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Experiential Learning for Circular Operations Management in Higher Education

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Abstract: This research-to-practice article delves into novel learning experiences for operations management education, involving the circular economy and experiential learning. Higher Education academics are required to develop effective learning that actively and impactfully helps nurture in students the essential competency to face sustainable development demands. In operations management education, one possibility is to integrate real-world circular economy challenges into learning activities that address issues concerning solid waste generation in business processes and operations. This type of innovative learning experience involves both conceptual understanding and practical implementation. Accordingly, experiential learning is considered a suitable pedagogy for this purpose in this work because of its hands-on applications, critical thinking, and active engagement. To illustrate this proposition, this paper presents a case study concerning an operations management undergraduate course at a Mexican university. The case study indicates how to translate a situation of solid waste generation in a business into relevant disciplinary experiential learning. The results show that students regarded the learning experience as motivating, interesting, and relevant while widely accomplishing their learning objectives. However, limitations did exist regarding experiential learning, the methodological approach, data collection, and implementation challenges. Future work points to the need for further learning experiences and to improve research reliability, transferability, and validity.

Keywords: circular economy; educational innovation; engineering education; experiential learning; higher education; operations management; sustainability; Sustainable Development Goals

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1. Introduction

This research-to-practice article concerns circular economy-based educational initiatives for operations management in Higher Education (HE). The circular economy relates to sustainability challenges involving waste and pollution elimination, the circulation of physical products and materials (minimizing economic loss), and the regeneration of nature [1]. Operations management is crucial for leading and conducting the necessary business processes and operations to facilitate these efforts [2]. In light of these sustainability demands, there is a need for HE students to gain the essential knowledge and skills beyond disciplinary expertise in isolation, to promote sustainable development now and in their future careers [3]. Additionally, considering sustainability issues in HE provides stimulating and pertinent learning challenges that can enhance student learning outcomes, motivation, and engagement.

Sustainability is one of the most pressing global challenges facing humanity, which the United Nations has defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [4]. The 2030 Agenda for Sustainable

Development and the Sustainable Development Goals (SDGs) set forth a global effort for this purpose [5]. However, the increasing economic, environmental, and social threats make this challenge even more significant. Elkington [6] defines this set of requirements as the Triple Bottom Line. In this context, sustainability is a crucial concept for HE institutions (HEIs) to educate students according to the SDGs [7,8].

HEIs must incorporate sustainability demands into educational models and pedagogical designs, in line with SDG #4 Quality Education, and Target 4.7, to ensure that all learners acquire the knowledge and skills needed to promote sustainable development [5]. Therefore, it is necessary to cultivate sustainability competency in graduates in their academic disciplines in a practical and impactful manner.

Integrating sustainable criteria and practices into HE curricula can offer students opportunities to learn about practical problems that are relevant to their lives and future career prospects, with an impact on their surrounding communities and the environment [9]. Hence, this work involves enhancing students' understanding of operations management by incorporating sustainability practices. One way of doing this is through the study of circular economy challenges [9,10].

According to Kurniawan and Fernando [11], the circular economy significantly contributes to SDG #2 Zero Hunger and SDG #12 Sustainable Consumption and Production, with additional implications for SDG #3 Good Health and Well-being, SDG #6 Clean Water and Sanitation, and SDG #8 Decent Work and Economic Growth. In the case of SDG #2, there are issues regarding food waste because it is not consumed on time or there is incorrect transportation, handling, or inventory management. Referring to SDG #12, the issues refer to natural resource depletion; the inefficient use of natural resources; waste release to release to air, water, and soil; procurement practices; and peoples' sustainability awareness [5]. Accordingly, circular economy practices are commonly applied in supply chain operations, including consumer product industries, food production in agriculture, electrical and electric products, and natural resource exploitation and extraction.

Some important aspects of the circular economy require changes in operations practices across supply chains, in which products are sourced, produced, delivered, consumed, and disposed of with a loss of economic value and other undesirable side effects [2,12]. However, the implementation of circular economy principles requires a deep understanding of the underlying concepts and a systemic type of thinking [13]. Therefore, HEIs have a critical role in preparing future professionals to drive this transition.

In this sense, suitable learning experiences are central to growing the knowledge, skills, and attitudes necessary to address complex challenges such as the transition to a circular economy [9]. In the context of circular economy and operations management, this type of learning experience involves both conceptual understanding and practical application through reflective practice and real-world projects [14].

Despite the growing importance of the circular economy and sustainable operations management, there is a need to develop effective instructional designs to enhance learning experiences in the field [15–17]. The research problem is, therefore, twofold: first, there is a need to explore suitable learning experiences related to the circular economy and sustainable operations management in HE, and, second, there is a need to identify effective pedagogical approaches to enhance these experiences.

Accordingly, the research aim of this work is to address these two problems by exploring suitable learning experiences related to the circular economy and operations management in HE and identifying effective pedagogical approaches to enhance these experiences. Specifically, the research aim is to achieve the following objectives:

1. To identify the key topics of circular economy and sustainable operations management for learning experiences in HE;
2. To propose an active pedagogical approach to enhance this type of learning experience for student engagement;
3. To assess how this type of learning experience impacts students' learning achievements.

To achieve these objectives, this document unfolds into five additional sections. Section 2 covers the supporting theories and notions of this work and a guiding approach to creating and developing relevant learning experiences for the circular economy and operations management education. Section 3 offers a methodology that guides this research work, involving a case study. Section 4 presents the work results regarding the learning experience of an undergraduate engineering course in operations management at a university in Mexico City. Section 5 refers to the results' discussion regarding findings, limitations, and future work. Finally, Section 6 covers the conclusions concerning the main takeaways of this work.

2. Background

2.1. Operations Management and the Circular Economy

Circular economy refers to an industry-based system approach that aims to transform the conventional linear economy of extract–produce–dispose into a circular structure of reduce–reuse–recycle [1]. Thus, the circular economy seeks to minimize/mitigate/eliminate waste, reduce resource consumption, and promote a regenerative and restorative approach to industrial activities [1].

In this sense, the circular economy entails avoiding losing economic value while doing environmentally well by changing viewpoints and mental models and transforming the existing structures alongside supply chains [18]. It emphasizes the importance of closing the loops of material, energy, and information flows within the economy, through strategies, such as product design for longevity, resource recovery, and waste reduction [19].

On the other hand, operations management is a field of study about the design, planning, control, and improvement of business processes and operations [20]. It encompasses various aspects of manufacturing, production, and service operations, including process design, capacity management, inventory management, quality management, project management, and supply chain management. Therefore, operations management plays a critical role in optimizing resource utilization, improving operational efficiency, and enhancing the overall performance of organizations. However, in this century, new challenges have emerged for businesses and operations beyond economic and technical aspects to consider sustainable development [6,21–23]. An exploration of the intersection of operations management and circular economy is required to clarify key concepts and findings in the field.

Accordingly, *circular operations management* focuses on integrating circular economy principles into the design and operation of business processes and supply chains [2]. It involves managing the reverse flows of materials, products, and information circularly, to maximize resource recovery, reduce waste, and minimize environmental and social impacts.

Figure 1 summarizes these possibilities for a (re-scalable) supply chain of finite or non-renewable material products. This supply chain framework covers a downstream forward flow from originating sources to end consumers while involving an upstream reverse flow of circular economy activities to reduce, mitigate, or eliminate economic losses and adverse social and environmental impacts. In the case of renewable products, alternatives do exist regarding bio-regeneration and biochemical feedstock for their reintegration as a natural resource [1]. Overall, these practices not only reduce waste and environmental impacts but also create opportunities for cost savings, revenue generation, and competitive advantage.

Despite the potential benefits of circular economy practices, organizations face various challenges and barriers in their implementation [24,25]. These challenges include technological, economic, regulatory, market, and organizational barriers. Consequently, operations management can influence the implementation of circular economy practices [2]. However, there is still pending work on the key role of circular economy-related operational practices in achieving the SDGs [26].

Hence, all these aspects and challenges of circular operations management define possibilities for identifying and selecting study situations to translate into relevant learning

experiences in HE. The notions of sustainability, circular economy, and the SDGs establish a platform for promoting responsible management education, as defined in the Principles of Responsible Management Education (PRME) to develop student capabilities, values, methods, partnerships, research, and stakeholder dialogue to equip today's students with the ability to deliver change tomorrow [27].

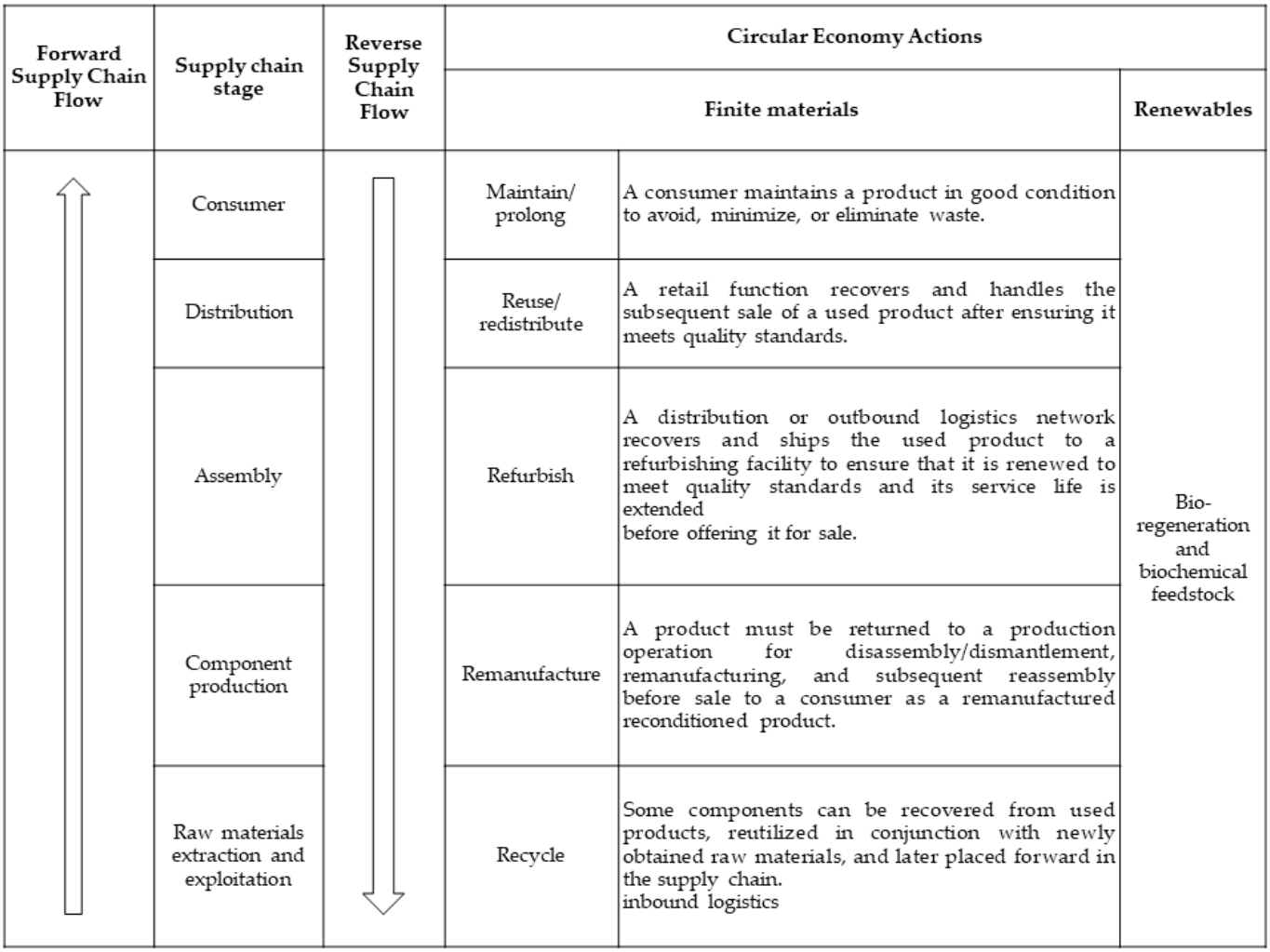

Figure 1. Circular supply chain flows framework (own elaboration) adapted from [1,28].

2.2. Learning Circular Economy in Higher Education

HEIs have recognized the importance of incorporating sustainability, and circular economy principles, into their curricula to prepare future leaders and professionals with the necessary competency for a more sustainable future [29,30]. The circular economy's current state in HE highlights key themes, approaches, challenges, and opportunities.

The literature highlights various approaches to the incorporation of circular economy topics in HE. One common approach is integrating circular economy principles into existing courses or programs [9,31]. This is the case in environmental science, economics, management, and engineering. Another alternative is developing dedicated courses or programs focused specifically on the circular economy [32,33]. In some other cases, efforts have been made to develop specific learning outcomes regarding sustainable development and the circular economy [9,34]. These courses often adopt an interdisciplinary or multidisciplinary approach to know and address the intricate challenges of the circular economy [35]. This is the case for engineering, environmental science, business, economics, policy, and social sciences [10,31].

Additionally, active methods have been employed in teaching circular economy and sustainable development [36,37]. HEIs have adopted innovative pedagogical approaches, such as case studies, simulations, field trips, design thinking, and problem-based learning, to engage students in active and practical learning experiences. In some of these cases, HEIs have also collaborated with external stakeholders, such as non-governmental organizations (NGOs), governments, and business companies, to provide students with real-world learning opportunities, foster partnerships for circular innovation, and build networks for future career opportunities.

Nevertheless, the incorporation of the circular economy in HE also faces several challenges and opportunities. One of the main challenges is the lack of a standardized curriculum and guidelines for circular economy education [10]. In addition, as the circular economy is inherently interdisciplinary, this study area frequently requires knowledge and skills from multiple fields. However, integrating and coordinating diverse disciplines cohesively and comprehensively can be challenging due to differences in pedagogical approaches, disciplinary boundaries, and faculty expertise. An additional limitation is a need for faculty expertise, instructional materials, and access to real-world examples and case studies. However, many HEIs may also face resource constraints, such as limited funding and access to relevant industry partners or stakeholders. These limitations may hinder the development and implementation of effective circular economy curricula and pedagogical approaches.

Despite these obstacles, the circular economy presents opportunities for fostering innovation and entrepreneurship among students [10,16]. Furthermore, teaching circular economy aligns with the increasing focus on sustainability and social responsibility in HE [38]. HEIs can position themselves as leaders in sustainability education by engaging students in community-based circular initiatives. This can attract environmentally conscious students, enhance the institution's reputation, and contribute to societal and environmental well-being.

Therefore, teaching and learning circular economy in HE are dynamic and evolving fields with interdisciplinary, experiential, and innovative approaches. Further research and collaboration among academia, industry, and policymakers can contribute to the development of effective circular economy curricula and practical implementations in HE. Accordingly, the work in this paper illustrates how circular economy learning experiences can be developed in operations management education.

2.3. Experiential Learning for Circular Operations Management Education

Education for circular operations management requires pedagogical approaches that support the use of practical applications, reflection and critical thinking, active engagement, innovation and creativity, and a holistic type of thinking. Therefore, active pedagogical approaches, and specifically, experiential learning, can support these efforts [39,40]. According to PRME [27], students should engage in the conceptualization and execution of learning experiences and opportunities that support experiential learning related to the SDGs.

Experiential learning is a pedagogical theory that goes beyond the passive acquisition of information, emphasizing in what manner learners actively grow knowledge through learning activities to accomplish their learning objectives and intended learning outcomes [41]. At the core of experiential learning is the notion of a recursive and continuous loop comprising four stages: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE).

The main task of this work is to design learning experiences for the circular economy in operations management education from the perspective of experiential learning. Learning experiences refer to those particular engagements through which both students and teachers undertake their daily lives, activities, and interactions within classrooms and beyond, for learning purposes [42]. A learning experience is considered in this work as the basic unit of study or the research object [43].

Referring to the integration of circular economy, operations management, and experiential learning, learning experiences must include the four stages of Kolb's learning cycle. Hence, each of the stages is described as follows.

- CE involves real-world applications and requires students to see the direct impact of circular practices on operations and understand the challenges and opportunities associated with implementing circular economy strategies in organizations. This can involve field visits, simulations, or hands-on activities to directly experience challenges and issues.
- RE considers that students should critically evaluate circular economy-related situations in operations management to deeply understand the underlying principles, identify potential barriers and challenges, and reflect on possible implications. Possible pedagogical alternatives in this case are class discussions, group reflections, or self-assessments where students can analyze and interpret their experiences and identify key insights and lessons learned.
- AC refers to students who should generate new ideas, make connections, and develop innovative solutions for the operational challenges of the circular economy. This proposition can involve designing circular economy strategies for specific operations management scenarios, developing circular design solutions, suggesting circular economy performance metrics, or creating circular business models.
- AE involves engagement and encourages students to design, test, and validate circular economy strategies in real-world contexts. This active engagement can take the form of implementation plans, demonstrations, practical implementations, presentations, debates, role plays, or simulations.

Experiential learning plays a key role in engineering education, where it can involve practical immersive activities, simulations, and the creation of technology-based designs and solutions [44–49]. It enables learners to establish stronger connections between their learning involvement, practices, and real-world applications, contributing to meaningful learning experiences for relevant intended learning outcome accomplishment [50].

Hence, intended learning outcomes must refer to those of circular operations management defined in a course or module. The definition process of learning outcomes is out of the scope of this work; however, it will be exemplified in Section 3. Moreover, valid methods of assessment should be designed to measure a student's ability to engage in the experiential learning cycle. Coherence among intended learning outcomes, experiential teaching and learning activities, and methods of assessment for circular operations management learning experiences must be assured as part of a constructive alignment [51].

In conclusion, teaching and learning circular economy in operations management based on the experiential learning theory can be highly effective in promoting a deep comprehension of circular economy fundamentals and their practical application to operations management. This approach can help learners develop decision-making, problem-solving, and policymaking skills that are essential for addressing the sustainability challenges of today's businesses. It can also help students attain a comprehensive understanding of the circular economy in operations management and become change agents who can contribute to creating a more sustainable and resilient economy.

3. Materials and Methods

This work proposes a methodology that delves into a real-world situation of circular operation management linked to a learning experience for engineering education. Hence, a five-step methodology was proposed using the ideas of De Zeeuw [43], Popper [52], Vahl [53], and Tharenou et al. [54] for carrying out research in the social field. The methodology unfolds as follows.

1. Select an operations management-related course linked to a real-world circular economy situation to develop relevant intended learning outcomes;
2. Develop a research design of a learning experience based on experiential learning;

3. Collect, organize, and analyze data, and make descriptions of the learning experience;
4. Evaluate and explain/interpret the learning experience results, and reformulate statements and claims, if required;
5. Report the discoveries and take further action by re-visiting the results from step 3.

Step 1 considers an operations management course for engineering education at Universidad Panamericana in Mexico City, in collaboration with a major wine and liquor retailer, to explore circular economy opportunities in supply chain and logistics operations. This course was selected as it offered the opportunity to ground the underlying theories and concepts in a real-world situation concerning this work's aim.

In step 2, an exploratory case study was developed to progress toward the research aim. This case study refers to a particular situation that explains and helps to gain an understanding of its fundamental elements, instead of other aspects or generic matters [55] (pp. 62–64). A case study was chosen since it pertains to unique circumstances, locations, groups of people, or events, or demonstrates the use of new methods and tools in situations with only one or a reduced number of occurrences. The case study describes a unique learning experience in an undergraduate engineering course during the first semester of 2023 using an in-depth investigation based on the experiential learning approach presented in Section 2. Thus, this work does not consider comparisons with control groups to make inferences or generalizations concerning other cases [56]. The case study is summarized in the following section.

Step 3 includes a mixed methods approach to collect, collate, and analyze data to construct statements and formulations on the learning experience [57]. The collected primary data included observational reports from instructors about their instructional design and the learning experience, providing course background information, intended learning outcomes, teaching and learning activities, and assessment methods. Secondary data included the course specification, assignment briefs, students' presentations and reports, and students' assignments and examinations. Moreover, secondary data were collected regarding student marks, learning outcomes assessments, the course student feedback survey results, and two student opinion surveys on the learning experience (initial and final during the semester). The data analysis was carried out using descriptive statistics and non-parametric tests of students' achievements and opinions to describe the learning experience's outcomes.

In step 4, results are discussed referring to the theory of experiential learning, the unit of study, and the research aim. In this case, the case study results allowed for illustrating a real-world learning experience on circular operations management for engineering education based on experiential learning in a real-world scenario. Discussions followed the experiential learning cycle and students' accomplishments in the learning experience. Hence, this section covers this work's major findings, limitations, and future research work.

Finally, step 5 refers to the concluding remarks concerning the research aim, this work's contributions to sustainability and circular operations management education, and an overall reflection on this work.

As this work explores learning experiences in a social context, the evaluation of the research findings must adhere to the criteria of transferability, reliability, and validity [53]. Transferability, in contrast to generalizability, indicates that this work's findings might not apply to other educational contexts, situations, times, or populations as collected data may differ from other subjects' opinions (for example, they might not answer in the same way) as well as in their contextual conditions or circumstances. This condition can lead to different results and interpretations. Reliability was addressed by providing a step-by-step methodology that consistently allows for the subsequent collection, analysis, and reporting of data from different learning experiences. Regarding validity, this was addressed by discussing result accuracy in the light of the experiential learning theory to identify coincidences or deviations. These criteria can serve to guide other discussions about learning experiences, identifying suggestions, implications, and possible further steps.

Summing up, the methodology comprehends the learning experience description as a research object, the research design, the types of data, and the experiential learning cycle, which leads to the research process and the evaluation of results. Considering these elements, the next section presents this work's results concerning one learning experience instance for circular operations management education.

4. Results

The case study in this section describes a learning experience concerning circular operations management in a Mexican university to illustrate the applicability of experiential learning ideas. First, the case elaborates on the course selection, including the background situation and its justification. Second, it elaborates on the experiential learning activities of this course linked to a real-world context. Third, the case study presents results concerning the students' learning achievements.

4.1. The Operations Management Course

To progress in this direction, a core undergraduate course on operations management was selected at Universidad Panamericana in Mexico City, to undertake the research design of a learning experience involving experiential learning.

The industrial engineering, data-driven innovation, mechatronics, and mechanical undergraduate engineering programs at this university share the core course in operations management in their specific curricula. This course aims to assess the impact of production management on company financial results and to develop managerial skills in students. Hence, this course helps students understand the importance of production management, how production decisions influence business performance, and how competitive advantages can be generated through operations.

Moreover, the course covers disciplinary content regarding production systems, product and process design, productive resource distribution, production systems operations, inventory management, scheduling, workplace planning, just-in-time (JIT) production, and the theory of constraints.

In 2022, a significant shift was sought in this course delivery to link operations management with circular economy and sustainable challenges. It was also needed to transition from a traditional teaching model to an active learning approach to better contribute to the university's aim. To achieve this, a partnership was formed with the country's leading wine and liquor retailer, Bodegas Alianza, and the Community Resilience and Sustainability Education Lab (CoRSEL) at Aston University in the United Kingdom.

The learning experience in this course involved fifty industrial engineering undergraduate students and one lecturer at Universidad Panamericana in Mexico City. There was also a guest speaker from Aston University to cover the circular economy topics and their connection to operations management. Additionally, the course included thirty-two one-and-a-half-hour sessions during the sixteen-week course delivery. This course mainly took place on campus with presence interactions; however, it also involved off-campus activities and online interactions with the company executives and staff.

Bodegas Alianza is a company with over seven decades of experience in the marketing of wines, liquors, and gourmet products. The company focuses on the exploration of diverse distribution channels and the continuous improvement of its processes to meet consumers' changing demands. Its strategy revolves around providing high-quality customer service, supported by promotional offers, to deliver a gratifying shopping experience. Thanks to this collaboration with the company, within the operations management course, two experiential learning challenges were formulated.

On the one hand, the control of product useful life challenge, Bodegas Alianza aimed at optimizing their goods management and control systems to comply with expiration dates or preferred shelf life. Their products encompass various categories, including table wines, liquors, and spirits, as well as deli products, like cheese, processed meats, and other European groceries. The inadequate handling of these products has resulted

in significant financial losses for the company, presenting a substantial opportunity for improving processes. The challenge posed to the students was to examine the root causes that led these products to the disposal stage and propose viable alternative solutions to reduce, mitigate, or eliminate the problem. This issue entailed two adverse effects: Firstly, substantial economic loss affecting the company, underscoring the importance of prioritizing the minimization of this problem. Secondly, there was a need to devise how these products could be utilized after surpassing their validity date, possibly through donations or distribution to charitable organizations to benefit those in need. The solution sought to address both the sustainability aspect and the circular economy concept of avoiding waste and the loss of economic value. This approach involved exploring potential applications for expired products, such as investigating the feasibility of reusing waste from wines, liquors, or alcoholic beverages and determining how such a reuse process could be carried out.

On the other hand, Bodegas Alianza sought new ways to reduce the impact generated by (solid) waste resulting from its operations. The distribution of its products required the use of various packaging and packing materials designed to facilitate handling and ensure safety during transportation. However, once their primary function has been fulfilled, these materials lack clear procedures for their collection and reuse. Most of these elements, such as bottles, cardboard, stretch films, and pallets, are handled in various ways, without a sustainable focus, both at points of sale and in warehouses. This situation revealed significant room for improvement within the company, which could establish innovative processes that potentially generate additional economic and environmental benefits. The challenge posed to students was the evaluation of the advantages and risks associated with the implementation of proper procedures for handling these materials considering circular economy criteria. This involved calculating the economic loss and other indicators related to solid waste, disposal, and pollution resulting from these materials, as well as identifying recycling and sustainability alternatives that could reduce the environmental impact. Additionally, innovative options were sought that could lead to new methods of operation, benefiting both the company and consumers. As an example, the question of glass used in bottle packaging was raised, exploring how its recycling could provide benefits for both customers and Bodegas Alianza. This analysis underscored the importance of considering sustainability and the management of packaging materials as essential components in the operation of companies like Bodegas Alianza, with a focus on innovation and minimizing the environmental impact.

4.2. The Experiential Learning-Based Learning Experience

The learning experience was divided into four key stages, each designed to promote experiential learning and effective collaboration between students and Bodegas Alianza executives. Details of these stages can be found in Figure 2, concerning the supply chain conceptualization of circular operations management for experiential learning, and Table 1, regarding learning activities at each experiential learning stage. A summarized description is presented as follows.

Table 1. Experiential learning stages and activities.

Experiential Learning	Activities Description
Concrete experience (CE)	Gather and classify quantitative data in retail points and warehouse operations regarding solid waste generation (type and quantity); Collect and organize qualitative data from retail points and warehouse operations regarding solid waste generation (characteristics and related descriptions); Examine key variables affecting solid waste generation linked to retail and warehousing operations; Define problems or issues of concern to improve waste generation regarding circular economy actions.

Table 1. *Cont.*

Experiential Learning	Activities Description
Reflective observation (RO)	Collate and analyze collected data, using descriptive and inferential statistics, to identify patterns, correlations, and relationships; Link the problem or issues of concern to operations management, sustainability, and circular economy theories and methods; Examine and diagnose the situation to identify solid-waste root causes in operations.
Abstract conceptualization (AC)	Design and propose operations changes in retail and warehousing operations to overcome the existing problems based on circular economy actions; Validate proposals with company staff to ensure applicability; Obtain formative feedback on the application of operations management concepts and methods.
Active experimentation (AE)	Summarize, present, and discuss circular operations management proposals; Write up and present a proposal report. Obtain summative feedback on circular economy proposals and their business value, relevance, applicability, and long-term impact.

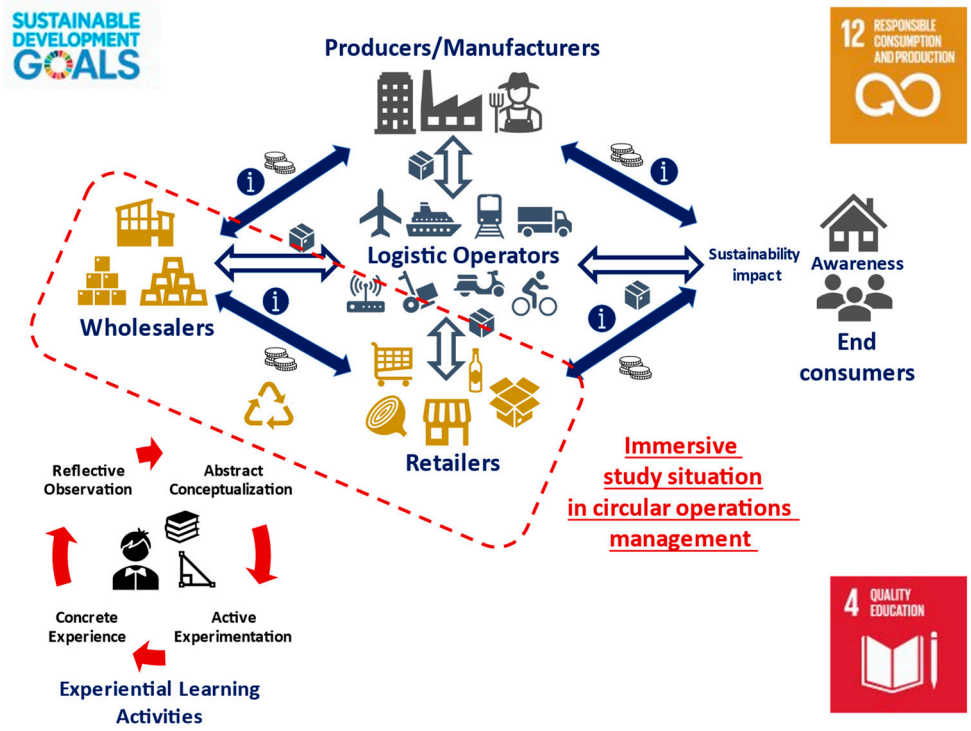

Figure 2. Circular operations management experiential learning (own elaboration) adapted from [41,58,59].

4.2.1. Concrete Experience

In this initial phase, the importance of experiential activities was underscored, as well as how they aligned with the objectives of the course and active learning. This phase consisted of an awareness session led by an executive from Bodegas Alianza, responsible for managing a segment of points of sale. During this session, the executive provided an overview of the existing issues and the company's overall landscape. Furthermore, he addressed the effects these problems had within the mentioned context and responded to general questions concerning consumer profiles and preferences, demand behaviour, and retail operations. Additionally, students were introduced by the course leader to the learning experience activities, their main assignment tasks, and the intended learning outcomes.

Moreover, students were grouped into teams to explore two specific points of sale during field visits. Students observed the current situation and existing procedures to verify the existing problems. Each team had the opportunity to make two scheduled

visits to the assigned points of sale. The first visit was conducted to gather data, and the second was scheduled to validate or adjust the proposals under development (see abstract conceptualization).

Overall, during their first visit, students explored shopfloor retail operations, looking at customer journeys, layout distributions, product assortments, inventory levels, quality issues, customer and material flows, frontstage and backstage staff interactions, warehousing tasks, product characteristics, and waste generation. Therefore, students had the chance to take notes and photographs, interview people, make direct observations, carry out measurements and counting, and review reports. The concrete experience stage gave students a full immersion into the store operations to identify issues of concern regarding product shelf life and solid waste generation. As a result, students linked operations management concepts and methods with the daily retail store operations in practice with a circular economy perspective.

4.2.2. Reflective Observation

Throughout the course, students received lectures and tutoring involving operations management and circular economy topics and the application of the tools outlined in the course program. Moreover, students, independently and through teamwork, had to make connections with academic support among the disciplinary topics of operations management, circular economy, and the company's practical issues linked to one of the learning challenges. Overall, this stage aimed at students making sense of the challenging situations in operations management terms.

Hence, during this stage, students discovered that waste generation can be linked to inefficient operations management practices in which inappropriate demand forecasting, poor inventory planning, inadequate materials handling, incorrect product assortments, and inefficient retail operations can lead to the mismanagement of product shelf lifetimes and the generation of expired products. Additionally, because of unsustainable consumption patterns and consumer preferences or ill-designed products, solid waste was generated as a part of a linear-economy business paradigm in product design, particularly concerning packaging, glass bottles, and cardboard. Students recognized that waste generation has effects on operations as this situation increases material, logistic, and inventory handling costs while also occupying warehousing space. As a result of this stage, students diagnosed the study situations to recognize the root causes of the problems.

To conclude this stage, students made PechaKucha presentations (20 slides, 20 s each) to share their findings and obtain feedback about the application of operations management concepts and methods to approach the study situation.

4.2.3. Abstract Conceptualization

This stage facilitated the formulation of proposals and action plans to tackle the issues of disposal, re-use, or recycling of products and packaging/packing materials based on the framework provided in Figure 1. Additional support and advice were also provided to students on sustainability and the circular economy before their second field visit. Hence, students prototyped operations management-based proposals that were further discussed during their second field visit with company staff at the points of sales or warehouses to obtain feedback and recommendations.

In this sense, students used different operations management concepts and methods to address the identified issues and their root causes by creating specific solutions. Students made use of topics, such as process mapping, product and service design and development, process layouts, supplier relationships, supply chains and inventory management, lean operations, continuous improvement, and project management. Finally, students presented their results to the company staff, explaining and justifying their practical value for implementation during their second field visits. Hence, students validated their proposals and received feedback to improve their designs. This stage was critical in terms of students' knowledge testing and understanding the professional implications of their work.

4.2.4. Active Experimentation

In this final stage, students concluded and delivered their proposals to test and validate their results. They presented their proposals as a team, providing detailed descriptions and justifications. An evaluation was conducted directly by Bodegas Alianza executives using assessment rubrics, who played a key role in providing feedback and assessing the projects. In this phase, students presented their proposals using the PechaKucha format in an agile format that encouraged synthesis and clarity in the presentations. Subsequently, feedback was provided regarding the proposals' business value, relevance, applicability, and long-term impact. Students' proposals covered the following operational aspects linked to waste generation and circular economy actions:

- Logistic strategies for glass bottle recovery from end-consumers and marketing events;
- Re-use processes of glass bottles for marketing promotion activities;
- Logistic strategies for packing and packaging material recovery from retail points and warehouses;
- Inventory management procedures to deal with expiration dates and damaged products;
- Product forecasting analysis and marketing strategies for demand seasonality and low-demand products.

However, further details of these proposals are not provided because of confidentiality agreements between the university and the company.

The challenging learning experience and structured assessment process allowed students to develop problem-solving skills, collaborate effectively with industry professionals, and apply theoretical knowledge in a real business context. Furthermore, it promoted sustainability and the circular economy as essential approaches in business decision making.

4.3. Sustainability Education and Pedagogical Results

Referring to the integration of sustainability and circular economy concepts into the design of experiential learning activities in the learning experience, the results show, in the pedagogical design, the following:

- A link of specific disciplinary content with circular economy themes was implemented in a way not indicated/explored in the course design or the existing literature. This prompted instructors to identify practical relationships between theoretical concepts and teaching and learning practice, aligning them with sustainability principles;
- The implementation of learning activities beyond the disciplinary course scope to understand their personal and professional responsibility towards the sustainability of their communities;
- The implementation of learning activities with a transdisciplinary sense of sustainability education;
- Collaboration and teamwork in multidisciplinary settings;
- The integration of the course activities with the local business environment as educational partners to develop real-world live case-study-based education.

4.4. Students' Results and Achievements

The main methods of learning assessment in this course involved a final summative exam (30%) and the learning challenge project (40%) as part of the final mark. Other methods of assessment included homework, reading journals, attendance, and two partial exams, which accounted for the remaining marks (30%).

The learning experience evaluation covered a student feedback survey and a student opinion survey (initial and final) about their interest and motivation and their learning relevance.

Data collection on students' opinions did not include student demographics or attendance records. All students voluntarily participated in the learning activities, including the data collection and surveys, with equal participation opportunity and accessibility. This condition means that there were no student samples or random selections during the

surveying process. Moreover, all survey data were anonymized, and no connections can be made between individual students, learning results, and their survey opinions. As students' answers in surveys correspond to their views and personal opinions of this unique learning experience, these may differ from any other learning experience or study situation with no possibility of comparison.

Additionally, as students freely and anonymously responded to the surveys, the participation rates varied. Students reported neither any significant difficulties nor disruptions during the learning experience.

The learning experience study variables, measurement scales, and evaluation/assessment instruments are summarized in Appendix A (Table A1). The variables define *how to assess* students' learning achievements and the learning experience. Results of the learning experience are presented in Appendix A (Tables A2–A5) to describe the study variables in detail.

The students' comments regarding the course, as presented in the student feedback survey, underscore the possibility of linking the course content to a professional context. Similarly, students highlighted that their learning environment was fostered by actively participating in class and expressing their ideas. Additionally, the course structure enabled the use of resources and teaching strategies that facilitated their learning. The learning activities also allowed for the objective evaluation of learning outcomes under the initially proposed learning objectives at the beginning of the course.

5. Discussion

5.1. Evaluation and Interpretation of Results

This study examined the outcomes of implementing experiential learning in an HE module focused on circular operations management. This allowed us to illustrate the pedagogical design, learning activities, learning achievements, student opinion feedback, and the impact on students' interest, motivation, and learning relevance while achieving the specific course objective.

The pedagogical design revealed strengths, weaknesses, opportunities, and threats in the incorporation of circular economy concepts into the operations management learning activities.

- Strengths:
  - a. The use of experiential learning as the guiding pedagogical approach to provide a methodological framework;
  - b. Relationship with an educational partner, who provided access to facilities, information, and assigned personnel to attend to students;
  - c. Pedagogical experience of the faculty members in carrying out experiences of this type in other courses and institutions;
  - d. Selection of a study topic that could be clearly identified in the company's operations and, at the same time, be evident in the daily lives of the students,
  - e. Participation and interest of students in developing practical activities with an impact on the community;
  - f. Students' independent research work and contextualized, reflective and hands-on learning;
  - g. The integration of interdisciplinary topics in the course to address multifaceted real-world challenges.
- Weaknesses:
  - a. The pedagogical design required to make time available to address sustainability topics in the course due to the formal time allocation in the analytical program. This was addressed by treating each sustainability theme as an inherent requirement in each disciplinary topic;
  - b. Available time was necessary for course planning. It was addressed with dedication and commitment from the faculty beyond their standard work commitment;

c. An assessment of the impact on student learning and the development of their learning outcomes was not conducted. Although the course results were satisfactory in surveys and grades, a precise evaluation and analysis of the effect on the achievement of learning outcomes, knowledge, and skills of the students are still pending;
d. As the course did not have an additional budget to support student activities, this condition limited the coverage of stores and student visit schedules and times. However, this condition was not reported in students' opinions.

- Opportunities:
  a. Explore other sustainability topics related to the course, such as gas emissions, food safety, traffic congestion, and energy consumption, among others. This possibility is now under review in the course;
  b. Expand the study to other courses in engineering programs; however, this possibility is not yet under evaluation as it requires expanding collaboration;
  c. Incorporate other teachers for their training and familiarization with sustainability education in future developments;
  d. There is an opportunity to establish ongoing collaboration with the company and other local companies depending on future course designs;
  e. Soft and hard skills, such as problem solving and decision making, offer opportunities for the personal and professional development of students. Future pedagogical designs can reinforce this proposition.
- Threats:
  a. Losing the connection with Bodegas Alianza or not having access to other companies. New collaborations should be developed with other educational partners;
  b. Losing the collaborative relationship between the course instructors (Universidad Panamericana–Aston University). A formal partnership must be developed.

Furthermore, the case study revealed appropriate results concerning the course passing rates, project marks, and students' opinions (see Appendix A Table A2). Referring to the methods of assessment, students obtained a higher mean and median mark in the project than in the exam, with a smaller standard deviation and interquartile range (IQR). These results are consistent with previous work with experiential learning experiences [40,60].

According to the student opinion surveys (see Appendix A Tables A3 and A4), the learning experience was highly regarded in the final survey as relevant and interesting, with median and mode scores of 5 and an IQR of 1 and 2, respectively. In the case of motivation, this was scored with 4, with an IQR of 1. In addition, students rated the development of their citizenship commitment ability with a median and mode score of 4 in the final survey, indicating a positive result. However, a Mann–Whitney test determined differences between the population medians of the initial and final survey (questions in Tables A3 and A4). This analysis assumed the data had a similar distribution, which did not need normality [61]. Referring to relevance, interest, and motivation, the p values of the two-tailed Mann–Whitney test resulted in $p > \alpha = 0.05$, which means that the null hypothesis could not be rejected in all cases. That is, for question 1 relevance $p = 1.0$, question 2 interest $p = 0.80$, question 3 motivation $p = 0.65$, and citizenship commitment $p = 0.094$. This result suggests that the medians of the initial and final survey answer results were not different (H_0: $\theta_x = \theta_y$, H1: $\theta_x \neq \theta_{y)}$. These results suggest that students maintained their level of recognition during the learning experience without change. However, the small number of data records used in this test makes it necessary to increase the number of participants in future cases.

Referring to the course feedback survey, the results show a high evaluation of the utilization of pedagogical strategies and resources to support learning in the course and the contextualization of learning within professional practice. In both cases, the results indicate a value of 5 in the median and mode, with an IQR of 1 and 0, respectively. These scores can be interpreted as the excellent appreciation students had of the course, which

might be created by the experiential learning challenge. This view is consistent with the only two comments obtained in the survey, which highlight the practical application of theories in the project and the great opportunity students obtain to understand learning contents linked to real-world settings.

Regarding the research process, the results require a discussion regarding transferability, reliability, and validity criteria. Regarding transferability, as generalizability, this work points to positive opinions on experiential learning experiences and learning achievements circular operations management learning experience. Accordingly, this work only contributes to exemplify, in one case, the use of experiential learning for circular operations management education. However, additional instances of learning experiences are required to identify similarities or invariances and make further inferences on other situations.

Concerning reliability, the collected responses in the different surveys show limitations. In the case of the initial student opinion survey, the student participation level represented 84%, whereas the final survey was 30%. Using the Yamane simplified formula of proportions [62], the survey results have a level of precision (e) of 6.17%. These calculations assume a confidence level (P) of 95%, population (N) equal to 50, and sample size (n), corresponding to the number of obtained answers (42) in the initial survey. In the case of the final student opinion survey, the sampling error is 21.60%. Referring to the course student feedback survey, the sampling error is 7.07%. A precision value of 0% points to 100% accuracy. Hence, reliability is limited in this work because of the inconsistent survey participation levels. However, this work illustrates an alternative to developing further instances of learning experiences for circular operations management and obtaining consistent results.

Finally, concerning validity, these work results have similarities with experiential learning theory, concerning a positive impact on students' learning, motivation, and interest [50,63]. However, future instances are required to make any further claims.

Furthermore, the students' work demonstrated their understanding and ability to develop alternatives to overcome circular economy issues in retail and warehousing operations, which contributed to their overall learning outcomes and skills development for operations management learning. Considering the course marks and survey results, the results suggest that students could appropriately accomplish their learning objective, and they were also highly interested and motivated and considered their learning relevant.

Referring to the learning experience design, the case study shows the opportunity to translate a real-world situation into immersive learning activities. This case study illustrates the application of the experiential learning cycle to conceptualize and adapt learning activities linked to the stages of CE, RO, AC, and AE.

Finally, concerning students' work on circular operations management, the results suggest that students successfully explored solid waste issues in real practice. This experience allowed students to integrate a real-world circular economy challenge, operations management learning content, and a practical problem-solving process. Hence, students conducted an experiential learning problem-solving process to benefit both their personal development and the educational partner. This learning experience also shows how undergraduate students can learn beyond the classroom and expand application cases for operations management education.

5.2. Findings

This work contributes to education and teaching practice in the discipline to expand experiential learning cases in the literature for HE. Nevertheless, future work and further examples remain necessary to expand disciplinary topics, contexts, and challenges.

The findings highlight the innovative and effective integration of sustainability and circular economy concepts into the pedagogical design, leading to diverse positive outcomes that extend beyond traditional disciplinary boundaries.

The pedagogical design shows that there is still a need for further investigation into the impact of course design on specific learning outcomes to ensure alignment with

intended goals. Exploring additional sustainability topics within the course could enhance its professional relevance and scope. Additionally, assessing the long-term impact of the course on students' professional development and application of learned concepts could provide valuable insights. Moreover, investigating the long-term collaborative relationships with external partners and their impact on course outcomes is crucial.

Moreover, the case study provided a novel opportunity to go beyond traditional in-classroom study situations to explore real-world sustainability-related problem situations for students. By directly looking at the effects of solid waste, students were able to identify their business and sustainability impact, not only on the company but also on their cities and communities.

Referring to the learning experience, the results suggest that students regarded this as relevant, motivating, and interesting, which may be linked to their opinion on learning contextualization, the use of pedagogical strategies, and the proportion of passing marks. Therefore, the learning experience might contribute to the effective accomplishment of learning objectives and students' learning. However, this requires further investigation.

In conclusion, the findings supported the effectiveness of experiential learning in promoting sustainable practices and engaging students in their education. This study provides valuable insights for educators aiming to create motivating and relevant learning experiences while fostering students' commitment to sustainability and moving toward the circular economy.

5.3. Limitations and Further Actions

Limitations do exist in this work regarding different aspects of the learning experience. First, a limitation exists in the work concerning the ideas of experiential learning. Other pedagogical approaches do exist for instructional design and learning understanding and conceptualization. However, this approach is well known but requires further implementations in the discipline. Other pedagogical approaches such as challenge-based learning or problem-based learning could underpin future efforts.

Another limitation concerns the methodology of this work. A single case study can only provide conclusions about a single instance of a learning experience, which limits research transferability and validity but provides insights for similar initiatives that might be taken in the future. There is also a limitation in terms of data collection regarding the opinion surveys. In this case, survey results depend on students' viewpoints and opinions, which might be misleading or influenced during a learning experience. However, the learning experience survey results were compared with course feedback survey results for validation. Both consistently resulted in high scores. Last, the number of participating students in the surveys limited the statistical analysis, making it necessary in future instances to increase the number of response records.

Additionally, limitations also exist regarding the assessment and evaluation instruments specifically tailored to the learning experience. Accordingly, further tools should be developed for specific data collection on student learning effectiveness, satisfaction, engagement, and course recommendation.

Last, incorporating a learning challenge as part of a course involved an additional workload and effort of the instructor and supporting team. The extra requirements involve resources for the learning experience design, planning, execution, and evaluation. Consequently, this extra effort can discourage other academics from developing and implementing this type of learning experience in the future.

5.4. Future Work

Further implementations of new instances of learning experiences for operations management and circular economy education are required to improve their impact on learning effectiveness and sustainability education. Additionally, future work should focus on creating new instances of other sustainability-related topics but also in other business and operational contexts for novel learning experiences in the discipline. Moreover, further

work is needed concerning the research methodology limitations. This effort requires upgrading data collection methods and instruments of analysis for new possible study variables and improving research reliability, transferability, and validity. An analysis is also required concerning students' learning outcome development under this type of learning experience. Finally, other pedagogical approaches might be adopted to illustrate their use for circular operations management. This is the case of project-based learning, gamification, or challenge-based learning.

6. Conclusions

The circular economy can help to create novel experiential learning experiences for operations management education to engage students in the accomplishment of their learning objectives. Relevant study situations can be conceptualized by linking current sustainability issues affecting humanity with those challenges companies face in their operations and teaching and learning activities in HE.

This work illustrates how topics of the circular economy concerning solid waste generation and economic value loss can be linked to operations management regarding aspects of inventory management, logistics, retail operations, and warehousing. It also shows that novel learning experiences in circular operations management can be created for undergraduate engineering education.

Accordingly, the main contribution of this work is a pedagogical approach in terms of experiential learning. Specific activities for the four stages of the experiential learning cycle are proposed to provide students with a concrete experience in solid waste generation in business processes and operations, reflective observation to understand the underlying causes of waste, abstract conceptualization to create plausible operations management-based alternatives to tackle the originating causes, and active experimentation by presenting and validating proposals with business executives.

A case study allowed for illustrating these ideas and provided insights about creating further learning experiences in circular operations management. The main aim was to create highly relevant learning experiences that foster students' interest, motivation, and relevance across different business industries. However, there is also pending work to conclude on this type of learning experience and their contribution to enriching students' learning. Therefore, further cases must be developed to validate this work and refine formulations and statements on this work.

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Appendix A

Table A1 shows students' marks in their course assignments. Table A2 shows students' mark scales on the final summative exam and the report (including the presentation). Tables A3 and A4 present the student opinion survey results through a longitudinal process, at the start and end of the course, with an intervening period. The survey questions referred to students' interest, motivation, learning relevance perception, and their ability to create solutions for the social transformation of cities and communities. Finally, Table A5 shows the student feedback survey results of this course.

Overall, Tables A2–A5 explain the data distribution, such as the means, standard deviations (Std Dev), medians, modes, quartiles (Q1 and Q3), IQR (interquartile range), minimum and maximum values (MIN and MAX), and range, if applicable. Furthermore, students attained a 100% passing rate in their course evaluation, 84% passed the final summative exam, and 100% passed the learning challenge report.

Table A1. Study variables of the learning experience.

Variables	Scale	Instrument
Final course mark (individual)	0–100	Weighted mark calculation
Final summative exam (individual)	0–100	Mark calculation
Report mark (teamwork, including presentation)	0–100	Rubric
Level of interest (initial and final)	1–5	Survey
Level of motivation (initial and final)	1–5	Survey
Level of learning relevance (initial and final)	1–5	Survey
Level of citizenship commitment * (initial and final)	1–5	Survey

* Citizenship commitment is defined as the ability to create committed, sustainable, and supportive solutions to social problems and needs through strategies that strengthen democracy and the common good.

Table A2. Students' marks.

Marks	N	Mean	StdDev	Min	Q1	Median	Q3	Max	IQR	Mode
Final (100%)	50	8.3	0.93	5.0	7.85	8.4	8.99	9.6	1.14	NA
Exam (30%)	50	7.8	2.15	0.0	6.35	8.6	9.3	10.0	2.95	10
Report (40% including, presentation)	49	9.0	0.46	8.0	8.66	9.0	9.33	9.7	0.67	8.33

Table A3. Student Opinion Survey of the Learning Experience (Initial Results).

Question	N	Min	Q1	Median	Q3	Max	IQR	Mode	N Mode
1. How RELEVANT is doing circular economy learning activities in this course to your studies and professional practice?	42	2	4	5	5	5	1	5	23
2. What level of INTEREST do you get from doing circular economy learning activities in this course to benefit your future professional practice?	42	2	4	4	5	5	1	5	19
3. What level of MOTIVATION do you get from this course's circular economy learning activities?	42	2	3	4	5	5	2	4	16
4. How do you now consider the level of development of your CITIZENSHIP COMMITMENT ability?	42	1	3	4	5	5	2	3	13

Table A4. Student Opinion Survey of the Learning Experience (Final Results).

Question	N	Min	Q1	Median	Q3	Max	IQR	Mode	N Mode
1. How RELEVANT was doing the circular economy learning activities in this course to your studies and professional practice?	15	2	4	5	5	5	1	5	9
2. What level of INTEREST did you get from doing the circular economy learning activities in this course to benefit your future professional practice?	15	3	3	5	5	5	2	5	8
3. What level of MOTIVATION did you get from conducting the circular economy learning activities in this course?	15	3	4	4	5	5	1	4	6
4. How do you consider the development of your CITIZENSHIP COMMITMENT ability in the circular economy learning activities in this course?	15	3	4	4	4	5	0	4	11

Table A5. Results of the course student feedback survey.

Question	N	Min	Q1	Median	Q3	Max	IQR	Mode	N Mode
Utilizes pedagogical strategies and resources to support learning	40	3	4	5	5	5	1	5	29
Contextualizes course learning topics within professional practice	40	3	5	5	5	5	0	5	37

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