FOSTERING ENVIRONMENTAL AWARENESS THROUGH RECOVERED MATERIALS IN ACADEMIC PROJECTS

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ABSTRACT

In response to increasing environmental challenges, design and engineering education must embrace sustainability as both theory and practice. This study examines how integrating recovered, recycled, and upcycled materials—alongside circular strategies—into academic projects fosters environmental awareness among students in creative and technical fields. Through surveys, reflections, and case studies, findings show that working with repurposed materials deepens students' understanding of sustainability and material lifecycles, encouraging sustainable habits, innovation, and ethical responsibility in future professionals.

Keywords: Professional education, educational innovation, materials, environmental awareness, circular strategies (R's)

1 INTRODUCTION

The escalating environmental challenges of the 21st century demand a transformative shift in professional education, particularly within the fields of design and engineering. These disciplines are uniquely positioned to address sustainability concerns by embedding environmental awareness into their fundamental practices. Engaging with the constraints and possibilities of recovered materials directly influences key aspects of professional formation, including material selection, manufacturing processes, design decisions, problem-solving, and innovation.

However, achieving meaningful integration of sustainability in education requires moving beyond theoretical frameworks toward practical, hands-on experiences. Such approaches expose students to the complexity and potential of sustainable design and engineering in real-world contexts. Studies have underscored the pedagogical value of incorporating recovered and upcycled materials [1], [2], [3]—which contribute to slowing resource loops—and recycled materials, which support the closing of resource loops. These practices enhance students' understanding of resource conservation and circular economy principles [4].

Circular strategies [5], often conceptualised through the "R's" framework (reduce, reuse, recycle, recover, repair, and rethink), offer a foundational approach to cultivating environmental consciousness in learners. By actively engaging with these strategies, students are encouraged to investigate material lifecycles, adopt innovative perspectives on resource use, and develop practical solutions to sustainability challenges [6].

This paper investigates the educational impact of integrating repurposed materials and circular strategies into academic projects within design and engineering programmes. Using a mixed-methods approach—comprising surveys, personal reflections, and case studies conducted across diverse higher education contexts—the research assesses how these pedagogical practices shape students' environmental awareness and influence their adoption of sustainable behaviours. The findings suggest that such experiential interventions not only deepen understanding of sustainability but also foster innovation and ethical responsibility in design and engineering processes.

We argue that material choices and circular strategies in academic projects are critical pedagogical tools for shaping future professionals equipped to address global sustainability challenges [7]. By fostering a sustainability mindset, these practices help bridge the gap between theoretical instruction and applied knowledge, promoting responsible innovation in the creative and technical disciplines.

2 METHODOLOGIES

2.1 Research Design

This study uses a mixed-methods approach to explore the impact of integrating recycled, recovered, and upcycled materials, along with circular strategies (R's), into academic projects within design and engineering disciplines. The projects that were considered for this study are:

Project 1: Fashion Accessories engaged 79 early-semester creative students in designing accessories from recycled plastic bottle caps. The project introduced them to the design process through a Circular Economy lens, using an adapted methodology inspired by Biomimicry's "Challenge to Biology" framework developed by A. Acuña [8]. Key design decisions were shaped by considerations of accessibility, functionality, and aesthetics. Students used the Precious Plastic Press Sheet to transform the caps into sheets, which were then cut and sanded into final products. Figure 1 documents stages of this hands-on process.

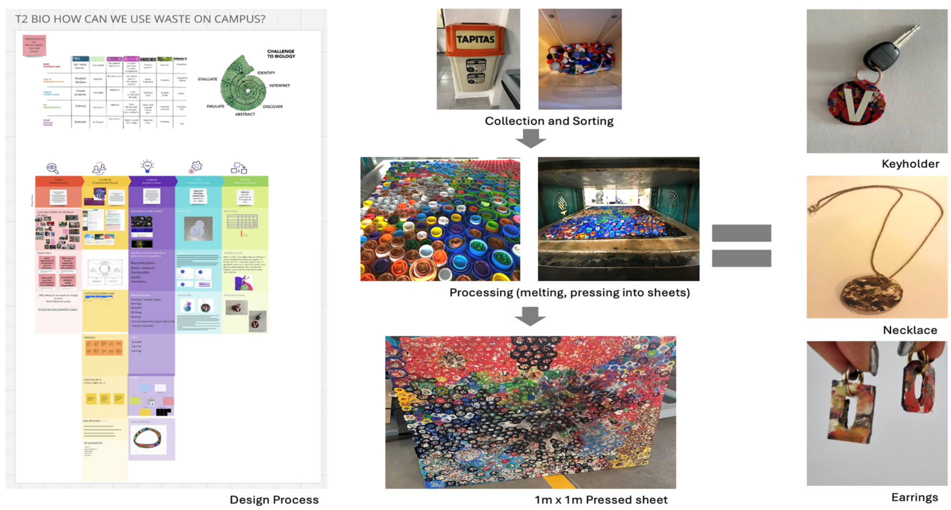

Figure 1. Methodology, process of recycling and use of material

Project 2: Inédito involved ten 5th to 7th semester design students in creating innovative office objects from components over 25 years old. Aimed at challenging planned obsolescence, the project promoted a rebellious, sustainable design mindset and open-source sharing.

Students disassembled obsolete items to generate raw materials, then redesigned function and form using recovered components. Final products were shared on open-source platforms to enable broad replication.

This hands-on process shaped design and engineering decisions, applying principles such as functionality, aesthetics, material properties, and structural behavior. Figure 2 documents the transformation of waste into functional, replicable objects, a hands-on exercise in sustainability and innovation.

Figure 2. Collected products and materials and designed open-code objects by students

Project 3: Robot Track was developed by 20 final-semester engineering students, who repurposed waste material generated on campus to produce recycled plastic sheets later used as structural walls for a robot navigation track. The project emphasised the application of engineering principles in a real-world sustainability context.

The process involved collecting, classifying, cleaning, crushing, melting, and pressing plastic waste using Precious Plastic machines. This hands-on approach influenced key engineering decisions, including the selection of materials suitable for guiding the robot, the structural design of joints, and the optimisation of processes and material use.

As shown in Figure 3, students documented the complete cycle from waste collection to the implementation of recycled sheets in functional robotic infrastructure, demonstrating practical skills in sustainable engineering and materials revaluation.

Figure 3. Process of recycling and use of material

2.2 Participants

Participants include 109 undergraduate students from creative disciplines, design and engineering programmes from the same Campus (see Table 1). Selection criteria ensured diversity in academic levels, disciplines, and prior exposure to sustainability concepts. Only 74 students answered the surveys.

Table 1. Students Information in Projects

Students Information in Projects		
Information of Implementation		Edition
Project 1: Fashion Accessories	Number of Students	79
	Academic programs	Architecture (12) Communication (8) Industrial design (31) Animation and digital art (16) Music Production (12)
	Semester	1-2
Project 2: Inédito	Number of Students	10
	Academic programs	Indutrial Design
	Semester	5-7
Project 3: Robotics	Number of Students	20
	Academic programs	Robotics
	Semester	9

2.3 Data Collection and Analysis

The methodology combines qualitative and quantitative techniques to ensure a comprehensive understanding of the subject matter [9].

- ***Quantitative:***
  A structured questionnaire based on the short-version of **Sustainability Consciousness Questionnaire (SCQ-S)** [10] was used to assess participants' sustainable knowledge, attitudes, and behaviours before and after projects with recycled, reused, or repurposed materials. Descriptive statistics were calculated for each item. Cronbach´s alpha was performed with a result of 0.8099, enough to trust that the survey reliably evaluates the same construct (Theoretical construction to understand a specific problem)
- ***Qualitative:***
  Open-ended questions provided qualitative insights into experiences and the value of circular strategies. Responses were analysed for key themes, including hands-on learning impact, ethical responsibility, and barriers to sustainability.

This combined approach provided a comprehensive understanding of both measurable changes and underlying contextual factors.

3 RESULTS

3.1 Quantitative Findings

The pre-intervention and the post-intervention survey reveal notable improvements in several quantitative domains.

- First, the **sustainable consciousness** score, as measured by the "sustainability knowingness" factor, shown in Figure 4, exhibited a significant increase. For instance, items such as "The use of recycled materials in academic, professional or problem-solving projects contributes to sustainable development" showed mean scores rising from approximately 60.8% to 77.9% who totally agreed. This suggests that students' knowledge of critical environmental issues improved substantially following the intervention.

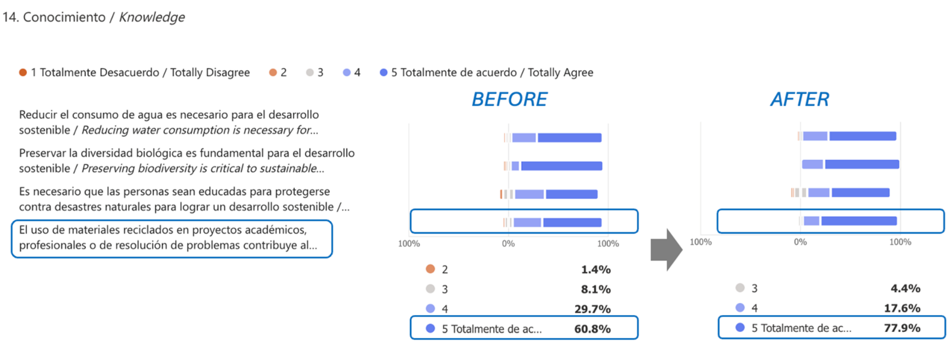

Figure 4. Sustainable knowledge before and after de intervention

- Moreover, the adoption of **sustainable practices** increased significantly. Figure 5 highlights behavioural and reflective growth between assessments. Initially, responses showed moderate, inconsistent adoption of recycling, waste separation, and using recycled materials. Post-intervention, participants increased frequency, recognised barriers, and strengthened ethical commitment. This shift reflects quantitative gains in integrating sustainability.

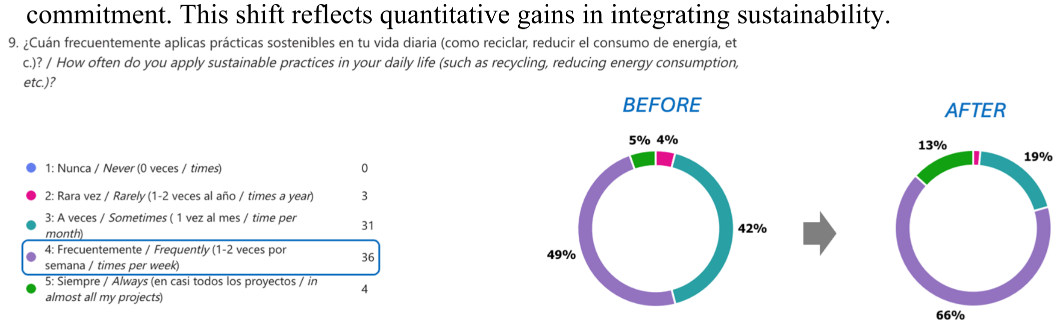

Figure 5. Sustainable practices in daily life before and after de intervention

- In the initial survey, Figure 6 indicates a moderate level of engagement with **sustainable practices**, with fewer than half of the participants (approximately 40%) reporting regular integration of ecofriendly materials or methods in their projects. By contrast, the final survey showed a marked increase, with over 60% of respondents consistently incorporating sustainable approaches. This shift underscores a growing willingness to utilise recycled or responsibly sourced materials and reflects an enhanced understanding of the broader environmental benefits associated with such practices.

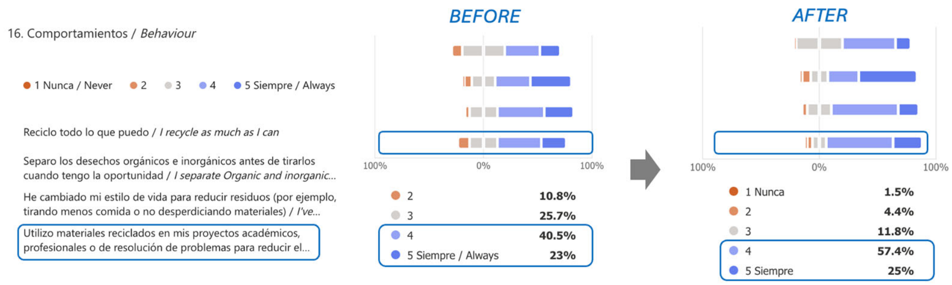

Figure 6. Sustainable behaviour before and after de intervention

- Additionally, the results in Figure 7 show a significant rise in **environmental awareness** after the intervention. Initially, most participants were “Slightly” (9.5%) or “Moderately Aware” (33.8%), with only 8.1% as “Highly Aware.” Post-intervention, these lower categories dropped (9.5% and 17.6%), while “Highly Aware” rose to 36.8%. The combined “Aware” and “Highly Aware” group grew from 56.7% to 83.9%, demonstrating a strong shift toward greater environmental consciousness in material use for academic and professional projects.

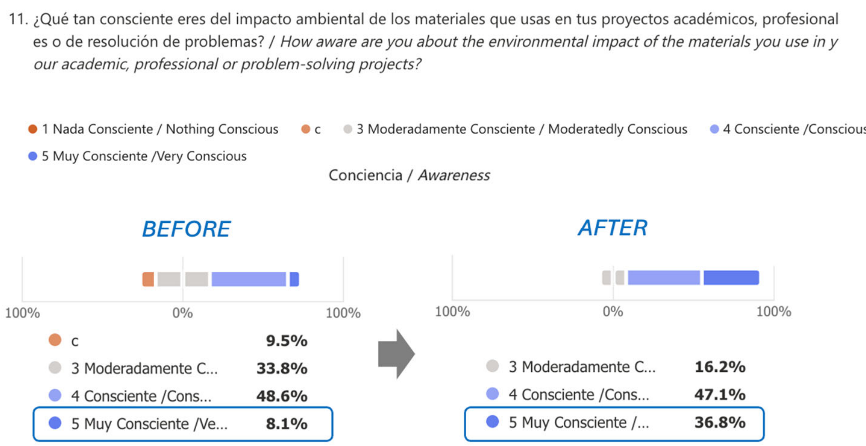

Figure 7. Environmental awareness before and after de intervention

3.2 Qualitative Insights

The three most significant qualitative findings from the open-ended responses in the final questionnaire are:

- **Hands-on Learning Impact**: Participants highlighted that direct engagement with recycled materials deepened their understanding of sustainability, making theoretical concepts more tangible and applicable.
- **Ethical Responsibility**: Many expressed a heightened sense of personal and professional duty to adopt sustainable practices, viewing sustainability not just as a design constraint but as an ethical imperative.
- **Identified Barriers**: Participants recognised logistical and systemic challenges, such as difficulties in sourcing enough clean materials, access to specific processing equipment, workshop space limitations, time constraints within the course structure, lack of knowledge of how to use certain machines, which makes it difficult to adopt sustainable practices.

4 CONCLUSIONS

This study shows, in this specific group, that integrating recycled and upcycled materials into design and engineering education significantly enhances students' sustainability awareness, innovation

capacity, and ethical responsibility. Hands-on experiences bridge the gap between theory and practice, fostering resource conservation and preparing students for real-world environmental challenges.
Comparisons before and after the intervention show notable growth in sustainable thinking, adoption of responsible practices, and ethical engagement. Both quantitative and qualitative results confirm that experiential learning effectively promotes shifts in knowledge, attitudes, and behavior toward sustainability.
These outcomes suggest that working directly with recovered materials equips future professionals in design and engineering to address global sustainability challenges with practical, responsible, and innovative solutions.

5 FUTURE WORK

Future work includes creating accessible repositories of quality recycled and upcycled materials to support circular design in education; integrating digital tools like virtual material lifecycle simulations to enhance experiential learning; embedding sustainability more systematically in curricula to build both awareness and practical skills [11]; and conducting paired t-tests to analyse differences in responses and factor combinations.

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