



Exploring Online Education for Circular Economy: Content Analysis and Didactical Approaches in Plastic Waste Management Courses

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Purpose: The increasing emphasis on sustainable practices in managing plastic waste underscores the importance of education and training in fostering a circular economy. This article aims to elucidate the critical role of awareness-raising and capacity-building initiatives, which have become pivotal as societies transition towards more sustainable economic models, particularly concerning plastic management.

Study design/methodology/approach: This article investigates online courses' availability, content, and methodological frameworks dedicated to the circular economy and plastic-related issues. The primary objective is to develop a comprehensive theoretical framework that elucidates how these courses are designed to enhance awareness of plastic-related challenges, disseminate relevant knowledge, and educate the public about potential solutions.

Findings: The analysis focuses on these courses' structure, content, and pedagogical methodologies to evaluate their effectiveness in informing and engaging learners. It assesses how effectively these courses enhance learners' capacities to tackle plastic-related challenges and equip them with the skills necessary for fostering innovation within the plastic value chain.

Originality/value: While awareness-raising and capacity-building are essential for advancing a circular economy, systemic changes in production and consumption patterns are equally critical. The integration of advanced recycling methods, renewable energy solutions, and carbon capture technologies can significantly mitigate the plastic industry's carbon footprint. A holistic approach that comprehensively addresses the lifecycle of plastics—from design to disposal—is essential for achieving a genuinely circular and climate-neutral economy.

Keywords: Circular Economy, Plastic Waste Management, Online Education, Sustainable Practices, Didactical Approaches

Introduction

The increasing need for sustainable practices in managing plastic waste and promoting a circular economy has heightened the significance of education and training in these fields. Awareness-raising and capacity-building have become critical components as societies move toward more sustainable and circular economic models, particularly in plastic management.

The article investigates the availability, content, and methodological approaches of online courses focused on the circular economy and plastic-related topics available on the internet. The primary objective is to establish a comprehensive theoretical framework for understanding how these courses are designed to raise awareness of plastic-related issues, disseminate current affairs, and educate the general public on these problems and potential solutions. Additionally, the article examines the current landscape of course availability.

The article analyses these courses' structure, content, and methodologies to evaluate their effectiveness in informing and engaging learners. It assesses how well these courses build learners' capacity to address plastic-related challenges and equip them with the necessary skills to foster innovation within the plastic value chain.

Literature review

Awareness Raising and Capacity Building

Awareness raising and capacity building are crucial for promoting a circular and climate-neutral economy, particularly in the management of plastics. Education and training initiatives are powerful tools that promote sustainable practices, enhance stakeholder engagement, and drive innovation throughout the plastic value chain. Recent research highlights the importance of these elements in advancing a circular economy for plastics. Key areas include stakeholder engagement through workshops and collaborative platforms, community involvement in recycling efforts, and youth education to create future leaders in climate change mitigation. These approaches are vital for sharing knowledge, identifying technological gaps, and fostering a culture of sustainability. For example, workshops and collaborative platforms organised by entities like the Bioenergy Technologies Office and the Advanced Materials and Manufacturing Technologies Office are essential for building connections among stakeholders and identifying opportunities for innovation in plastic sustainability (Fitzgerald et al., 2023). Similarly, projects like MAREA Plastic emphasise the role of social education and community engagement in recycling efforts, fostering a culture of sustainability and circular economy principles (Muñoz et al., 2023). Training programs targeting young people, such as those proposed in Romania, focus on renewable energy, circular economy, and zero waste systems, equipping participants with the skills to act as change agents in their communities (Dragomir et al., 2019).

Capacity building is essential in developing the skills to transition to a low-carbon economy. Training programs focusing on decarbonisation and circular economy principles are vital for building these skills, enabling participants to understand and implement sustainable practices professionally and personally (Dragomir et al., 2019). Additionally, industry-specific training is necessary for integrating plastic waste into various sectors, such as the construction industry. For instance, research in Egypt highlights the importance of industry-specific training to promote the circular economy by turning waste into valuable resources, aligning with sustainable development goals (Ahmed, 2023). Furthermore, fostering technological innovation through technical training is essential for advancing recycling technologies. Innovations such as redesigning low-cost extruders for recycling demonstrate the importance of technical training in extending the life cycle of materials and reducing costs, thus supporting the circular economy (Muñoz et al., 2023).

Collaborative efforts and policy support are also crucial in achieving a circular economy. Collaboration between industry, academia, and government is necessary to advance technologies and implement sustainable practices at scale. Such partnerships can accelerate the transition to a circular economy by aligning efforts across the value chain (Fitzgerald et al., 2023). In addition, effective management of plastic waste requires supportive policies and regulations. Establishing plastic taxes, credits, and extended producer responsibility can incentivise sustainable practices and enhance the competitiveness of recycled plastic products (Rani et al., 2024; Purwanto et al., 2024).

While awareness raising and capacity building are essential, transitioning to a circular economy also requires systemic changes in production and consumption patterns. Integrating advanced recycling methods, renewable energy, and carbon capture technologies can significantly reduce the plastic industry's carbon footprint (Pathak et al., 2023; Schirmeister & Mülhaupt, 2022). A holistic approach that addresses the entire lifecycle of plastics, from design to disposal, is necessary to achieve a truly circular and climate-neutral economy (Hahladakis et al., 2020).

In conclusion, capacity building, collaboration, and policy support are essential in advancing a circular economy for plastics. These elements provide a strong foundation for further

exploration into how they can be effectively integrated into the design and delivery of online courses, ensuring impactful and comprehensive educational experiences that drive sustainable practices.

Didactics of Online Courses

With the rapid shift towards digital learning environments, the didactics of online courses have evolved significantly, requiring the adaptation of traditional teaching methods to virtual platforms and the development of innovative and interactive strategies that cater to diverse learning needs. Online courses have adapted to address challenges such as learner engagement, subjective assessments, and the digital divide, particularly relevant when teaching complex topics like plastics and the circular economy. The transition to online didactics involves maintaining course efficiency despite the lack of direct interaction, integrating digital tools to enhance learning experiences, and co-designing course materials to increase engagement. Various models of interaction and engagement, including blended learning approaches that combine online and face-to-face elements, are essential for effective online learning. Understanding these dynamics provides a foundation for analysing the methodologies used in online plastics and circular economy courses. It offers insights into how these courses can be effectively designed and delivered.

Research shows that online teaching can effectively incorporate traditional didactic methods. For instance, a study on French lexicology at Moldova University highlights that online platforms can address challenges such as subjective learner assessment that are common in face-to-face settings (Coşciug, 2023). The COVID-19 pandemic further accelerated the transition to online education, prompting educators to develop new educational modalities emphasising continuous interaction to compensate for the physical separation between teachers and students (Guzmán et al., 2022). However, this transition has introduced both advantages and disadvantages. The shift to courses like "Machine Drawing" revealed initial distrust among educators due to the lack of direct interaction. Nonetheless, using communication platforms has shown the potential to maintain course efficiency, as evidenced by student performance metrics such as exam success rates and grades (Rizzuti & Napoli, 2022). While online learning offers flexibility and accessibility, it also presents challenges like the digital divide and the need for teacher preparedness in managing technology (Jeruszka, 2023).

Instrumental Digital Didactics (IDD) emphasises using digital tools to enhance learning experiences. This approach supports creating interactive models and data visualisation, which is particularly crucial for subjects like STEM, where practical application is key (Slipukhina et al., 2022). Co-designing online materials for mathematics and science didactics has shown that involving students in the design process can lead to more engaging and effective learning units (Bogaart et al., 2019). Effective online didactics also require robust interaction mechanisms, particularly in remote lab settings. Key interactions—such as student-lecturer, student-student, and student-content—are essential for maintaining engagement and ensuring effective learning outcomes (Vries & Wortche, 2020). Using digital didactics technologies in training pedagogical staff has improved the effectiveness of distance learning by incorporating blended learning models that combine online and face-to-face elements (Mamarajabov, 2022).

While online didactics offer benefits such as flexibility and personalised learning, they also present challenges like the digital divide and the need for technological literacy among educators and students. The shift to online learning underscores the importance of continuous adaptation and innovation in teaching methods to meet diverse learner needs. As educational institutions continue to refine online didactics, the focus remains on creating inclusive and effective learning environments that leverage technology to enhance educational outcomes.

Ensuring Engagement in Online Courses

Ensuring engagement in online courses is a complex challenge that requires a strategic approach to course design, teaching methods, and the use of technology. A key framework for creating flexible and inclusive learning environments is Universal Design for Learning (UDL), which focuses on providing multiple means of engagement, representation, and action and expression. By addressing these areas, instructors can develop more inclusive and engaging courses that cater to diverse learners (Owiny & Hartmann, 2020; Hollingshead, 2018). Effective engagement in online courses also relies on integrating instructional technologies such as discussion forums, video conferencing, and interactive multimedia. These tools facilitate interaction between students, faculty, and peers, making learning more engaging and meaningful. When combined with pedagogical strategies that promote active learning and collaboration, these technologies can significantly increase student motivation and the perceived value of the course content (Peter, 2022; Whiter, 2020).

In addition to these technologies, implementing intelligent predictive systems can help instructors anticipate students' engagement levels and tailor their teaching approaches accordingly. Machine learning models, like Long Short-Term Memory Networks (LSTM), have proven effective in predicting engagement levels based on students' online activities. By providing regular feedback based on these predictions, instructors can motivate students and help them stay engaged by addressing specific needs and challenges (Sashank et al., 2023). Course design also plays a crucial role in early engagement and retention. The initial weeks of an online course are particularly important for student retention, and a well-structured course with clear objectives, a detailed syllabus, and a strong instructor presence can help students connect with the course content and each other (Mucundanyi, 2021). Building a learning community and using free educational materials can enhance engagement by making learning more accessible and collaborative (Mucundanyi, 2021).

Monitoring engagement through technology is another critical strategy. Technologies like automatic facial expression recognition can provide valuable insights into students' emotional and attentional states during online sessions. This data can adjust teaching strategies in real time to better engage students and address disengagement (Dubbaka & Gopalan, 2020). By identifying when students are disengaged, instructors can take corrective actions to re-engage them effectively (Dubbaka & Gopalan, 2020).

While these strategies offer a comprehensive framework for enhancing engagement in online courses, there are challenges in implementing them. Technological limitations, varying levels of digital literacy among students, and the need to continuously adapt teaching methods pose significant hurdles. Moreover, the effectiveness of these strategies can vary depending on the subject matter and the specific context of the course. Therefore, instructors must remain flexible and responsive to the evolving needs of their students to ensure sustained engagement.

Investigation of Existing Online Courses

Research Data and Methods

The previous section provides a theoretical foundation for understanding online courses' structure, content, and methodologies focused on plastics and the circular economy. Examining the landscape of awareness-raising and capacity building, didactic approaches, and engagement strategies in online education offers valuable insights to guide empirical investigations of current online courses in these essential areas. This theoretical background aids in identifying best practices and gaps in existing online educational offerings, ultimately creating more

effective and impactful courses that facilitate the transition to a circular and sustainable economy.

We conducted our investigation as part of the Erasmus+ project "EDU4PlastiCircular" to identify gaps in existing online courses related to plastics and the circular economy, specifically regarding didactics and content. The project aims to develop engaging and effective online courses that address these gaps.

Building on insights from our literature review, we formulated the following research questions to guide our investigation:

1. What specific content areas are covered in online courses on plastics and circular economy to address key concepts such as sustainability, waste management, and circular practices?
2. Which learning methodologies are commonly employed in online courses on plastics and circular economy to facilitate knowledge acquisition, skill development, and practical application?
3. What strategies are used in online courses on plastics and circular economy to ensure and maintain student engagement and participation throughout the course duration?

The analysed courses aim to achieve several key learning outcomes and develop relevant skills among participants. Most courses focus on building a broad understanding of circular economy concepts, highlighting their significance in promoting sustainability. Additionally, circular design and business model courses emphasise practical skills, enabling learners to apply these concepts in real-world scenarios and preparing them for professional implementation. Courses that address policy and governance further enhance strategic thinking and provide a comprehensive understanding of the regulatory landscape. These courses cater to a diverse audience, including students, researchers, business professionals, and policymakers. Their accessibility is enhanced by the widespread availability of free or low-cost options, and the online format offers flexibility, accommodating various learning needs and schedules.

Thematic Analysis

This section provides a thematic analysis of the content and didactical approaches employed in online courses focusing on the circular economy and plastic. The analysis is based on data collected from various online courses offered by institutions worldwide. All the information was collected from the learning management system's websites or the websites where the courses were hosted or described.

The primary objective of the analysis is to understand the recurring themes, target audience, learning outcomes, and instructional methods used in these courses. This analysis might also help educators, educational institutions, and learners better grasp the current state of circular economy education and identify potential areas for enhancement.

Table S1 in the Supplementary Materials presents the online courses on circular economy and plastics that were identified through an Internet search and included in the thematic analysis. The table provides additional information about the courses analysed in the thematic analysis.

Key Themes - Course Content

The thematic analysis focused on the course's contents reveals that the courses predominantly focus on the following key themes:

1. *Circular Design and Ecodesign*

Courses under this theme emphasise the principles of designing products and systems that minimise waste and environmental impact. The focus is on integrating sustainability into the product lifecycle from the design phase.

2. Plastics Circularity and Waste Management

Many courses address the challenges related to plastic waste and the adoption of circular strategies to manage and reduce this waste. Topics include recycling, bioplastics, and the impact of plastic waste on the environment.

3. Circular Business Models and Sustainable Strategies

These courses explore how businesses can transition from traditional linear to circular models. They focus on creating value through circular practices, developing sustainable business strategies, and effectively implementing them.

4. Policy Implementation and Governance

Courses in this theme focus on the policy aspects of the circular economy, including the development and implementation of regulations and governance strategies and the challenges of enforcing these policies.

5. Sustainable Materials Management

These courses focus on sustainable materials management, including recycling, resource efficiency, and renewable materials. They aim to provide knowledge on managing materials sustainably across different sectors.

6. Circular Economy Fundamentals and Principles

These courses provide a broad introduction to the fundamental concepts of the circular economy, including its principles, frameworks, and potential benefits. They serve as an entry point for those new to the subject.

7. Green Skills and Capacity Building

Aimed at specific groups, such as teachers and students, these courses focus on building green skills and raising awareness about sustainability and circular economy practices through innovative pedagogical methods.

8. Industry-Specific Applications

These courses provide targeted knowledge and skills for specific industries, such as packaging or construction, emphasising the application of circular economy principles within these sectors.

Key Themes - Didactical Approaches

The thematic analysis focused on the courses' didactical approaches reveals that the courses predominantly focus on the following key themes:

1. Content Delivery Methods

Online lectures are the most common approach, offering structured content delivery that presents theoretical knowledge and comprehensively explains key concepts. This method is widely used across courses to ensure learners grasp foundational principles effectively. In advanced courses, expert talks are often featured to provide in-depth insights and real-world perspectives from industry leaders and academics, enriching the learning experience with specialised knowledge and practical applications.

2. Engagement and Application Methods

Case studies are widely used to demonstrate the practical application of circular economy principles, enabling learners to understand complex scenarios and decision-making processes. Interactive exercises are designed to actively engage learners, fostering critical thinking and problem-solving skills through simulations and scenario analysis. Quizzes and assignments are effective tools for reinforcing learning and assessing comprehension, helping to ensure that learners retain and can apply the information taught.

3. Collaborative and Experiential Learning

Group work encourages peer learning and collaboration, though it is less common in fully online settings due to logistical challenges. Some courses employ roundtable discussions to foster deeper understanding through dialogue and debate. Blended learning, which combines online content with in-person interactions, offers a richer learning experience, but it is less prevalent in purely online courses.

4. Experiential Learning

Field visits are rare in fully online courses but are highly valuable for practical learning. Alternatives like virtual tours could be explored to provide experiential learning remotely, allowing students to gain insights and real-world experience without needing physical presence.

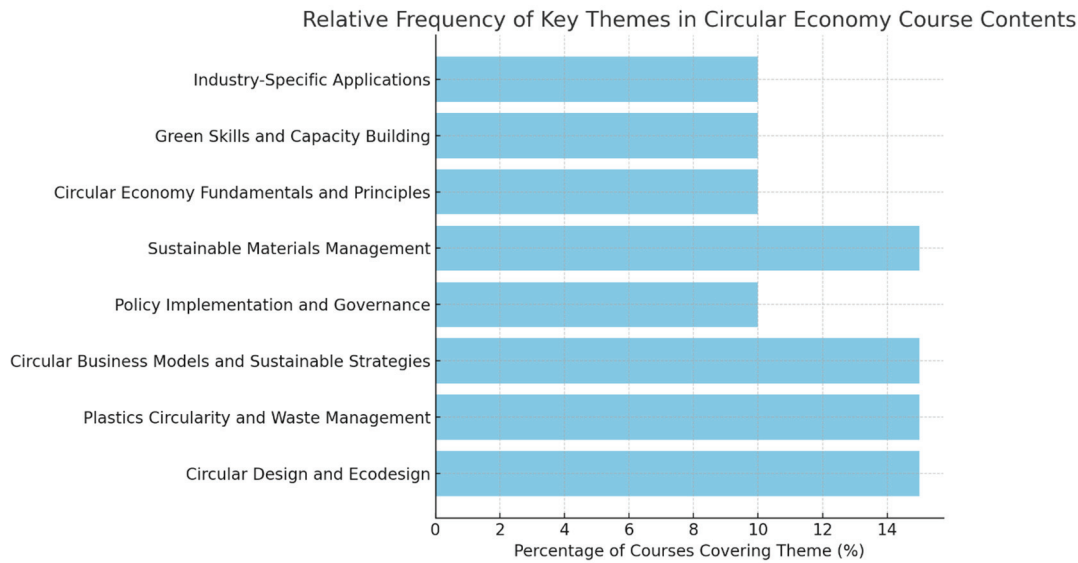
Summary Findings Based on the Key Themes Analysis

The thematic analysis highlights the diverse focus areas of online courses, catering to a wide range of educational needs and professional interests in the circular economy. The analysis of the courses' content reveals a strong emphasis on several key themes related to the circular economy, as seen in Figure 1. Circular design and eco-design are primary themes, focusing on designing products and systems that minimise waste and environmental impact by integrating sustainability from the design phase. Another prominent theme is Plastics Circularity and Waste Management, which addresses the challenges of plastic waste through strategies like recycling and bioplastics. Circular Business Models and Sustainable Strategies explore the transition from linear to circular models, highlighting value creation through sustainable practices and effective implementation strategies. Policy Implementation and Governance focuses on developing and enforcing regulations and governance strategies in the circular economy. Sustainable Materials Management emphasises the responsible use of resources, recycling, and adopting renewable materials across various sectors. Circular Economy Fundamentals and Principles provide a foundational understanding of circular economy concepts, serving as an entry point for beginners. Green Skills and Capacity Building targets specific groups like teachers and students to build skills and raise awareness about sustainability and circular economy practices. Finally, Industry-Specific Applications offer targeted knowledge and skills for particular sectors, such as packaging and construction, focusing on the practical application of circular economy principles within these industries.

Figure 1: Visual presentation of the relative frequency of key themes

The thematic analysis of the didactical approaches reveals a prevalence of traditional methods in online courses, with online lectures being predominant in nearly all offerings, as seen in Figure 2. This indicates a reliance on conventional content delivery, which is effective for foundational learning but may lack interactivity. Case studies and expert talks are also widely used to provide practical context and specialised knowledge, making complex concepts more relatable and understandable. Interactive learning techniques, such as quizzes and assignments, are common in courses aiming to assess understanding regularly. These methods support

retention and enable learners to apply concepts in a structured manner. Although less common, interactive exercises add significant value by promoting engagement and active participation.



Collaborative and experiential methods are underutilised, with limited use of group work and discussions due to logistical constraints. Despite being crucial for deep learning and collaborative problem-solving, these approaches are challenging to implement online. Blended learning, which offers a balanced approach by combining online content with in-person interactions, is less feasible for global online learners who cannot attend physical sessions. A notable gap exists in experiential learning, as field visits provide valuable hands-on experience and are generally absent in online courses. To bridge this gap, innovative alternatives such as virtual simulations and case study tours could be explored to simulate real-world experiences and enhance the learning process.

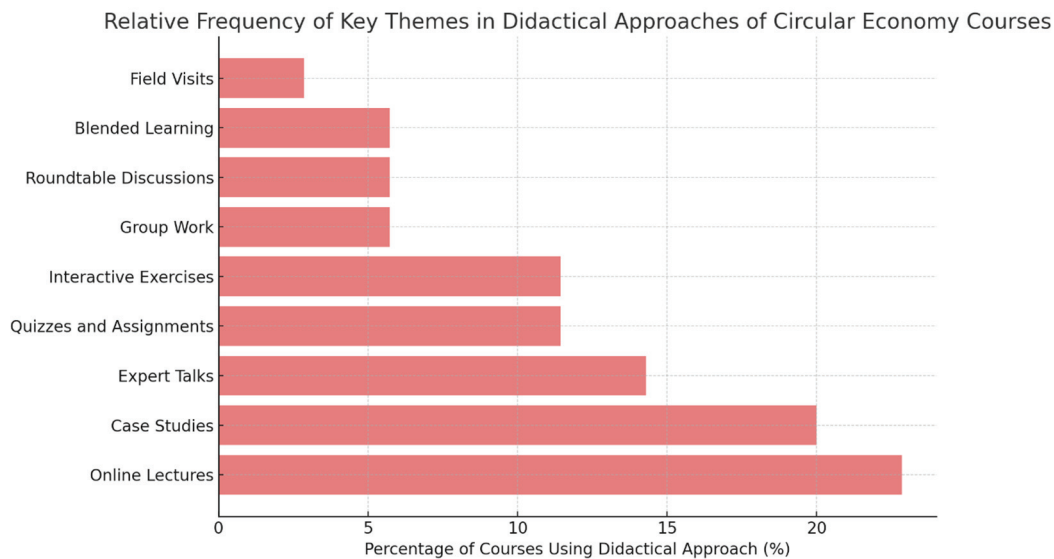


Figure 2: Visual presentation of the relative frequency of key themes in didactical approaches

Addressing the Research Questions and Discussion

What specific content areas are covered in online courses on plastics and circular economy to address key concepts such as sustainability, waste management, and circular practices?

Online plastics and circular economy courses cover specific content areas such as plastics circularity, waste management, and sustainable practices. These courses address key concepts

by focusing on the life cycle of plastics, including production, consumption, and disposal, and emphasising strategies for reducing plastic waste through recycling, reuse, and adopting bioplastics. They also cover the impact of plastic waste on the environment and human health, techniques for effective waste management, and case studies of successful plastic waste reduction initiatives. The circular design and eco-design principles are also a major focus, teaching how to design products and systems that minimise waste and promote resource efficiency. This includes designing for disassembly, material recovery, and integrating sustainability into the product lifecycle from the design phase. Courses also explore circular business models, examining how businesses can transition from linear to circular models, create value through circular practices, and overcome barriers to adopting these practices. Finally, sustainable materials management is addressed through life cycle assessment of materials, innovations in material science, and strategies for reducing material waste in production and consumption.

To further enhance the development of new courses, expanding the content to include more advanced topics such as innovative bioplastic technologies, circular economy strategies for emerging sectors, and the integration of digital tools for monitoring and optimising circular practices is recommended. Including modules on policy frameworks and their practical implementation across different regions would provide learners with a comprehensive understanding of global and local regulatory landscapes.

Which learning methodologies are commonly employed in online courses on plastics and circular economy to facilitate knowledge acquisition, skill development, and practical application?

The learning methodologies commonly employed in these online courses include content delivery methods such as online lectures and expert talks. Online lectures are the most frequently used method for comprehensively conveying theoretical knowledge and explaining key concepts. At the same time, expert talks provide industry leaders and academics with advanced insights and real-world perspectives. Engagement and application methods like case studies, interactive exercises, and quizzes are also prevalent. Case studies illustrate the application of circular economy principles in real-world scenarios, helping learners connect theory with practice. Interactive exercises, such as problem-solving tasks and simulations, engage learners in active learning and develop critical thinking skills. At the same time, quizzes and assignments are effective tools for reinforcing learning and assessing comprehension. Collaborative and experiential learning approaches, including group work and roundtable discussions, are used less frequently due to the logistical challenges of online settings. However, blended learning combines online lectures with face-to-face interactions, providing a richer learning experience in some cases.

To enhance the effectiveness of new courses, it is recommended to diversify and integrate learning methodologies that actively engage students and bridge the gap between theory and practice. Incorporating more collaborative activities, such as virtual group projects and peer discussions, can foster community and enhance learning through peer-to-peer interaction. Additionally, expanding the use of interactive simulations and scenario-based learning can provide hands-on experience in a virtual environment, making complex concepts more accessible and engaging. Implementing adaptive learning technologies that tailor content and assessments to individual learner needs is also beneficial, ensuring a more personalised and practical learning experience. Blended learning models should be further explored, combining asynchronous online content with synchronous live sessions or virtual workshops to provide opportunities for deeper engagement and direct interaction with instructors and peers. These enhancements would create a more dynamic and interactive learning environment, supporting the development of practical skills and critical thinking.

What strategies are used in online courses on plastics and circular economy to ensure and maintain student engagement and participation throughout the course duration?

To ensure and maintain student engagement and participation throughout the course duration, online courses use various strategies such as incorporating interactive and engaging content, utilising quizzes and assessments, and offering interactive exercises and simulations that require active participation. Real-world case studies are integrated to provide context and relevance to theoretical concepts, maintaining learner interest by showing the practical impact of circular economy principles. Expert talks and guest lectures offer diverse perspectives and keep the course dynamic by providing learners with varied insights from the field. Courses are often structured into manageable modules with clear objectives and outcomes, helping learners track their progress and stay motivated. Discussion forums and peer interaction opportunities are provided in many courses, fostering a sense of community and enabling learners to discuss content, share ideas, and ask questions. Finally, offering certificates of completion serves as an incentive for learners to complete the course, providing a tangible goal and recognition for their efforts. These strategies collectively contribute to maintaining student engagement and participation throughout the course.

To further enhance student engagement and participation in new courses, it is recommended to integrate gamification elements such as badges, leaderboards, and progress tracking, which can motivate learners by rewarding achievements and creating a sense of accomplishment. Introducing more interactive tools, such as live polls, breakout rooms for group discussions during synchronous sessions, and real-time feedback mechanisms, can increase active participation and keep learners involved. Additionally, incorporating multimedia content like short videos, animations, and interactive infographics can break the monotony of traditional lectures and make learning more dynamic and visually appealing. Personalised learning paths based on pre-assessment results or learner preferences can also help tailor the course experience to individual needs, increasing relevance and motivation. Regular live Q&A sessions with instructors and industry experts can deepen engagement by providing direct interaction opportunities and fostering a deeper connection with the course content. These strategies can create a more interactive and engaging learning environment, ensuring sustained student participation and interest throughout the course.

Conclusions

This study explored online courses' availability, content, and methodological approaches focusing on plastics and the circular economy. The goal was to assess how these courses are designed to raise awareness, disseminate information, and educate the public on sustainable practices and plastic waste management. The investigation, guided by insights from a literature review and thematic analysis, revealed key themes in course content and didactical approaches, highlighting the current landscape and suggesting areas for enhancement in online circular economy education.

The content analysis identified several predominant themes, including Circular Design and Ecodesign, Plastics Circularity and Waste Management, Circular Business Models, Policy Implementation and Governance, and Sustainable Materials Management. These themes are covered through a combination of theoretical knowledge and practical applications, with a strong focus on addressing the life cycle of plastics and promoting sustainable practices. The didactical analysis revealed a reliance on traditional content delivery methods like online lectures and expert talks, complemented by interactive exercises and case studies. However, a notable underutilisation of collaborative and experiential learning approaches limits deeper engagement and practical application.

To develop more impactful and engaging online courses, it is recommended to include advanced topics such as innovative bioplastic technologies and digital tools for circular practice optimisation. Expanding learning methodologies to incorporate more collaborative activities, interactive simulations, and adaptive learning technologies can bridge the gap between theory and practice. Gamification elements like badges and leaderboards, multimedia content, and personalised learning paths can further enhance student engagement and participation. Regular live sessions and real-time feedback mechanisms should be integrated to provide more direct interaction and foster a deeper connection with the content.

The study was limited to analysing online courses, which may not fully represent the diversity of educational offerings in circular economy and plastic management. The analysis relied on course descriptions and information available on websites, which may not capture the complete scope of course content and methodologies. Additionally, the study did not include learner feedback or outcomes, which could provide further insights into the effectiveness of these courses.

Future research should include a broader range of courses offered in different languages and regions to capture a more comprehensive picture of global circular economy education. Incorporating learner feedback and analysing learning outcomes would provide a deeper understanding of the effectiveness of these courses. Investigating the impact of different didactical approaches on learning outcomes and engagement, especially in a fully online context, would also be beneficial. Further exploration into integrating emerging technologies, such as virtual reality and artificial intelligence, in circular economy education could offer innovative solutions for enhancing learner experience and engagement.

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Table S1: List and descriptions of the analysed courses

COURSE NAME	INSTITUTION/PLATFORM	COURSE CONTENT AND FOCUS AREAS	TARGET AUDIENCE AND ACCESSIBILITY	LEARNING OUTCOMES AND SKILLS DEVELOPMENT	COURSE STRUCTURE AND DURATION	COVERAGE	DIDACTICS/TEACHING METHODS	COST AND CERTIFICATION
PLASTICS CIRCULAR ECONOMY E-LEARNING COURSE	ASEAN Circular Economy Stakeholder Platform	Plastic circularity, plastic waste policies, circular business models	Polymakers, business owners, third-parties (Singapore, Thailand); Online, Free	Knowledge of plastics circularity, policy implementation, private-public partnerships	~2 hours	ASEAN region (Singapore, Thailand)	Online lectures, case studies, policy discussions	Free, No certification
CIRCULAR DESIGN WITH PLASTICS	IPCA (Portugal), NHL-Stenden, AIT, LIT	Circular design, circular economy policies, sustainability of product life cycles	RUN-EU students; Blended, Free	Understanding circular design, ecodesign, sustainable modeling, circular supply chains	17 days	European (RUN-EU network)	Blended learning, online lectures, expert talks, group work	Free, Yes (2 ECTS credits)
THE NEW PLASTICS ECONOMY: CIRCULAR BUSINESS MODELS AND SUSTAINABILITY	University of Bologna	Legislative, technical, and managerial issues of the "New Plastics Economy"	Students, researchers, young entrepreneurs, managers; Online (MOOC), Free	Capacity building in bio-based and biodegradable plastics, policy understanding	4 weeks	European (EU-funded Horizon 2020)	Expert lectures, roundtable discussions, quizzes, case studies	Free, Certificate of Accomplishment
CIRCULAR ECONOMY -SUSTAINABLE MATERIALS MANAGEMENT	Lund University, Coursera	Environmental policies, circular business models, material design	Open to all; Online (MOOC), Free	Policy analysis, business model analysis, environmental impact understanding	3 weeks	International (various European universities)	Online lectures, case studies, policy analysis, assignments	Free, Certificate
DESIGNING OUT WASTE: THE CHALLENGES TO FULL CIRCULARITY	Circular Economy Alliance	Waste management, sectors increasing waste pollution, circular economy for waste elimination	Open to all interested; Online, 95 euros + VAT	Strategies to address waste pollution, value creation, behavioural change	1.5 hours	International (online)	Explanations, case studies, policy discussions	95 euros + VAT, Certificate
CIRCULAR ECONOMY SPECIALIST (HIGH MASTERY)	Circular Economy Alliance	Circular design, circular supply chains, circular industry 4.0, specialised electives	Professionals in the circular economy field; Online, Paid	Strategic design, consulting on circular economy projects, leadership	45 hours	International (online)	Advanced training with theoretical and practical scenarios	1,085 euros + VAT, Certificate
CIRCULAR ECONOMY MANAGER (ADVANCED)	Circular Economy Alliance	Circular design, circular business models, energy policy, industry 4.0	Professionals and interested individuals; Online, Paid	Understanding strategic design, value cycles, partnering in the circular economy	30 hours	International (online)	Theoretical knowledge combined with practical applications	745 euros + VAT, Certificate
CIRCULAR ECONOMY PROFESSIONAL (FOUNDATIONAL)	Circular Economy Alliance	Fundamentals of circular economy: terminology, principles, frameworks	Individuals new to circular economy; Online, Paid	Basic knowledge of circular economy, tools, and best practices	16 hours	International (online)	Foundational training with interactive content and theoretical insights	385 euros + VAT, Certificate

RELEARN PLASTICS	Erasmus+ Partnership	Plastic production, waste impact, recycling, reuse, and climate change	High school teachers, students; Online, Free	Technical knowledge, innovative pedagogy, environmental awareness	Varies	European (Slovenia, Serbia, Spain, Cyprus)	Online modules, artistic expression, innovative methods	Free, No certification
BACHELOR'S DEGREE IN POLYMER TECHNOLOGY	Faculty of Polymer Technology	Polymer materials, renewable raw materials, circular economy in plastics	Students; Face-to-Face, Free (tuition fee)	Practical knowledge in polymer processing, waste management, sustainable production	3 years	European (Slovenia)	Lectures, lab work, project-based learning	Free (tuition fee), Bachelor's Degree
MASTER'S DEGREE IN POLYMER TECHNOLOGY	Faculty of Polymer Technology	Sustainable polymer development, management of polymer waste, advanced technologies	Students; Face-to-Face, Free (tuition fee)	Independent research, advanced processing, sustainable design	2 years	European (Slovenia)	Lab experiments, case studies, project management	Free (tuition fee), Master's Degree
CIRCULAR ECONOMY AND SUSTAINABILITY STRATEGIES	University of Cambridge	Circular economy principles, sustainability strategies, sustainable business growth	Open to all interested; Online, Paid	Building sustainable business models, investment strategies, leadership	6 weeks, 4-6 h/week	International (online)	Lectures, case studies, interactive exercises, assignments	£1,632, Digital Certificate of Completion
THE CIRCULAR ECONOMY FOR PLASTICS, SUPERSERIES	Fuller Academy	Circular economy for plastics, policy trends, life cycle thinking, circular design	Open to all; Online, Paid	Understanding circular economy drivers, global policy trends, life cycle principles	10 hours (available for 12 months)	International (online)	Online modules with expert insights, practical applications	399 USD, Certificate of Completion
SUSTAINABLE PACKAGING IN A CIRCULAR ECONOMY	Delft University of Technology (TU/Delft)	Design of sustainable packaging systems, business strategies, circular design	Students, researchers, professionals; Online, Paid	Applying circular design for packaging, renewable materials	6 weeks, 3-4 h/week	International (online)	Video lectures, case studies, practical exercises	149 USD, Certificate
CIRCULAR ECONOMY: THE BIG IDEA	Ellen MacArthur Foundation	Circular economy principles, policy development, circular design techniques	Open to all; Online, Paid	Circular economy understanding, business model evaluation, policy development	3 weeks, 4 h/week	International (online)	Video lectures, readings, discussions, practical exercises	149 USD, Digital Certificate
CIRCULAR ECONOMY	Technical University "Gheorghe Asachi"	Circular economy principles, benefits, rural application case studies	Open to all; Online, Free	Understanding circular economy fundamentals, rural applications	Flexible	European (Romania)	Online course with case studies, practical examples	Free, No certification