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The Student's Environmental Footprint: A pilot experience of research-based learning in higher education

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Abstract

A pilot project has been designed and implemented in a Master's degree course in engineering, using Research-based learning methodology and grounded in the Life Cycle Assessment framework. The aim was to develop sustainability skills by applying a scientific-technical methodology to the daily habits of the students in order to determine their environmental footprint and subsequently propose measures to reduce their environmental impact.

Experience has shown that student engagement has been high. While analysing their individual impact, students also understand how life cycle assessment provides valuable information to assess a product or process. Finally, they see how aggregate changes in individual behaviour can have a significant collective impact.

Keywords: *Life Cycle Assessment; sustainability; green skills; research-based learning; environmental footprint; SDGs.*

1. Introduction

The concept of sustainability is becoming increasingly important in universities around the world; the importance of different international agreements such as the United Nations Agenda 2030 or the Paris Agreement (United Nations Climate Change Conference) both signed in 2015, have highlighted the need for a change in the economic and social system in all regions of the world.

University, as a place of learning, reflection and acquisition of professional competences for students, is an exceptional framework for sustainability to be incorporated as a fundamental competence, related to the set of basic and specific technical skills of each university degree.

The set of skills linked to sustainability, biodiversity, climate change, circular economy and renewable energy, among other topics, are now grouped together under the term green skills (European Commission, 2023).

However, university students, who are also citizens and members of the urban or rural communities in which they live, often lack the skills to translate classroom learning into real-life situations (García-Aranda et al, 2020).

There are a variety of teaching methodologies that allow learning to be connected with real contexts (Hernández de Menéndez, 2019), among them, Research-based learning has been chosen in this experience, which is based on the scientific method in teaching (Obwegeser & Papadopoulos, 2017). In this case study, it has been applied to analyse the environmental impact of each student's consumption habits, as a model of practical learning and identification of improvements in real situations.

2. Context or Framework

This experience has been implemented in the context of engineering studies, specifically within the Master's Degree in Chemical Engineering at the Universidad Politécnica de Madrid (UPM). Master's studies imply that students have already completed an undergraduate degree—four academic years under the Spanish university system—so their age and prior education should have provided them with a higher level of professional and personal competencies.

However, the professors who have developed this project have observed in previous courses that the students' knowledge in the field of sustainability is mainly theoretical. When practical applications are introduced in the course, students often face significant challenges in applying these concepts to real-world cases.

Specifically, one of the competencies that students are expected to achieve, as stated in the syllabus is: *"To adapt to structural changes in society driven by economic, energy-related, or natural factors, in order to address emerging challenges and provide technological solutions with a strong commitment to sustainability."*

To address this identified gap and meet the established learning objectives, this pilot project has been designed and implemented using a Research-based learning methodology. It is grounded in the framework of Life Cycle Assessment (LCA), which constitutes one of the core content areas of the course. This first experience has been tested with a small group, to be extended to more groups in the next course.

The main goal is to familiarise students with the scientific-technical methodology of LCA through the use of an impact assessment tool developed by the European Life Cycle Assessment Platform (EPLCA, https://eplca.jrc.ec.europa.eu/).

3. Objectives

The main objective of the project is for students to learn about environmental impact through a personal research experience focusing on their habits, and how our individual impact influences our collective impact. It focuses on the following secondary objectives:

- Calculate the environmental impact associated with the students' consumption habits and compare their environmental impact with the average impact of their classmates and an average EU citizen.
- Analyze the main contributors to individual environmental impact for specific environmental factors, such as climate change or water resource consumption.
- Identify and evaluate measures that can be implemented to reduce both individual and collective environmental impact among students and develop a best practice guide for our daily habits to reduce environmental impact, ensuring that it is easily "transferable" to other groups within society.

4. Methodology

In the educational context, the methodology used in the project has been Research-based Learning, which is focused on teaching students through practical research experiences, each student's research is part of the learning, data or models are provided, complex questions are asked and students are researchers (Dekker & Walsarie, 2016).

The working methodology used in the project can be summarised in the next 4 stages.

4.1. Familiarization with Life Cycle Impact Assessment and Impact Categories

The first step involves introducing students to the key concepts related to the LCA methodology and the life cycle impact assessment method to be used, which is the Environmental Footprint (EF) method**,** in accordance with EU Commission Recommendation 2021/2279**.** This method includes 16 environmental impact categories and has been developed by the EPLCA. It is also the method used in the Consumer Footprint Calculator (CFC) (Sala et al., 2022; Genta et al., 2022), a tool developed by EPLCA and applied within the framework of this project.

4.2. Calculating the environmental impact associated with students' consumption patterns

Students use the CFC tool to determine the environmental impact associated with their consumption habits and their relation to planetary boundaries (Fig. 1). This stage is carried out in two phases:

- Introduction to the tool: A session led by the professors in which the tool is explained, and students are provided with a questionnaire containing the type of information they need to

gather about their consumption habits in the five considered areas: food, mobility, household goods, housing, and appliances.

- Calculation of individual environmental impact associated with consumption habits: After a week in which students gather data related to their consumption habits, they input it into the tool to calculate their environmental impact. Once the environmental impact is calculated (e.g., carbon footprint or water footprint), the tool allows for comparisons with the average environmental impact of a European citizen and with the trajectory of achieving the Sustainable Development Goals (SDGs) set out in the 2030 Agenda. For instance, assessing the environmental impact associated with the consumption of products and services is crucial for achieving SDG 12 (Responsible Consumption and Production). In addition, students compare their results with those of their classmates and identify the main contributions to the selected impacts. That is, they analyze which aspects of their daily life or which products/services/habits are responsible for their collective impact.

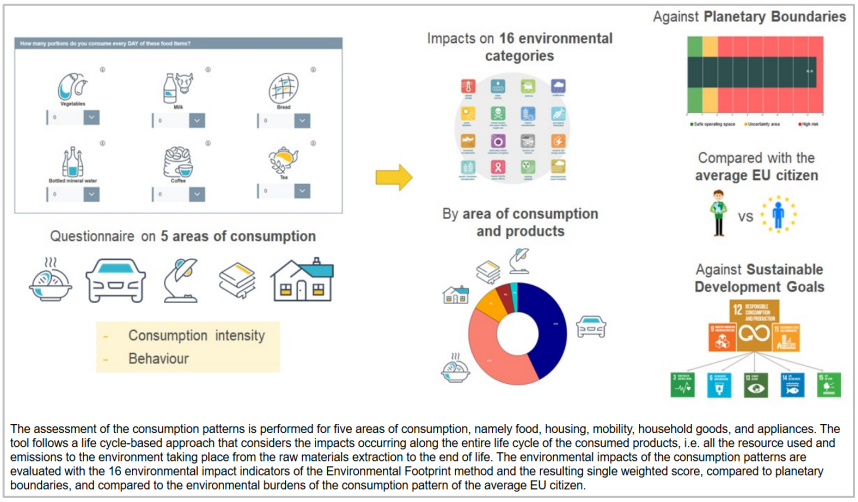

Figure 1. Schematic of the EPLCA CFC tool. Source: EPLCA (2024).

4.3. Research phase on measures that can reduce environmental impacts

Once the individual impact is determined, students conduct research, guided by professors, on specific measures they can easily incorporate into their daily consumption habits to reduce their impact.

4.4. Proposed actions to reduce the impact based on the goals set at different levels

Once a significant set of measures to reduce environmental impact has been identified, each student is required to propose a small number of measures aimed at reducing their environmental impact. But what level of reduction is needed? In the project conducted, students

are asked to reduce their impact on climate change by 65%, in line with European, national, and local greenhouse gas emission reduction targets, with the goal of bringing this impact below the "high-risk" threshold when compared to the planetary boundaries model.

5. Results

The project has been carried out in the "Industrial Ecology" course of the Master's Degree in Chemical Engineering (first year) with 19 students. The environmental impact generated by each student's consumption habits, weighted across the 16 impact categories of the EF method, is shown in Figure 2. This figure allows for the analysis of results in relative terms and provides insight into each student's position compared to the class average. The same information is presented in Figures 3 and 4, but specifically for the impact categories of climate change and water use.

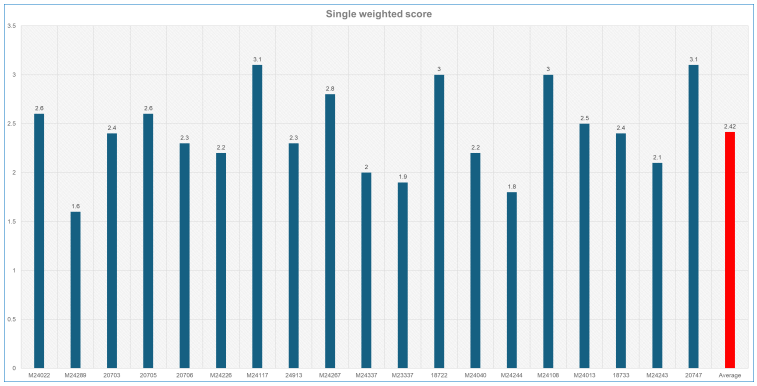

Figure 2. Environmental impact of each student and the average value obtained for the group as a whole (in red), expressed in terms of the weighted assessment. Source: By the authors (2025).

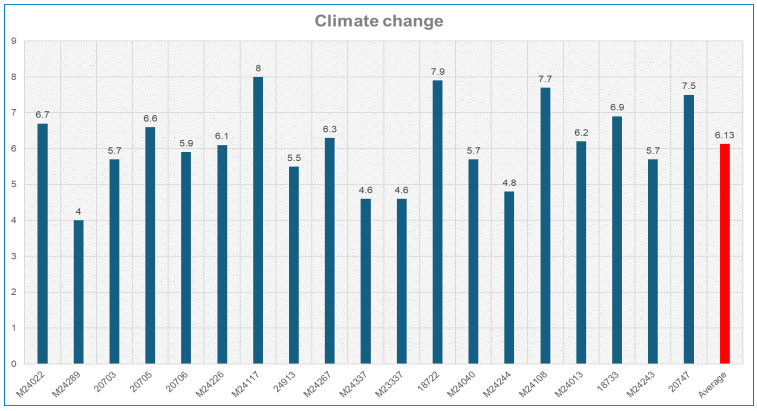

Figure 3. Environmental impact of each student in climate change and the average value obtained for the group as a whole (in red), normalized values (dimensionless). Source: By the authors (2025).

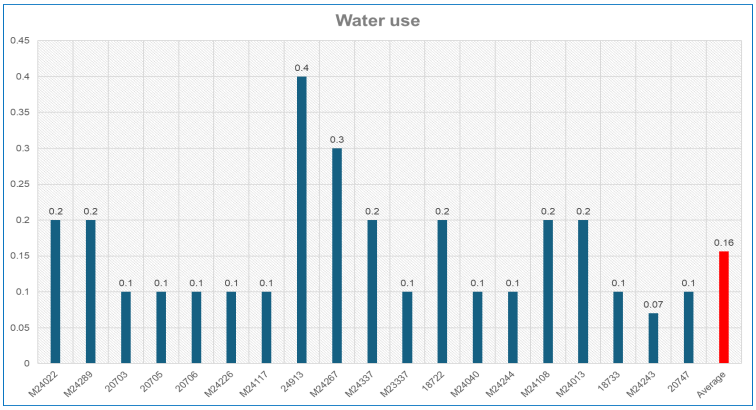

Figure 4. Environmental impact of each student in water use and the average value obtained for the group as a whole (in red), normalized values according to the tool (dimensionless). Source: By the authors (2025).

After estimating their impact by category, each student is asked to analyze and reflect on their results. For this purpose, they must assess their situation in relation to planetary boundaries, the results by consumption area, and a comparison with the impact of an average European citizen. An example of these results, for one of the participating students and for the climate change impact category, is shown in Figure 5.

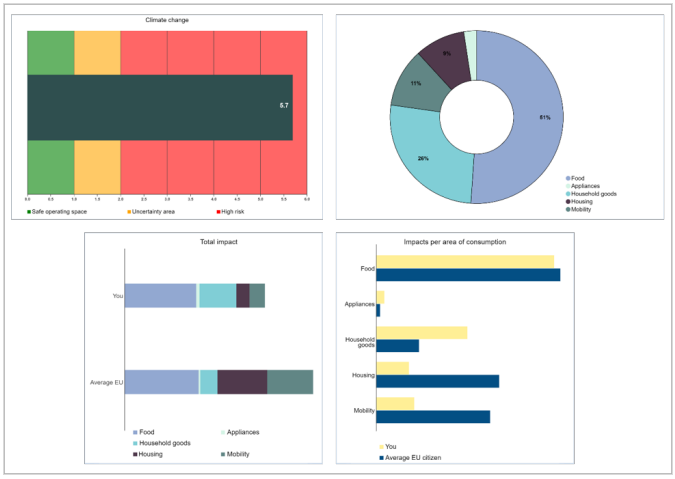

Figure 5. Analysis of the situation in relation to planetary boundaries (top-left), results by consumption area (top-right), and comparison with the total impact of an average European citizen (bottom-left) and by consumption area (bottom-right) for the climate change category and a specific student. Source: Consumer Footprint Calculator (2024).

Students find (and are often surprised) that their greatest contributions to climate change impact come from food consumption, followed by mobility/transportation and household goods. Compared to the average European citizen, the contribution of housing is lower due to Spain's specific climate conditions (Madrid).

After this initial analysis, each student proposes a set of measures to implement in their daily lives to reduce their impact and achieve the proposed goal. In this way, each student must attempt to reduce their impact by aligning it with planetary boundaries, keeping it below the "high-risk" threshold.

The measures proposed by the students focus on changing dietary habits (reducing meat, dairy, and cocoa consumption, etc.), improving or reducing mobility habits by using public transport, increasing product reuse, and prioritizing "servitization" over product/device ownership.

To conclude the research activity, students respond to a survey assessing their satisfaction with the activity based on three questions (Figure 6), with the following average results:

- **Q1:** Rate the overall usefulness of the activity (0 = useless within the course framework, 10 = very interesting within the course framework) → **8.2/10**
- **Q2:** Evaluate whether the activity helps in understanding the methodology and applications of LCA (0 = not helpful at all; 10 = significantly facilitates understanding and comprehension of the methodology) → **7.6/10**
- **Q3:** Assess whether the practical activity should be carried out in future courses (0 = should definitely be eliminated, 10 = would be very useful to repeat) → **8.3/10**

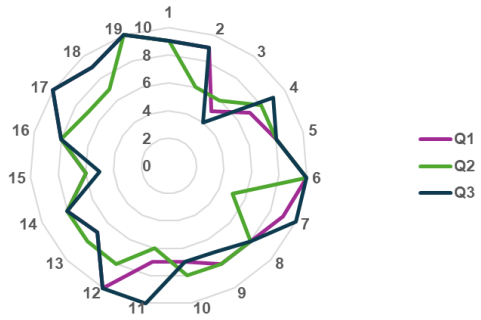

Figure 5. Satisfaction survey results from the nineteen students. Source: By the authors (2025).

6. Conclusions

The proposed project provides an answer to two current challenges in university education. First, the shift in the model of subject learning, making the student the protagonist of the process and advancing toward active learning. On the other hand, it incorporates skills into the academic curriculum that will allow university graduates to adapt to a changing job market, where the

sustainability of activities is crucial, and within this, the reduction of environmental impacts caused by industrial activities throughout the entire production and consumption process.

This research-based learning model allows students to seek solutions and improvement actions, with the positive impact results being measured on their own habits. In this way, learning becomes more personal and deeper, making students aware of their environmental impact so that they can apply it in their future professional activity.

The project evaluation shows a high level of satisfaction. Students state that it helps them understand the subject's core topics, as well as the origin and nature of the environmental impacts caused by their consumption habits, enabling them to become aware of the magnitude of the impact and how they can act to minimize these impacts.

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