Chapter Six

Conclusions

Anca Draghici
Politehnica University of Timisoara, Romania

Valerij Dermol
Dermol Ltd., Slovenia

Dana Perniu
Transilvania University of Brasov, Romania

Anja Bubik
Faculty of Environmental Protection, Velenje, Slovenia

Elena Cristina Rada
University of Insubria, Italy

Santiago Ferrándiz Bou
Universitat Politècnica de València, Spain

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Key Messages

The increasing scale and complexity of plastic pollution, particularly the proliferation of micro- and nanoplastics, represent one of the most pressing environmental challenges of the 21st century. As highlighted throughout this book, the persistence of plastics in terrestrial and aquatic ecosystems, combined with their entry into food chains and potential impacts on human health, underscores the urgency of systemic change (Geyer et al., 2017; United Nations Environment Programme, 2021). Addressing this challenge requires not only technological innovation and regulatory frameworks, but also a profound transformation in knowledge, values, and behaviours across society. In this regard, education emerges as a critical driver of the transition toward a circular and climate-neutral economy (Calleja, 2019; Giurea et al., 2024; Draghici et al., 2024).

The evidence presented in this volume confirms that the current linear 'take-make-waste' model of plastic production and consump-

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tion is inherently unsustainable. The exponential growth in plastic production, coupled with low recycling rates and high material value loss, reveals systemic inefficiencies that contribute to environmental degradation and economic loss (Davis, 2022; Islam, 2025). Despite policy efforts such as the European Green Deal, the circular material use rate for plastics remains low, and significant quantities of plastic waste continue to be landfilled, incinerated, or leaked into the environment (Mulita, 2023). These findings reinforce the need for a transition toward circular systems that prioritize prevention, reuse, recycling, and sustainable design.

A central conclusion of this book is that such a transition cannot be achieved without rethinking education. Traditional, knowledge-transmission models of teaching are insufficient for addressing complex, interdisciplinary challenges such as plastic circularity. Instead, effective education must adopt transformative, experiential, and systems-oriented approaches that enable learners to critically engage with real-world problems and develop actionable competencies (Dermol & Dermol, 2024; Hamid et al., 2024). Transformative learning, in particular, plays a crucial role in fostering critical reflection and shifting deeply embedded assumptions about consumption, resource use, and environmental responsibility (Mezirow, 1991, 2000; Taylor, 2007).

Experiential and hands-on learning approaches have proven especially effective in enhancing understanding and promoting behavioural change. Activities such as waste audits, recycling projects, and design of products from recycled materials enable learners to connect theoretical knowledge with practical applications (Kolb, 1984; Kolb & Kolb, 2005; Nguyen, 2023). Similarly, citizen science initiatives have demonstrated strong potential for increasing scientific literacy and environmental awareness, particularly in relation to microplastics pollution, by engaging learners directly in data collection and analysis (Popa et al., 2022; Školnik Škrabe et al., 2025).

The integration of digital technologies into education represents another key dimension of this transformation. Digital platforms, e-learning environments, and open educational resources provide opportunities for flexible, scalable, and inclusive learning (Means et al., 2014; Laurillard, 2012). The EDU4PlastiCircular project exemplifies how digital tools can support knowledge dissemination and capacity-building across diverse contexts. However, the findings also indicate that digital learning is most effective when combined with interactive,

collaborative, and experiential elements, suggesting that hybrid learning models offer the greatest potential for impact (Dermol & Dermol, 2024; Draghici et al., 2024).

Another important conclusion relates to the diversity of educational contexts and target groups. Effective circular economy education must be tailored to different audiences, including students in primary, secondary, and higher education, as well as professionals, policymakers, and community members. Higher education institutions, in particular, play a pivotal role as hubs of knowledge creation, innovation, and capacity-building. They are uniquely positioned to integrate circular economy principles into curricula, foster interdisciplinary collaboration, and act as 'living laboratories' for sustainable practices (Bugallo-Rodríguez et al., 2020; Giurea et al., 2024).

At the same time, the book highlights the importance of community-based and informal education in reaching broader audiences and promoting behavioural change at the societal level. Initiatives that engage local communities, encourage participation, and connect learning with real-life challenges have demonstrated significant potential for fostering environmental responsibility and collective action (Widiastuti et al., 2023; Velis et al., 2022). International and cross-cultural collaboration further enhances these efforts by enabling knowledge exchange and adaptation of best practices across different contexts (Kruja et al., 2025).

Despite these promising developments, substantial challenges remain. Institutional barriers, including rigid curricula, disciplinary silos, and limited incentives for pedagogical innovation, continue to constrain the integration of circular economy education (Giurea et al., 2025; Stathatou et al., 2025). In addition, gaps in educator knowledge and competencies, insufficient resources, and limited infrastructure hinder the implementation of effective educational initiatives (Školnik Škrabe et al., 2025; Dermol & Dermol, 2024). Addressing these challenges requires coordinated efforts at institutional, national, and international levels, supported by appropriate policy frameworks and funding mechanisms.

The findings also reveal a critical need for more robust evaluation of educational interventions. While many initiatives report positive outcomes in terms of knowledge and attitudes, there is limited evidence regarding long-term behavioural change and environmental impact. Future research should therefore focus on longitudinal studies, the de-

velopment of standardized assessment tools, and the measurement of real-world outcomes (Hamid et al., 2024; Dermol & Dermol, 2024).

From a policy perspective, the transition toward a circular economy must be supported by comprehensive educational strategies. This includes integrating circular economy principles into curricula at all levels, investing in teacher training and professional development, and promoting interdisciplinary and experiential learning approaches. Policies should also encourage collaboration between educational institutions, industry, and communities, recognizing that circular economy requires coordinated action across sectors (Mulita, 2023; Draghici et al., 2024).

In conclusion, this book demonstrates that education is not merely a supportive element of the circular economy transition-it is a foundational pillar. By equipping learners with the knowledge, skills, and values necessary to understand and address complex sustainability challenges, education can drive systemic change and support the development of more resilient and sustainable societies. The EDU4PlastiCircular project provides a valuable model for how such education can be designed and implemented, combining innovative pedagogy, digital tools, and international collaboration.

Ultimately, achieving a circular and climate-neutral future depends on our collective ability to rethink existing systems and embrace new ways of learning and acting. This requires not only institutional and technological innovation but also a cultural shift toward sustainability and responsibility. The insights presented in this volume offer both a critical reflection on current practices and a forward-looking vision for the role of education in shaping a more sustainable world.

Limitations and Future Research

Despite the comprehensive scope of this book and the valuable insights generated through the EDU4PlastiCircular project, several limitations should be acknowledged.

First, the analysis of educational initiatives in circular economy and plastic circularity is largely based on existing literature and project-based evidence. While this provides a broad and structured understanding of current practices, it may not fully capture the diversity of informal, emerging, or non-documented educational approaches, particularly those developed in less-researched regions or outside formal institutional settings. Additionally, the majority of the reviewed studies

focus on short-term outcomes, such as increased knowledge or awareness, while longitudinal evidence on sustained behavioural change and real environmental impact remains limited.

Second, the empirical insights derived from the EDU4PlastiCircular project are context-dependent. The project is primarily rooted in European higher education systems and reflects specific institutional, cultural, and policy environments. As a result, the transferability of findings to other geographical or socio-economic contexts (especially low- and middle-income countries) may require careful adaptation. Differences in infrastructure, access to digital technologies, and educational traditions can significantly influence the effectiveness of proposed pedagogical approaches.

Third, while the book highlights the role of digital tools and e-learning environments, the evaluation of these tools is constrained by user preferences and implementation variability. Evidence suggests that digital learning, although scalable and flexible, is not always the most engaging format for learners when used in isolation. The lack of standardized evaluation frameworks for digital and hybrid learning in circular economy education also limits the comparability of results across initiatives.

Fourth, the interdisciplinary nature of circular economy education presents methodological and practical challenges. Integrating knowledge from engineering, environmental science, economics, and social sciences requires coordinated curriculum design and collaboration among educators, which is often difficult to achieve within existing institutional structures. This complexity may have limited the depth of analysis in certain thematic areas.

Looking ahead, several directions for future research can be identified.

There is a clear need for longitudinal studies that assess the long-term impact of educational interventions on behaviour, professional practices, and environmental outcomes. Such research would provide stronger evidence on the effectiveness of circular economy education in driving systemic change.

Future research should also focus on the development of standardized assessment frameworks for measuring competencies related to circular economy and sustainability. This includes not only cognitive knowledge but also skills, attitudes, and behavioural intentions.

Another important avenue is the exploration of hybrid pedagogical

models that effectively combine digital and experiential learning. Investigating how digital tools can support hands-on activities, collaboration, and real-world problem-solving will be critical for enhancing learning outcomes.

Further studies are needed to examine context-specific adaptations of circular economy education, particularly in diverse cultural and socio-economic settings. Comparative research across regions can help identify best practices and support the development of globally relevant yet locally adaptable educational strategies.

In addition, future work should explore the role of industry partnerships and stakeholder engagement in education. Strengthening collaboration between academia, industry, and communities can enhance the relevance and practical impact of educational initiatives.

Finally, the integration of circular economy principles into formal curricula and policy frameworks warrants deeper investigation. Research on institutional change, governance mechanisms, and policy support can provide valuable insights into how educational systems can more effectively contribute to the transition toward a circular and climate-neutral economy.

In conclusion, while this book provides a solid foundation for understanding and advancing education for plastic circularity, it also highlights the need for continued research, innovation, and collaboration. Addressing these limitations and pursuing the identified research directions will be essential for strengthening the role of education as a driver of sustainable transformation.

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