

Circular Operations Management in Higher Education

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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. Operations management is crucial for leading and conducting the necessary business processes and operations to facilitate these efforts. In light of these sustainability demands, there is a need for Higher Education (HE) students to gain the essential knowledge and skills beyond disciplinary expertise in isolation, to promote sustainable development now and in their future careers. Additionally, considering sustainability issues in HE provides stimulating and pertinent learning challenges that can enhance student learning outcomes, motivation, and engagement.

circular economy

educational innovation

engineering education

experiential learning

higher education

operations management

sustainability

Sustainable Development Goals

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 ^[2]. 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 ^[3], resource recovery, and waste reduction ^[3].

On the other hand, operations management is a field of study about the design, planning, control, and improvement of business processes and operations ^[4]. 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 ^{[5][6][7][8]}. 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 [9]. 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 [10][11]. These challenges include technological, economic, regulatory, market, and organizational barriers. Consequently, operations management can influence the implementation of circular economy practices [9]. However, there is still pending work on the key role of circular economy-related operational practices in achieving the SDGs [12].

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 [13].

Forward Supply Chain Flow	Supply chain stage	Reverse Supply Chain Flow	Circular Economy Actions		
			Finite materials		Renewables
↑	Consumer	↓	Maintain/prolong	A consumer maintains a product in good condition to avoid, minimize, or eliminate waste.	Bio-regeneration and biochemical feedstock
	Distribution		Reuse/redistribute	A retail function recovers and handles the subsequent sale of a used product after ensuring it meets quality standards.	
	Assembly		Refurbish	A distribution or outbound logistics network recovers and ships the used product to a refurbishing facility to ensure that it is renewed to meet quality standards and its service life is extended before offering it for sale.	
	Component production		Remanufacture	A product must be returned to a production operation for disassembly/dismantlement, remanufacturing, and subsequent reassembly before sale to a consumer as a remanufactured/reconditioned product.	
	Raw materials extraction and exploitation		Recycle	Some components can be recovered from used products, reutilized in conjunction with newly obtained raw materials, and later placed forward in the supply chain. inbound logistics	

Figure 1. Circular supply chain flows framework (own elaboration) adapted from [1][14].

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 [15][16]. 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 [17][18]. 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 [19][20]. In some other cases, efforts have been made to develop specific learning outcomes regarding sustainable development and the circular economy [17][21]. These courses often adopt an interdisciplinary or multidisciplinary approach to know and address the intricate challenges of the circular economy [22]. This is the case for engineering, environmental science, business, economics, policy, and social sciences [18][23].

Additionally, active methods have been employed in teaching circular economy and sustainable development [24][25]. 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 [23]. 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 [23][26]. Furthermore, teaching circular economy aligns with the increasing focus on sustainability and social responsibility in HE [27]. 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.

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 [28][29]. According to PRME [13], 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 [30]. 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 [31]. A learning experience is considered in this work as the basic unit of study or the research object [32].

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 [33][34][35][36][37][38]. 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 [39].

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. 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 [40].

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.

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