</i>													0
<i>Systematic work process</i>													0
<i>Distinguish main from side issues</i>													0
<i>Agreeing on a common scope</i>													0
<i>Rather quick satisfaction</i>													0
<i>Asking for help</i>													0
<i>Problem solving</i>													0
<i>Knowing when to stop ideating</i>													0
<b>Total</b>	13	12	9	9	8	8	8	7	6	3	2	0	

Appendix VIII: Frequency table energy track

Skills mentioned	Ene-S15	Ene-S4	Ene-S12	Ene-S8	Ene-S2	Ene-S10	Ene-S3	Ene-S9	Ene-S14	Ene-S1	Ene-S5	Ene-S13	Ene-S6	Ene-S16	Ene-S7	Ene-S11	Total
<i>Take initiative and finds way to make the project run better</i>	x	x	x	x		x	x	x	x	x	x		x	x	x	x	14
<i>Expressing thoughts (coherence, appropriateness)</i>	x	x		x	x	x	x	x	x			x	x	x			11
<i>Being open minded (e.g. culture, perspective, criticism) and flexible (e.g. responsibility, tasks, patience)</i>	x	x	x	x	x	x	x		x	x	x		x				11
<i>Systems thinking</i>	x		x	x	x	x		x	x	x	x		x				10
<i>Contribution (confidence about peers and own; participating in discussions)</i>	x	x	x				x	x	x	x	x		x	x			10
<i>Asks relevant questions and makes connections between ideas</i>	x	x	x	x		x			x		x	x	x				9
<i>Listening</i>	x		x	x	x	x	x	x							x		8
<i>Processing new information</i>	x	x		x			x	x	x	x					x		8
<i>Feedback (receiving and giving)</i>		x	x	x					x	x	x				x		7
<i>Eagerness to help/provide input</i>	x	x		x				x		x	x	x					7
<i>Courage to explore</i>	x			x	x		x		x						x		6
<i>Make fair contributions</i>	x			x		x		x				x				x	6
<i>Actively help team members</i>		x	x		x	x						x	x				6
<i>Working creatively with others, synergizing for maximum impact</i>			x		x	x	x		x								5
<i>Time management (individual and group influence)</i>		x	x	x	x		x										5
<i>Writing</i>			x	x			x	x									4
<i>Keen to take on new responsibilities or tasks</i>		x				x			x	x							4
<i>Actively share knowledge and progress</i>	x	x						x		x							4
<i>Steer activity according to the agreed course of action</i>			x		x											x	3

Skills mentioned	Ene-S15	Ene-S4	Ene-S12	Ene-S8	Ene-S2	Ene-S10	Ene-S3	Ene-S9	Ene-S14	Ene-S1	Ene-S5	Ene-S13	Ene-S6	Ene-S16	Ene-S7	Ene-S11	Total
<i>Data analysis</i>		x			x	x								x			4
<i>Distinguish main from side issues</i>					x	x								x			3
<i>Agreeing on a common scope</i>							x					x		x			3
<i>Argumentation</i>						x					x	X					3
<i>Problem solving</i>	x	x								x							3
<i>Finding interesting ways to approach tasks</i>			x				x	x									3
<i>Presenting</i>								x		x	x						3
<i>Asking for help</i>	x		x														2
<i>Organisational skills and creativity</i>	x				x												2
<i>Systematic work process</i>	x				x												2
<i>Knowing when to stop ideating</i>				x													1
<i>Letting go of perfectionism (e.g. wanting to do everything, pressure to know everything)</i>											x						1
<i>Rather quick satisfaction</i>									x								1
<i>Speak up</i>												x					1
<i>Total</i>	16	14	14	14	13	13	12	12	12	11	10	8	7	6	5	3	