Teaching sustainability through group work: A six-week guided research project on life cycles

Rebecca K. Pittkowski

Department of Chemistry
University of Copenhagen

Introduction

Sustainability is a focus when developing new higher education (Žalėnienė & Pereira, 2021). The UN's sustainability development goals are, e.g., used to map sustainability-related courses at the University of Copenhagen. Addressing the complex and interconnected global climate challenges requires new knowledge and skill sets. Therefore, the European Commission has developed a European Sustainability Competence Framework, GreenComp, to foster competence-based sustainability education (Bianchi, G. et al., 2022). The competence area “embracing complexity in sustainability” aims to develop systemic and critical thinking skills, encouraging students to assess information, reflect on challenges, and identify connections within and between systems.

Circular economy and *life cycle thinking* (LCT) are key concepts for understanding sustainability complexities. LCT is increasingly implemented in higher education to train students in analyzing complex sustainability challenges (Viere et al., 2021). *Life cycle assessment* (LCA) quantifies environmental aspects of products and services across the value chain. LCA is implemented in various higher education programs, especially in engineering degrees.(Mälkki & Alanne, 2017; Viere et al., 2021) Effective pedagogical approaches to develop systems thinking and problem-framing skills include active learning, student-centered, and problem-based learning. (Bianchi, G et al., 2022).

LCT is often taught through research and project-based learning, allowing students to conduct life-cycle analysis. (Mälkki & Alanne, 2017; Viere et al., 2021). Integrating LCT in project-based engineering education at KU Leuven helped students reflect on helped students reflect on environmental trade-offs and system interconnections. (Reich & Vermeyen, 2025)

Motivation and aim

GreenEnergy: Chemistry in the Green Energy Transition is a new elective bachelor course for chemistry and nanoscience (2024/2025). The course aims to integrate LCA to teach sustainability complexities, helping students to reflect on the interconnectivity of material flows and technologies. A guided six-week group project was developed for the students to research and assess the life cycle of a chosen chemical/product. The aim was to introduce research-based group work in chemistry bachelor education, which is largely skill and knowledge-focused, often focusing on teacher-centered pedagogical practices. (Stains et al., 2018) Essential collaborative skills such as effective communication and teamwork can be trained through group work. A teacher-guided, structured project process was developed, to reduce negative perceptions associated with group work. (J. Knox et al., 2019; Logan et al., 2015).

Methods & project organization

The LCA group project ran for six weeks. The students worked independently on the research in weeks 1-5, followed by a poster presentation in week 6. A teacher-guided session introduced each week's theme, and groups were requested to hand in deliverables at the end of each week, to structure the project as shown in **Fig. 1**.

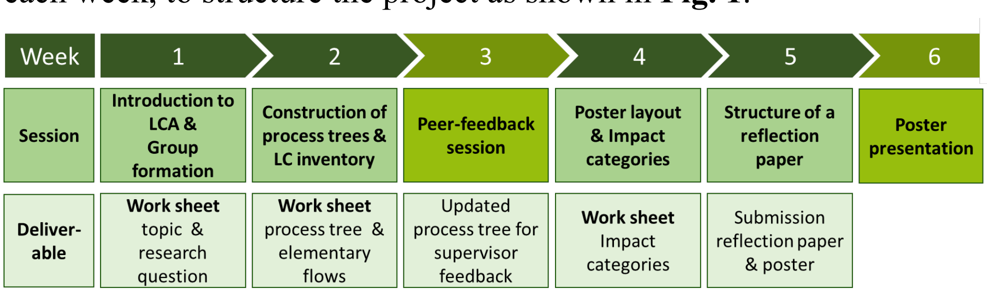

Fig. 1. Flow chart of the LCA project sessions and weekly deliverables.

Deliverables included short worksheets to reflect on the research questions, project progress, and division of work. Students were asked to provide feedback in weeks 3 and 6 (highlighted in **Fig. 1**.), after the peer-feedback session and the final poster presentation, through online questionnaires and oral discussions. The class was very diverse: 13 students (7 bachelor, 6 master) participated from different educational backgrounds (chemistry, nanoscience, physics, and exchange programs) with a high degree (40%) of international students. Feedback was collected from 6 students mid-term and 11 at the end. The collected feedback is analyzed and discussed in the results.

Results & Discussion

Group formation

In the project introduction (week 1), different chemical classes were defined for the LCAs. At the end of the session, students ranked 3 preferred chemicals classes. Based on these preferences and educational background, students were divided into 4 groups of 3-4 students, mixing bachelor/master, Danish/international, and students from different programs to create diverse groups. It was communicated to the students that group formation was based on interests and the heterogeneous class. The mid-term feedback showed that 5/6 students found the group formation was clear or very clear. One student commented:

> “It was REALLY nice the way the groups were formed ... I just wrote down the topics and it was taken care of, and we could easily find a common topic. “

Only one student found the group work challenging. Based on the positive responses, guided group formation seems effective in taking the pressure of creating groups of students and helps to limit the frustration often associated with group work. In this way, it was possible to form very heterogeneous groups that worked well together.

Peer feedback session

In week 3, the groups presented process trees of their chosen chemicals as a key poster component. The peer feedback session aimed to let the students assess the project's progress and exchange improvement ideas. The mid-term feedback indicated that all students found the peer feedback session useful or very useful. However, one student suggested a review of the preliminary poster designs. Based on this, moving the peer feedback session to later in the course might be an idea.

Final product

Students submitted posters for printing with a 2-5 page reflection paper in week 5. The students were very positive about posters as a presentation format. Only one student would have preferred a group presentation, and none would have liked a longer report (pie chart **Fig.2**). Eight students found the poster helpful for structuring their analysis, while three disagreed. In the reflection paper, the students could comment on challenges in their analysis, and add supplementary information. Most students found the reflection paper useful for adding information that lacked space on the poster and helped them reflect on the project. Some students suggested earlier guidance on poster and paper design (discussed in weeks 4/5, see Fig 1). The posters clearly showed that the students updated their process trees based on the comments from the peer feedback.

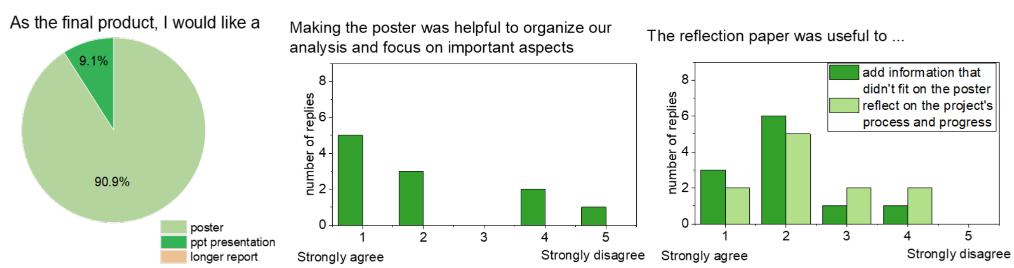

Fig. 2. Final feedback related to the products (poster and reflection paper).

General feedback on the guided project process

Overall, the students were very positive about the project. One noted:

> "I really enjoyed the poster project, I really developed my skills and my knowledge of my specific research area. It was nice for it not to be graded and really interesting to learn about other people's projects especially when they were so varied. Maybe some more specific criteria would be useful to get us going in the right direction but overall loved it and would recommend keeping it in the programme for next year."

To evaluate the effectiveness of the guided project process, students were asked to review the project sessions in both mid-term and final feedback

(Fig 3). Most students found the weekly guidance useful in organizing the group work. One student remarked that larger goals in the middle would have been helpful. Several students mentioned that the fact that the project was not graded led to larger flexibility, reduced stress, and enabled creativity. The students strongly agreed that they learned about the complexity of life cycles and that they gained new insights and perspectives through the open research project.

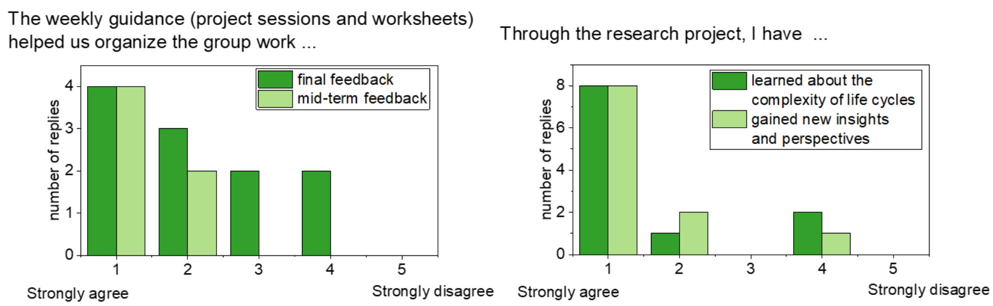

Fig. 3. Final feedback related to project structure and learning objectives.

Conclusions

The project successfully integrated an open group research component into a chemistry bachelor course. Students performed impressive analyses in six weeks, learning about chemical life cycles and enhancing research skills. The students learned about the complexity of life cycles for sustainability and developed research and analysis skills. However, the success might be linked to the high number of master students taking the course, which should be considered in future course iterations. The guided structure and emphasis on collaboration helped mitigate common challenges associated with group work. Students found posters an engaging format that they were keen to explore and earn hands-on experience with. To improve the project, some deadlines might need to be shifted for a more balanced workload, and there will be a stronger focus on literature research and critical source evaluation. This will be essential when more bachelor students participate in the course. Overall, the project demonstrated that open-ended, research-based learning can be successfully implemented in chemistry education. It can be used to develop competences related to the complexity of sustainability and foster both technical and collaborative skills among students.

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