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Integrating Eco-Design and Eco-Efficiency in Engineering Education

A Project-Based Learning Approach with Multidimensional Assessment

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Motivation

Engineering graduates must be able to integrate sustainability into engineering design and decision-making. However, sustainability is often taught separately from engineering practice.

This work proposes and evaluates a Sustainability-Oriented Project-Based Learning (PBL) Framework that combines authentic engineering challenges, interdisciplinary collaboration, and sustainability methodologies.

Pedagogical Framework

Figure 1 presents the proposed Sustainability-Oriented Project-Based Learning Framework, structured around five interconnected pedagogical pillars.

Students address authentic engineering problems using sustainability-oriented methodologies within interdisciplinary teams. Continuous formative assessment supports iterative learning, while Sustainable Product and Process Redesign promotes systems thinking and evidence-based engineering decisions.

Methodology

A mixed-methods approach was adopted to evaluate the framework. Quantitative data included student grades and institutional surveys, while qualitative evidence was obtained from project reports, quality assurance reports, and an end-of-semester discussion session.

These complementary data sources were integrated through methodological triangulation.

Results

The implementation of the proposed pedagogical framework demonstrated positive outcomes across multiple dimensions. Evidence obtained through academic performance, project evaluation, institutional surveys, and qualitative feedback consistently indicated high levels of student engagement, successful application of sustainability methodologies, and the development of both technical and transversal competencies.

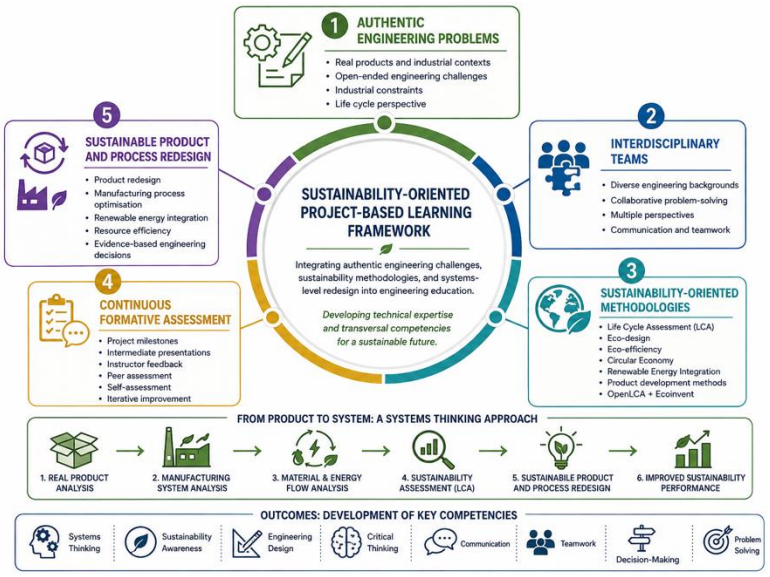

Fig.1 Sustainability-Oriented Project-Based Learning Framework, illustrating the pedagogical pillars, learning process, and intended educational outcomes.

Academic Performance

Students achieved consistently high academic performance, with an average final grade of 16.2/20 and no failures among students completing the course, indicating successful achievement of the intended learning outcomes.

Project Outcomes

Students successfully applied sustainability-oriented methodologies to analyze and redesign real engineering products. Beyond product redesign, many projects proposed improvements to manufacturing processes, renewable energy integration, resource efficiency, and circular economy strategies, demonstrating a systems-thinking approach to sustainable engineering.

Student Perceptions

Students reported high levels of motivation and recognized the value of authentic engineering projects, interdisciplinary teamwork, and milestone-based assessment.

Intermediate presentations were perceived as important for maintaining project progression, while OpenLCA was recognized as a valuable (although challenging) tool for sustainability assessment.

Key Qualitative Findings

- Authentic engineering problems increased student engagement;
- Interdisciplinary teams promoted systems thinking and collaboration;
- Continuous formative assessment supported iterative learning;
- Sustainability methodologies were successfully integrated into engineering design;
- Students progressed from product analysis to system-level redesign, developing evidence-based decision-making skills.

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