

Education for a Circular and Climate-Neutral Future: A Comprehensive Literature Review and Overview of the EDU4PlastiCircular Project Outcomes

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Abstract

The aim of the paper is present a comprehensive bibliographic analysis of similar initiatives in the field of education for responsible practices in the circular economy and to provide a detailed analysis of the EDU4PlastiCircular project (Erasmus+, 2023-1-RO01-KA220-HED-000166242) results as a good practice for responsible behaviour to combat plastic pollution (including micro/nano) by educating the public on the responsible use of plastics in a sustainable and climate-neutral economy. The initiative focuses on preventing the accumulation of waste in nature by providing essential educational resources, such as a digital library and online learning courses. This effort is supported by an international academic collaboration between universities and organizations from Romania, Slovenia, Spain and Italy. Through its strategic partnerships with local and regional stakeholders, the project promotes good practices for responsible resource management and environmental protection.

Keywords: Plastic materials, Micro/nano plastic, pollution, circular economy, education, open education resources (OERs), digital library, e-learning, EDU4PlastiCircular project

INTRODUCTION

The global waste plastic crisis represents one of the most pressing environmental challenges of the 21st century, with an estimated 8 million tons of plastic entering the oceans annually and microplastics detected in virtually every ecosystem on Earth. The persistence of plastic materials in the environment, combined with inadequate waste management infrastructure in many regions, has created environmental and health challenges that demand urgent, coordinated action. The transition from a linear “take-make-dispose” model to a circular economy framework has emerged as a critical strategy for addressing plastic pollution while maintaining economic viability (Calleja, 2019; Giurea et al., 2024). However, this transition requires fundamental shifts in knowledge, attitudes, and behaviours across all levels of society, positioning education as a cornerstone of systemic change (Dermol & Dermol, 2024; Dermol et al., 2024). Educational initiatives for circular economy and plastic circularity have proliferated globally over the past decade, spanning formal education systems, community-based programs, and professional training (Dermol et al., 2024; Školnik Škrabe & Bubik, 2024). These initiatives aim to develop green skills/competencies and foster responsible environmental practices through diverse pedagogical approaches. The EDU4PlastiCircular project, an Erasmus+-funded initiative, represents a significant contribution to this field by specifically targeting higher education institutions to build capacity for addressing plastic pollution through circular economy principles (Draghici et al, 2024).

In this context, the article aims to provide a comprehensive literature review on educational initiatives for responsible practices in circular economy and plastic circularity based on synthesizes evidence from more than 100 most relevant scholarly publications to (1) characterize the landscape of educational initiatives in circular economy and plastic circularity; (2) examine the EDU4PlastiCircular project and similar initiatives in depth; (3) identify effective pedagogical approaches and their outcomes; (4) analyze challenges and barriers to implementation; and (5) provide evidence-based recommendations for future educational interventions. The review addresses a critical gap in understanding how education can accelerate the transition toward responsible plastic management and circular economy practices. In addition, there will be presented the EDU4PlastiCircular project, an Erasmus+ funded initiative and best practice, which represents a significant contribution to this field by specifically targeting higher education institutions (HEIs) to build capacity for addressing plastic pollution through circular economy principles [8].

BACKGROUND AND THEORETICAL FOUNDATIONS

The circular economy represents a systemic approach to economic development that decouples growth from resource consumption through resource efficiency, waste minimization, and continuous material cycling (Vlad at al., 2022; Giurea et al., 2024; Dermol et al., 2024). Unlike the linear economy model that follows a “take-make-dispose” pattern, circular systems emphasize keeping materials and products in use for as long as possible through design innovation, maintenance, reuse, refurbishment, remanufacturing, and recycling. In the context of plastics, circularity involves reducing virgin plastic production, extending product lifespans through durable design, improving collection and sorting systems, and developing advanced recycling technologies that can handle diverse plastic types (Školnik Škrabe et al., 2025). The circular plastic economy also requires addressing the full lifecycle of plastic materials, from sustainable sourcing of feedstocks to end-of-life management that prevents environmental leakage.

Plastic pollution has reached crisis proportions, with microplastics contaminating marine ecosystems, freshwater systems, soils, and even human bodies. The persistence of plastic materials, combined with inadequate waste management infrastructure in many regions, has created environmental and health challenges that demand urgent action. Education emerges as a critical intervention point for changing consumption patterns, improving waste management practices, and fostering innovation in circular plastic systems (Vlad et al., 2022; Mulita, 2023; Giurea et al., 2024). Education for sustainable development (ESD) provides the theoretical foundation, emphasizing systems thinking, anticipatory competence, and transformative learning. Circular economy education extends ESD principles by focusing specifically on material flows, product lifecycles, and the economic dimensions of sustainability. Effective circular economy education requires interdisciplinary approaches integrating environmental science, engineering, economics, and social sciences (Dermol & Dermol, 2024; Dermol et al., 2024; Hamid et al., 2024).

The EDU4PlastiCircular project (<https://microplastics.today/>) represents a pioneering European initiative funded through the Erasmus+ program to address the critical need for circular economy education focused on plastic materials (Draghici et al, 2024). The project aims to drive the EU Green Deal through innovative university curricula that integrate circular economy principles, sustainable materials management, and systems thinking approaches. EDU4PlastiCircular employs a multi-institutional partnership model involving universities, research centres, and industry stakeholders across multiple European countries (Draghici et al, 2024). The project's primary objectives include: (1) developing comprehensive curricula for circular plastic economy education; (2) creating open educational resources accessible to diverse learners; (3) fostering green skills development among students and professionals; and (4) establishing networks for knowledge exchange and collaboration.

The project utilizes innovative pedagogical approaches including virtual learning environments, cyberpedagogy, and hybrid educational formats that combine synchronous and asynchronous learning (Dermol & Dermol, 2024; Draghici et al, 2024). These approaches enable flexible, scalable education delivery while maintaining high levels of student engagement and learning outcomes. The curriculum emphasizes experiential learning through case studies, industry partnerships, and real-world problem-solving activities. Early evidence suggests that EDU4PlastiCircular is successfully building capacity for circular economy thinking in higher education (Draghici et al, 2024; Školnik Škrabe et al., 2025). Students participating in the program demonstrate improved understanding of circular economy principles, enhanced systems thinking capabilities, and greater awareness of plastic pollution challenges. The project's open educational resources have reached diverse audiences beyond the initial partner institutions, amplifying its impact across Europe.

MAIN ISSUES HIGHLIGHTED BY THE LITERATURE

Pedagogical Approaches in Circular Economy Education

Experiential learning emerges as a dominant pedagogical approach, with hands-on activities fostering deep understanding and behavioural change. Activities such as waste audits, recycling workshops, and upcycling projects enable direct engagement with circular economy principles (Nguyen, 2023; Dermol & Dermol, 2024; Školnik Škrabe et al., 2025). In many universities and schools, outreach program using hands-on chemistry experiments with recycled plastics significantly improved students' understanding and attitudes toward sustainability (Hamid et al., 2024). Furthermore, citizen science has emerged as a powerful pedagogical tool, engaging diverse communities in data collection and problem-solving.

Microplastic monitoring projects involving school students successfully combine scientific learning with environmental awareness (Dermol & Dermol, 2024; Školnik Škrabe et al., 2025). The MALIA project exemplifies large-scale citizen science initiatives raising awareness about marine litter across multiple countries (Gravina et al., 2019). In the last years, serious games provide engaging platforms for exploring complex circular economy systems. Game-based approaches enable learners to experiment with strategies and observe system-level consequences. Effective circular economy education requires interdisciplinary approaches fostering systems thinking capabilities (Nguyen, 2023). STEM education frameworks increasingly incorporate circular economy concepts (Nguyen, 2023), while the CIRCULAR pathway methodology exemplifies structured approaches to teaching circular value chain redesign (Školnik Škrabe et al., 2025).

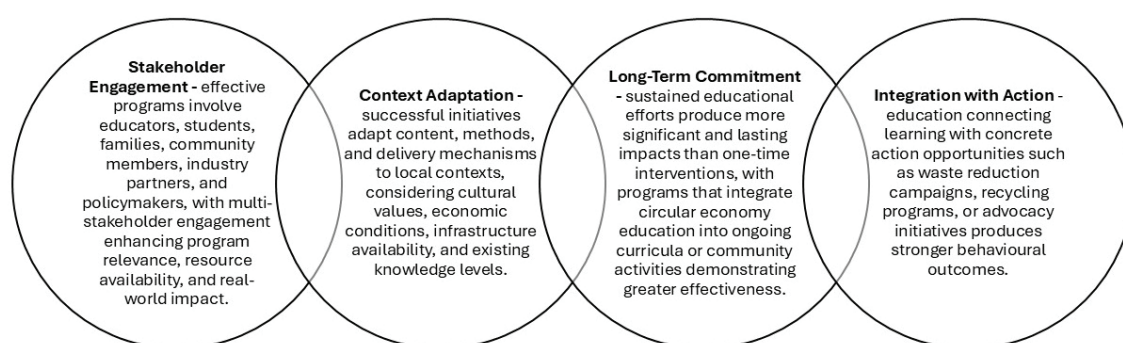
Educational Initiatives Across Different Contexts

Universities worldwide are integrating circular economy and plastic sustainability into curricula across multiple disciplines (Bugallo-Rodríguez et al., 2020; Giurea et al., 2025). Engineering programs emphasize sustainable materials management, business schools incorporate circular economy business models, and environmental science programs focus on waste management systems. In addition, primary and secondary schools represent critical intervention points for developing circular economy literacy (Laius et al., 2024). Educational initiatives emphasize age-appropriate hands-on activities such as waste sorting games and recycling projects. Integration of EU policies on plastics into teaching materials provides students with understanding of regulatory frameworks. Rural schools face unique challenges but can successfully develop students' understanding through adapted pedagogical approaches (Laius et al., 2024). Furthermore, community-based initiatives play vital roles in promoting circular economy practices, particularly in regions with limited formal education infrastructure (Widiastuti et al., 2023). These programs often combine environmental education with economic empowerment, teaching communities to transform plastic waste into valuable products. Professional training programs targeting waste management professionals and policymakers are essential for implementing circular economy systems at scale (Velis et al., 2022).

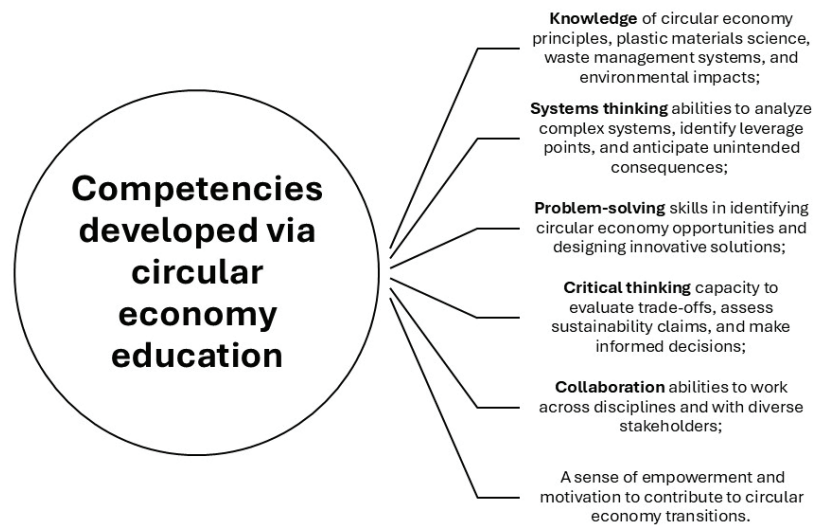
Key Findings and Comparative Analysis

Based on the literature review, several factors consistently emerge as critical for success are presented in Picture 1. Also, circular economy education develops multiple competencies as show in the synthesis presented in Picture 2.

Picture 1: A synthesis of key success factors circular economy education



Picture 2: The competencies developed via circular economy education



Research demonstrates that well-designed educational interventions significantly improve knowledge, attitudes, and behaviours related to circular economy and plastic. Studies report improvements in environmental awareness, waste reduction behaviours, and support for circular economy policies following educational interventions. However, experiential approaches generally produce stronger and more durable learning outcomes compared to lecture-based instruction alone. Interventions combining knowledge transmission with skill development and practical application demonstrate highest effectiveness. Furthermore, educational institutions face numerous structural barriers including rigid curriculum structures, disciplinary silos, and standardized testing requirements that limit flexibility for integrating new content and pedagogical approaches (Hamid et al., 2024). Teacher training programs often lack adequate preparation in circular economy concepts and sustainability pedagogy (Bugallo-Rodríguez et al., 2020). Resource constraints represent significant barriers, particularly in under-resourced schools and rural communities, where implementing hands-on circular economy education requires materials, equipment, space, and time that may not be readily available (Laius et al., 2024). Limited teacher knowledge and confidence in circular economy topics constrains educational quality and reach. Many educators lack training in circular economy principles, systems thinking approaches, and relevant pedagogical methods. Professional development opportunities remain insufficient to address these gaps at scale. Students often enter with misconceptions about recycling and waste management that must be addressed before deeper learning can occur (Dermol et al., 2024; Škrabe et al., 2024; Draghici et al., 2024). Limited prior knowledge of materials science, industrial processes, and economic systems can impede understanding of circular economy concepts.

Discussion and Implications

Education plays a vital role in advancing circular economy transitions and addressing plastic pollution, though it must be coupled with supportive policies, infrastructure development, and economic incentives to achieve systemic change (Bugallo-Rodríguez et al., 2020). The EDU4PlastiCircular project and similar initiatives represent important innovations through technology-enabled learning, multi-stakeholder partnerships, and open educational resources (Mulita, 2023; Draghici et al., 2024). The shift toward experiential, participatory, and action-oriented pedagogies reflects growing recognition that circular economy education must develop not only knowledge but also skills, values, and agency (Laius et al.,

2024). Citizen science approaches exemplify this shift, engaging learners as active contributors to knowledge production and environmental problem-solving (Školnik Škrabe et al., 2025). Interdisciplinary integration emerges as both a critical success factor and a persistent challenge (Nguyen, 2023). Circular economy concepts span multiple disciplines, requiring educational approaches that transcend traditional subject boundaries. The global nature of plastic pollution necessitates international collaboration in educational initiatives. Equity considerations must be central to circular economy education, ensuring accessibility to diverse learners regardless of geographic location or socioeconomic status (Velis et al., 2022).

EDU4PLASTICIRCULAR PROJECT OVERVIEW OF THE OUTCOMES

The project Consortium (<https://microplastics.today/partners/>) has produced a range of deliverables, focusing on gap analysis, training methodology design, and open educational resources to define the training and certification programme (Table 1).

Table 1: EDU4PlastiCircular project results

Results and their visibility	Description
D2.1 Gap analysis and collection of best practices / https://microplastics.today/project-results/	This includes a gap analysis and a collection of best practices related to plastic in the circular and neutral economy. It also features videos showcasing good practices from partner countries: Italy, Slovenia, Spain, and Romania.
D2.2 Training methodology design / https://microplastics.today/project-results/	This involves the analysis of existing training programs, synthesis of training programs, definition of training personas, syllabus, curricula, learning objectives, course levels (BSc, MSc, PhD, LLP, VET), learning paths, and course agenda. It also includes guidelines for organizing training in HEIs and defining training methods for live and online sessions. The project also performed online train-the-trainers' courses.
D2.3 Handbook for Trainers / https://microplastics.today/project-results/	A comprehensive handbook for trainers has been developed and translated into Italian, Slovenian, Spanish, and Romanian.
Digital Library / https://microplastics.today/digital-library/	It is an open repository of resources, including e-books, presentations, videos, and best practices. These resources are designed to foster green skills, promote sustainable behaviour, and support education, research, and innovation in plastic management. The library content is organized into modules, corresponding to the e-course structure.
E-learning Platform / https://elearningproject.eu/courses/edu4plasticircular-educating-for-sustainable-plastic-use-and-circular-economy/	The e-learning platform offers the comprehensive environment for EDU4PlastiCircular MOOC. The course is structured into modules covering topics such as: Introduction to the World of Plastics, Plastic Waste Management, Plastics in the Circular Economy and Climate Neutrality, Innovation in the Plastics Industry, and Awareness of Plastic Waste Impact and Responsible Behaviour.
News and Community Engagement / https://microplastics.today/news/ https://microplastics.today/newsletters/ https://www.facebook.com/Elearningproject.eu/	The Consortium members actively disseminate its results and engage with the community through its news section and newsletters, via the project web page or the FB page.

The EDU4PlastiCircular Consortium aims to have a significant impact by: (a) improving behaviour through increased awareness and responsibility in plastic use and management; (b) enhancing understanding of the plastic lifecycle and its environmental impact; (c) promoting best practices for plastic and packaging within the circular and climate-neutral economy; (d) fostering compliance with global and local policies and regulations related to plastic and packaging management; (e) developing green skills among HEI teachers, students, managers, and employees; (f) contributing to a climate-neutral economy by promoting sustainable plastic management.

CONCLUSION AND RECOMMENDATIONS

Educational initiatives for circular economy and plastic circularity have expanded rapidly over the past decade, employing diverse pedagogical approaches across multiple contexts. The EDU4PlastiCircular project exemplifies innovative approaches to circular economy education in higher education, utilizing technology-enabled learning and multi-stakeholder partnerships to build capacity for addressing plastic pollution. Evidence demonstrates that well-designed educational interventions can effectively improve knowledge, attitudes, and behaviours related to circular economy and plastic sustainability. Experiential learning, citizen science, interdisciplinary approaches, and action-oriented pedagogies emerge as particularly effective strategies. However, significant barriers remain, including institutional constraints, resource limitations, knowledge gaps, and systemic factors that limit opportunities to apply learning. Advancing circular economy education requires coordinated efforts across multiple levels, from individual educators and institutions to national policies and international collaborations. Education must be coupled with supportive infrastructure, policies, and economic incentives to achieve systemic transitions toward circular plastic economies. As the global community confronts the plastic pollution crisis, education will play an increasingly critical role in fostering the knowledge, skills, values, and agency needed to create sustainable, circular systems.

Future research should address critical gaps including longitudinal studies examining persistence of learning outcomes and behavioural changes; rigorous comparisons of different pedagogical approaches and program designs; research on effective strategies for scaling successful initiatives; and research on how educational initiatives interact with policy, infrastructure, and economic factors to drive systemic transitions. Policymakers should integrate circular economy and plastic sustainability into national education standards, invest in teacher training and professional development, support development of high-quality educational resources, create enabling conditions that allow learners to apply their knowledge, and foster international collaboration and knowledge exchange. Educators and program designers should employ experiential, hands-on pedagogies; adapt educational approaches to local contexts; foster interdisciplinary learning; connect education with concrete action opportunities; engage multiple stakeholders; use digital technology to enhance accessibility; and incorporate citizen science approaches where appropriate.

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