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Circular economy and sustainable development in primary education

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Acknowledging the importance of implementing environmental policies at the ground level, research reveals slow knowledge diffusion and behavioral challenges affecting policy outcomes. Despite the global consensus, national sustainable development policies often remain incomplete. Focusing on education, while the circular economy (CE) is extensively discussed in higher education, it remains notably absent in primary education curriculums. Drawing on the responses of 61 primary education teachers, this study (i) locates the lack of integration of circularity and sustainability concepts at Greek State primary schools, underscores the necessity for their inclusion into the curriculum more systemically and systematically to address disparities, and suggests solutions for a more comprehensive environmental education; (ii) unveils primary educators' awareness and positivity toward teaching-learning of sustainable development goals and education for a CE and emphasizes on their ongoing support, education, and training.

KEYWORDS

circular economy, education policy, environmental education, sustainable development goals, primary education

1 Introduction

The present study aims to contribute to the emerging field of Circular Economy (CE) in education by examining the attitudes of practicing educators toward implementing relevant curriculum changes. This field is still in its infancy, and much of the existing research pertains to tertiary education. There is currently little research on how educators understand environmental knowledge and learning in their environmental education philosophies and apply it to their practice (Cincera et al., 2020).

Our study focuses on primary education, recognizing its formative and essential role in shaping social, communal, and individual development. Primary education is pivotal because of its capacity to provide foundational knowledge and attitudes, making it an ideal starting point for instigating broader discussions and further research in this area.

Existing educational ideas may or may not align with the environmental educators' views in formal and informal learning settings. Cincera and Johnson (2013) and Clayton et al. (2014) highlight, that the relationship between educational theory and practice is often dynamic. It depends on the strategies used to support theoretical knowledge during teacher preparation and the preconceived notions and philosophies educators bring to their practice. Recent research across diverse countries also reveals the need for (i) deepening the primary teachers' understanding of the concepts of circularity and sustainability, and improving their attitudes and behaviors towards them (ii) an education policy embedding these concepts in the curriculum at all levels, and (iii) testing specific and various teaching methods to bridge the

gap between theory and practice and to develop students' relevant practical skills and required knowledge for long-term impacts (Laioise, 2023; Hamid et al., 2024; Bugallo-Rodríguez and Vega-Marcote, 2020; Yuana et al., 2024).

This interplay between theory and experiential application is central to understanding how educators can integrate CE principles into their curricula, particularly in primary education. By addressing this gap, our research seeks to provide meaningful insights into how educators conceptualize and implement environmental education, ultimately contributing to both theoretical and practical advancements in the field.

To this end, we selected a sample from the provincial prefecture of Larissa in central Greece to assess the attitudes of primary school teachers towards sustainable development and CE. We aimed to understand their predispositions to incorporate the CE principles into the curriculum. Additionally, we assumed that the study's findings might inspire participating teachers to consider adjusting their teaching methods to align with the CE principles. The main research questions (RQ) seeking answers from this work are the following:

RQ1: What are the attitudes and behaviors of primary education teachers towards CE Strategies?

RQ2: What is the stance of primary education towards including CE in their school curriculum?

RQ3: Find any significant demographic disparities in their responses.

1.1 Circular economy in education

In the current economic and environmental circumstances, cross-examination by various disciplines is critical (Beynaghi et al., 2016). Researchers and policymakers have emphasized the need for innovative and radical change as a prerequisite for establishing a new economic model, specifically, focusing on the accomplishment of CE in practice (Acemoglu et al., 2009; Leube and Walcher, 2017). This idea, rooted in Joseph Schumpeter's concept of the 'Schumpeter gale' (Schumpeter, 1942), highlights the need for transformation in production and design (Pitt and Heinemeyer, 2015) and procedural advancement towards a CE (Bocken et al., 2017). Some researchers even suggest that public consensus at the individual level is essential before CE can be achieved (Andrews, 2015).

According to the European Parliament, CE is defined as: "The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended." (European Parliament, 2023). The transition to such a model requires the consensus of various interest groups (Lieder and Rashid, 2016) not only in theory but also in a multi-layered manner, which results in socioeconomic 'embeddedness' (Blomsma and Brennan, 2017). The private corporate sector's response is critical (Bocken et al., 2017), and the adoption of cradle-to-cradle, transferable design models for companies of all sizes is necessary for CE to be widely feasible (Lewandowski, 2016). Corresponding to the EU's plan, Greece composed the National Action Plan for CE, which focuses on

fostering innovation and eco-design for manufacturing recyclable and more durable and repairable products, industrial symbiosis creating closed-loop systems, and supporting enterprises that utilize recycled materials. Moreover, the National Circular Strategy promotes reducing resource consumption, enhancing materials reuse and recycling, and developing sustainable production and consumption patterns. However, no references to education are included in these documents (European Commission, 2015; Circular Greece, 2020).

A comparison between linear and circular economy paradigms has become central to discussions regarding education. An important body of work has already been produced in tertiary education curricula (Filho, 2018). However, rapid changes in the complex international political landscape affect large-scale policy, often leading to revisions of universally accepted, time-scaled, and recognized goals. This opens an otherwise forward-looking discussion on the future of education.

Introducing CE at all educational levels is crucial. Over the past decade, CE has gained momentum as an optimal, implementable notion in academic and corporate economic circles (Kirchherr et al., 2017). While sustainable development has been discussed for nearly six decades (UNESCO, 2014), it is only through the recent recognition of CE as a practically perceptible and tangible political practice that more general principles find applied fruition (Winanas et al., 2017). Education on CE not only promotes (Bonnett, 2012) and formulates (Kirchherr and Piscicelli, 2019) its principles but also indicates effective pathways for implementation (Kopnina, 2018) and accelerates the transition from linear to circular models (D'Amato et al., 2017).

Several researchers have turned their attention to education focused on CE promotion and application (Kopnina, 2014). Citizens of an average educational level in a community have been proven to affect public policy and public tendencies; this may be seen as an incentive or evidence for the need to further education and introduce the subject of CE to the primary education level (Pelău and Chinie, 2018). The argument has been made that primary education constitutes an indicator of communal reception due to its particular and familial constituent parts (Zorpas et al., 2017). Education, in terms of CE, is not to be restricted to national education systems but a broader communication of its tenets to the public through a bottom-up itinerary involving consumers first, stakeholders involved next, and lastly in governmental agencies (Wu and Wu, 2019).

The effectiveness of a gameplay-based approach in education has garnered attention. According to Lange et al. (2022), it engages students with new ideas and technologies. Katie Whalen's table-top game "In the Loop" (Whalen et al., 2018) deals with the life extension of critical raw materials and CE, making it suitable for educational purposes. Other education programs promoting design and production circularity and sustainability have been led by Knudby and Larsen (2017) and Sanchez-Romaguera et al. (2016), focusing on engineering students' socioeconomic and ethical awareness. Finally, some neo-naturalist and non-anthropocentric research has also been published to qualify 'connectedness' with nature as a stepping-stone towards an organic sense of ecological conscience within educational settings (Arbuthnott and Sutter, 2019). This is a common, however, interesting angle as it informs – amongst other things – the rich history of politics, aesthetics, and attitudes in the ecological movement, which remains associated with sustainable development and CE.

Despite this significant and diverse output, concerns has been raised about its educational application. CE tackles a complex range of systemic approaches toward sustainable development (Sauvé et al., 2016); understandably, nurturing future economic leadership in tertiary education is one of the main aims of educational institutions for promoting environmental policies (Webster, 2013). Kılış and Kılış (2017) developed a tripartite approach for the integration of a CE system with a course on energy policy involving a university-founded dairy in the province of Ankara, Turkey. They combined high-end theoretical and technical expertise, an active student body, a real-life scenario, and result-based framework research. Another study with similar results was conducted by Halbe et al. (2015) as a community-involved, multi-causal, and multiple-stakeholder engineering paradigm, which the researchers themselves deemed ‘particularly important for integrated and adaptive resource management’ and which helped tertiary education students obtain hands-on experience on how to deal with real-life challenges.

A third example of pioneering research was produced by the environmental anthropologist Helen Kopnina, who sought to describe the function of CE with an application in tertiary education; students were asked to evaluate a CE design process whilst determining a series of practices and theoretical challenges (Kopnina, 2018). More recently, Kopnina discussed post-humanism and post-qualitative, bioethical extensions of CE practice in the corporate world within a pedagogical framework, thus broadening the scope of the debate beyond its industrial scope (Kopnina, 2022).

1.2 Sustainable development in education

Sustainable development has been a focal point of global discussion for nearly six decades (UNESCO, 2014). While the CE concept has recently gained traction as a practical political strategy, the principles of sustainable development have been effectively integrated into educational frameworks for much longer (Winanas et al., 2017). Environmental education has proven crucial in fostering both social and individual understanding of sustainability as a practical and actionable concept (Keramitsoglou et al., 2023). Environmental education not only promotes sustainability (Bonnett, 2012) but also helps formulate and identify effective strategies for its implementation (Kirchherr and Piscicelli, 2019; Kopnina, 2018). It challenges linear economic models (Twomey and Washington, 2016) and accelerates the shift toward a CE (D’Amato et al., 2017).

Education remains the most basic social catalyst in transforming knowledge, values, behavioral patterns, and prevalent lifestyles. As early as the Rio de Janeiro Summit of 1992, sustainable development was a robust debate topic (Fulton, 2012). UNESCO declared the period from 2005 to 2014 a decade of sustainable development education (UNESCO, 2014). Despite various definitions and models, the relationship between CE and sustainability remains a subject of ongoing research and discussion (Kirchherr et al., 2017).

The literature on sustainable development in education shows varying levels of commitment. Funding is a significant obstacle (Huckle, 2012), and questions about the efficient social impact of sustainability education persist (Jickling, 2016). Nonetheless, specific case studies have shown the benefits of incorporating sustainability into educational programs (Kirchherr and Piscicelli, 2019).

Several researchers have focused on education to promote sustainable development. Programs emphasizing practical, experience-based knowledge impact students’ social behavior and sustainability understanding (Andrews, 2015). In a 2017 project implemented by four Spanish universities, it was argued that the participation of 8-12-year-old students in real-life industrial production settings could drive societal change (Buil et al., 2017). Other programs focusing on sustainable design and practical purposes have also shown significant impacts (Pitt and Heinemeyer, 2015; Leube and Walcher, 2017).

To conclude without exhausting related sources, the extant literature on sustainable development, CE, and education is growing rapidly. Its main learning angle owes to a comportment of knowledge as researched and described by Kirchherr and Piscicelli: “the pedagogical principles of constructive alignment and problem-based learning, as well as interactivity, non-dogmatism, and reciprocity” (Kirchherr and Piscicelli, 2019). Otherwise, as was formerly stated, result-based learning is preferable when seeking to satisfy the needs of students and the wider community (Biggs and Tang, 2011).

In this principally holistic light, this current study aimed to engage teachers who are differently seldom consulted on environmental education in their workplace, with a possible view to further involve them in more holistic, reciprocal, and community-aligned research for the future.

2 Materials and methods

A questionnaire was constructed to be completed online with the 1KA tool (<https://www.1ka.si/>). The survey was conducted in two parts, with 26 close and open-ended questions, as detailed in the [Supplementary File](#). The approach was chosen to ensure that the questions were tailored to the specific objectives of the study while aligning with the established literature in the field. The first part considered the terminology, sustainable development goals (SDGs), CE, and their possible inclusion in the curriculum, while the second part aimed at collecting participants’ demographic data. The response options included multiple-choice and Likert scales.

A pilot test with fifteen participants ensured the clearness of any language and technical issues of the questions asked. The survey took place in the autumn of 2021. A questionnaire was administered online to the teachers working in primary and pre-primary schools and nurseries through the Primary Education Authorities of the Prefecture of Larissa. First online and then direct contact followed with teachers in 40 urban and 21 rural primary education units. Of the final, anonymous participants, 61 submissions were deemed fully completed and valid out of 195 delivered with the aim to achieve a representative sample based on urban and rural schools. This response rate, 31.3% (>30%), could be considered statistically valid. It is typical in online surveys, sufficient for gaining reliable insights, and warranted for a clearly defined sample (Wu et al., 2022; Baruch and Holtom, 2008; Fan and Yan, 2010).

In the first part of the questionnaire, we aimed to explore the existing knowledge concerning sustainable development and CE. Participants were asked to define them by selecting or writing their answers.

Following the Millennium Development Goals period, the United Nations renewed its declarative strategy by adopting and announcing

17 SDGs, also known as Agenda 2030, indicating the year of completion. These 17 goals are assigned 169 targets and reviewed by 232 indicators. What is of considerable interest to environmental studies is that sustainability has become the official aim expressed in this central United Nations declaration. To determine our participants' dispositions towards this declaration, they were asked to indicate which of these 17 goals they considered essential by sketching their preferred hierarchies in what Agenda 2030 critics consider a vast and utopic wish list beyond accountability.

3 Results

This section first details the sample composition, followed by descriptive statistics and frequencies. Finally, some statistical relations are explored.

3.1 Sample composition

The participants' profiles are shown in [Table 1](#); the 77.05% female (47) and 22.95% male (14) rates are in relative statistical parity with female–male ratios in primary education employment. Age group distribution is also typical of education employment in Greece currently, from 30 to 62 years old (*Mean* = 44.18 and *Std. Dev.* = 7.818). About 40 % of the participants (40.98%) are holders of

a Master's degree, and obviously, all are university-educated. Regarding job status, 80.33% of the participants hold a tenured civil servant position, whereas 19.67% are substitute/part-time employees, i.e., under a 9-month contract with the local primary education authorities. The participants' employment experience ranges from 3 to 37 years (*Mean* = 18.08 and *Std. Dev.* = 7.669). The pay scale has little deviation of significance among school teachers in Greece. Quotients of locality, work experience, specialization, parenthood, and type of school unit are also well proportioned across the board.

Concerning environmental education, more than half of the participants have never organized environmental projects despite a mode category of 10–20 years in employment. The remaining teachers are active on annual and monthly schedules, with 30 participants organizing 118 projects in total. Monthly environmental programs include activities that last a month and are designed to introduce students to recycling, water and energy conservation, wildlife awareness, or biodiversity protection. In contrast, annual programs are based on the project teaching method and involve students in implementing real-world assignments and solving practical problems during a school year. However, just 4 participants carried out 67 of those projects, which indicates that environmental enthusiasm is not evenly distributed among teachers.

3.2 Descriptive statistics

[Figure 1A](#) shows that the participants were, in their slight majority, unaware of the particulars of sustainable development as a sequential notion in detail. Answering our RQ1, results show that the relative teachers' majority recognizes the authoritative terminology, which hints that a piece of certain common knowledge is present in the survey body. Even though a similar prevailing definition does not exist for the CE, as discussed previously, participants demonstrated a far more accurate grasp of the concept in their responses regarding what the CE is related to ([Figure 1B](#)).

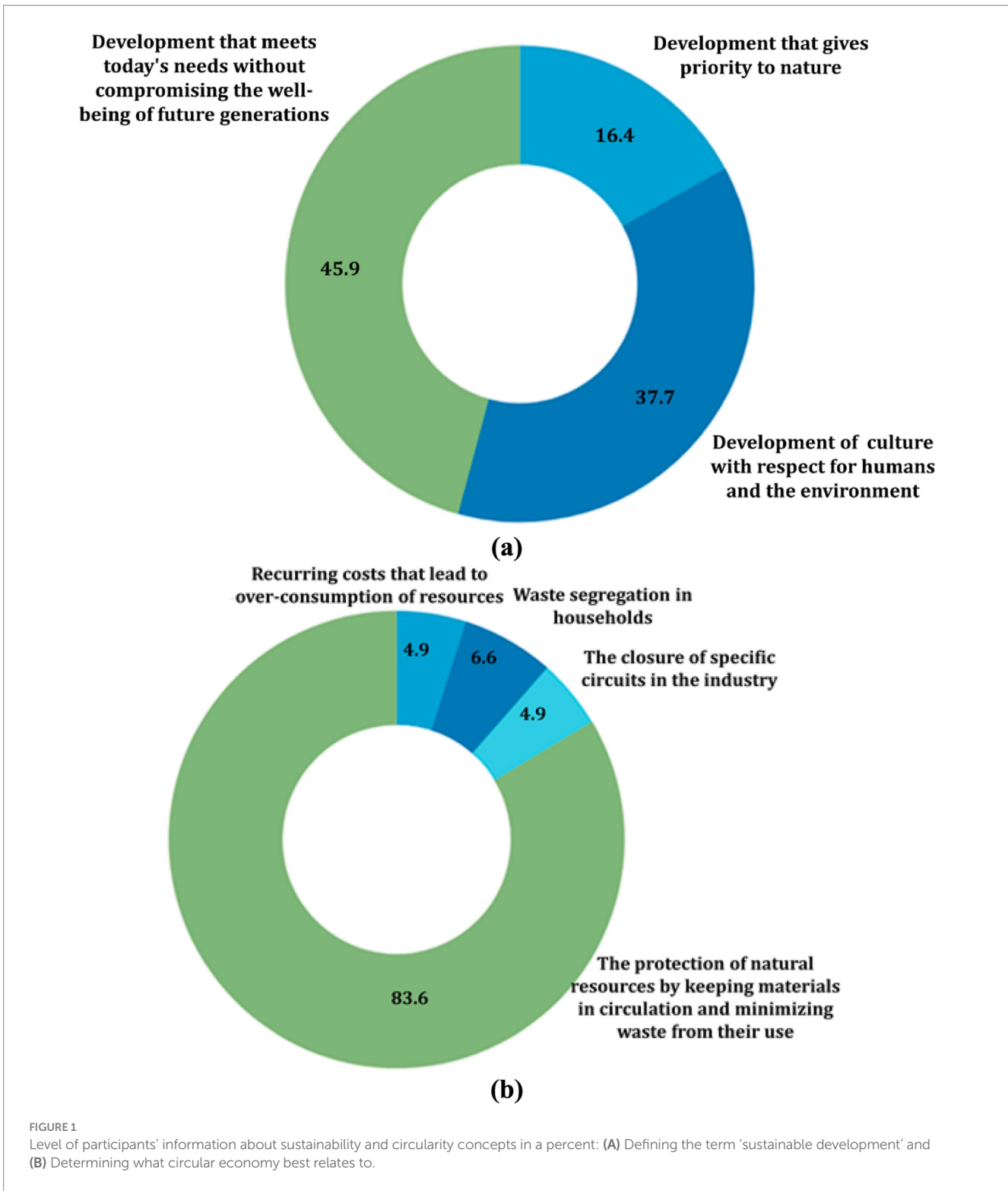
Regarding the SDGs question, findings reveal an anthropocentric attitude; fauna, flora, and industrial needs came last, while well-being, affluence, and the health of human beings came first ([Figure 2](#)). However, this may have to do with the debatable wording of the 17 goals, as some titles suggest a desired state while others demand responsible action. Running Cronbach's alpha, and the value of 0.883 ensures that the SDG items yield consistent responses.

As a side note, despite audio-visual materials being offered for the SDGs and the CE strategies for better comprehension, the majority (61.5%) did not use them. The outcomes could have differed marginally if everyone had received the information. It should be considered that online surveys accelerate the use and expand the radius of material dissemination. However, it might frequently lack the same level of consistency found in traditional physical space practices, given that all other factors are equal.

Almost all participants (97.4%) reflected that a CE is to be jointly achieved by businesses and consumers. Regarding the '10 Rs' of circularity, i.e., strategies of design, use, and the extension and return of products, the participants gave the benefit of their majority, except for three. Translation of these terms into Modern Greek can seem a little affected, so there is an issue here for a common, international deciphering code when rhetorical repetitions of suffixes are used to conceptualize any series of figures. Whereas this may enhance

TABLE 1 Participants' profile.

Profile and characteristics of the sample in percent (%) N = 61			
Gender		Employment status	
Male	22.95	Tenured	80.33
Female	77.05	Non tenured	19.67
Age		Years in employment	
30 to 39 years old	32.70	3–10 years	13.11
40 to 49 years old	36.30	10–20 years	59.20
50 to 59 years old	27.80	20–30 years	19.67
Above 60 years old	3.20	More than 30 years	7.95
Level of education		Specialization	
University degree	100.00	General education	37.10
Master's degree	40.98	Physical education	9.68
Second degree (other subject)	4.92	Music	6.45
Parents		Foreign languages	6.45
No	26.23	Information technology	4.84
Yes	73.77	Preschool	35.48
School Level		Experience in environmental projects	
Pre-primary	16.40	No	50.80
Primary	83.60	Yes	49.20
School location		Annual	13.10
Urban	65.60	Monthly	27.80
Rural	34.40	Annual/monthly	8.30



memorizing in the original language, care needs to be taken in retaining the rhetoric without altering the meaning in translations. Such care was taken into account in this study, and the results concerning the strategies are reflected with maximum accuracy in Figure 3. A high Cronbach's alpha of 0.859 indicates acceptable reliability of responses to R items.

Recycling earning 1st place is not surprising as also Tsironis et al. (2024) reported for a study on companies worldwide with CE interests. Attitudes towards recycling are generally positive. This may relate to

the extensive campaigning of previous decades in educational settings and the fact that recycled products have entered the marketplace.

The responses presented in Table 2 demonstrate that this attitude is translated into recycling behavior, but one needs to consider the significance of choice and feasibility. By adding "Often" and "Always" findings indicate that the majority of participants (83.61%) stated recyclers and adopters of circular and sustainable practices. The low Cronbach's alpha of 0.534 does not indicate



FIGURE 2 Assessing the essential goals of sustainable development (% of responses).

questionable validity of the scale measuring the teachers’ behaviors, as the items do not indispensably correlate with each other (Tavakol and Dennick, 2011). In Figure 4, collected points are favored against all other options of personal waste management, indicating that where facilities exist for waste recycling, the effort is not lacking.

In the concluding section of the survey, the participating teachers unanimously responded to the idea of CE entering the curriculum, answering research question RQ2. More specifically,

59.2% called for mandatory and 40.8% for voluntary incorporation in environmental studies. From the point of view of pedagogy and cognizance, the most appropriate age seemed to be towards the end of level with Grade F collecting marginally the most votes (Table 3).

To the question of which are the most suitable subjects to accommodate the inclusion of CE in the curriculum, this was the Environmental study, proposed by 59 of the 61 participants. The next suggestion was the “Flexible Zone” proposed by 47 participants. The

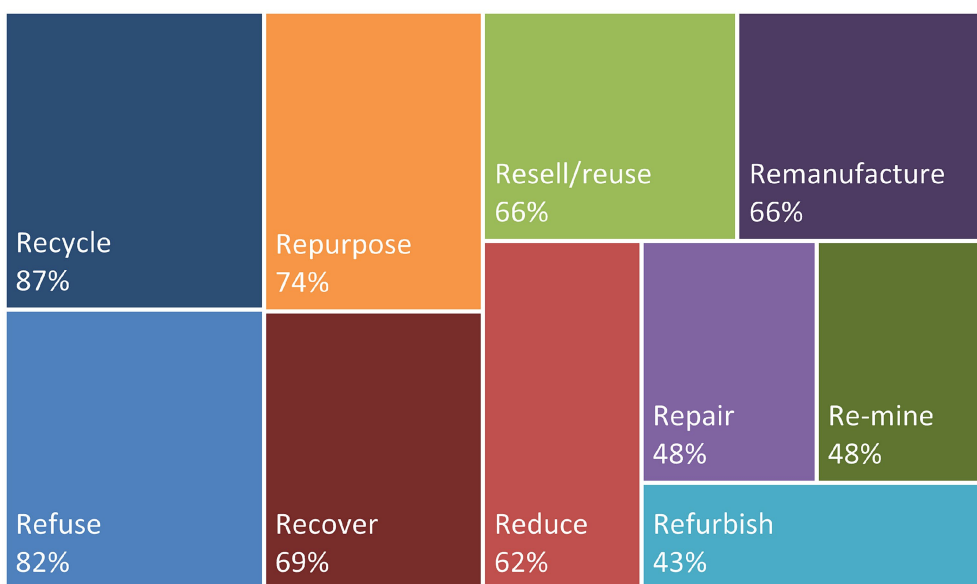


FIGURE 3 Considering the importance of strategies for the development of a circular economy (% of responses).

TABLE 2 Participants' behaviors towards circular and sustainable practices in percent.

Behaviors	Never	Rarely	Often	Always	Often and always	Rank
Paying attention to packaging materials during purchase in order to minimize environmental impact	3.28	21.31	60.66	14.75	75.41	3
Choosing recycled products if possible	0	11.48	54.10	34.43	88.52	1
Purchasing remanufactured/s hand products (e.g., mobile telephones, clothing, books etc.)	9.84	55.74	32.79	1.64	34.43	4
Recycling domestic solid waste	3.28	13.11	31.15	52.46	83.61	2
Composting organic domestic waste	42.62	32.79	21.31	3.28	24.59	5

Bold values are most preferable behaviors.

Flexible Zone of Interdisciplinary and Creative Activities is part of the weekly program of at least two hours duration, which seeks with its free thematic and active methodology to achieve the connection between the school knowledge with students' interests and life situations through the guidance of the teacher. The third possible suggestion was the Physics classes proposed by almost half (30) participants. Running Cronbach's alpha on these responses, the result of 0.703 reveals acceptable reliability.

3.3 Statistical relations

At this point, it is important to draw from the statistical relations between demographics and survey results, to answer question RQ3. The non-parametric Spearman's correlations indicated a positive statistically significant value between the teachers' level of education and the number of environmental programs they implemented ($r_s = 0.296, p = 0.021$). Moreover, more educated respondents selected goals of sustainability, quality education, SDG4 ($r_s = 0.264, p = 0.040$), sustainable cities and communities, SDG11 ($r_s = 0.262, p = 0.041$), responsible consumption and production, SDG12 ($r_s = 0.314,$

$p = 0.014$), partnership for the goals, SDG17 ($r_s = 0.270, p = 0.035$) and the strategy of refurbish ($r_s = 0.256, p = 0.048$). A positive correlation was found between the number of environmental programs and the goals of quality education, SDG4 ($r_s = 0.267, p = 0.037$) and decent work and economic growth, SDG8 ($r_s = 0.318, p = 0.012$), and the strategies of resell and reuse ($r_s = 0.258, p = 0.046$), recycle ($r_s = 0.299, p = 0.020$), recover ($r_s = 0.301, p = 0.019$) and remanufacture ($r_s = 0.311, p = 0.016$). Positively correlated also were found the level of teachers' information about sustainable development and the goals of good health and well-being, SDG3 ($r_s = 0.256, p = 0.046$), and the behavior of paying attention to packaging materials during purchase to minimize environmental impact ($r_s = 0.278, p = 0.030$). Running the Mann-Whitney U test, the results indicated that female participants were more aware of the sustainable development concept than males ($z = -2.229, p = 0.026$).

4 Discussion

The CE is increasingly recognized as a fundamental approach to sustainable development and global economic resilience. However,

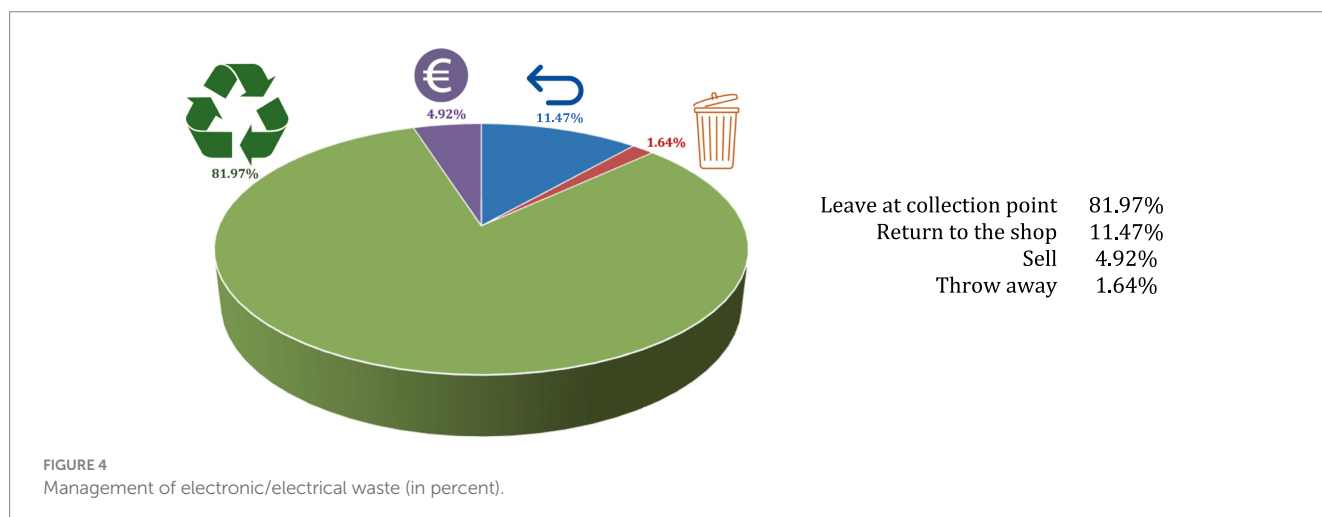


TABLE 3 Recommending age for the inclusion of circular economy in the curriculum (N = 61).

Years of study	Percent (%)
Grade A – 6 years old	14.8
Grade B – 7 years old	4.9
Grade C – 8 years old	19.7
Grade D – 9 years old	21.3
Grade E – 10 years old	13.1
Grade F – 11 years old	26.2

within the limited existing research, there is a divide among scholars. Some argue that promoting these concepts through education offers minimal benefits and numerous obstacles, while others advocate for significant advantages. Research by Keramitsoglou et al. (2023) emphasizes the importance of education in imparting theoretical knowledge and simultaneously cultivating practical skills, ecological consciousness, and sustainability. Incorporating CE and other alternative economic frameworks into teacher education, as suggested by Kowasch (2022), facilitates critical reflections on prevailing economic paradigms and fosters more sustainable futures. Similarly, Bugallo-Rodríguez and Vega-Marcote's (2020) research underscores how activities to reduce environmental impacts can shape student behavior and attitudes toward sustainability.

A closer examination of the results revealed several crucial insights into integrating sustainability and circularity in education. First, the level of teachers' education, information, and awareness of sustainability and circularity play a pivotal role in their ability to take the initiative and integrate environmental programs into their teaching methodology and practice. Teachers who are well-educated and informed about these topics are more likely to adopt and promote sustainability practices within their classrooms. Female teachers, key players in early childhood education because of the gender imbalance at this level, seem more concerned about environmental problems. They were found to have higher awareness and were more willing to promote sustainability than males. Personal values, active participation in environmental programs, or professional responsibilities could explain this gender asymmetry in the knowledge of the sustainability concept (Petkou et al., 2021; Mahbub et al., 2019). The discrepancy between the lack of theoretical knowledge and the precise and formal

definition of sustainable development, as it yielded low scores by less than half of the participants, and their recognition and implicit understanding of SDGs, might be explicable that the latter are connected to sustainable practices. The respondents can be familiar with goals as separate entities like 'end poverty', 'climate action', 'zero hunger', or 'quality education' without distilling into a concise and multifaceted concept, even though the SDGs intertwine with the three pillars of sustainable development, and without understanding the interaction among them (Alcamo et al., 2020; Renaud et al., 2022; Kleespies and Dierkes, 2022). Furthermore, the teachers declared the circular strategies of repair, remine, and refurbish less favorable. They might connect them with the possibility of their effective implementation individually, or consider integrating them as challenging in their classrooms, given that they require facilities and resources, flexible curriculum and institutional support, special effort, and training (Galvão et al., 2018; Ranta et al., 2018; Gonella et al., 2024). These findings underscore the importance of providing continuous professional development opportunities for teachers to enhance their knowledge and understanding of sustainability and CE.

Second, teachers inherently connect quality education with environmental education, well-being, decent work, and the adoption of daily circular practices. This holistic view suggests that for teachers, quality education is not just about academic excellence, but also about fostering a sustainable mindset and lifestyle among students. Environmental education is a fundamental component that enhances overall well-being, prepares students for a sustainable job market, and encourages practices such as recycling, reusing, and reducing waste in their quotidian lives. This interconnectedness implies that to achieve quality education, schools must integrate these elements into their curriculum and daily operations.

Finally, there is a significant lack of systemic and systematic education on sustainability and CE. The current educational framework often fails to provide a cohesive, and consistent approach to teaching these crucial topics. Consequently, the effectiveness of sustainability education is highly dependent on individual teachers' personality, passion, and training. This variability can lead to disparities in students' learning experiences concerning sustainability and circularity. All students should have access to the relevant knowledge, and information, and adopt the appropriate skills on equal terms. To address this issue, there is a pressing need for standardized curricula and comprehensive teacher training programs that ensure

that all educators are well-equipped to teach effectively sustainability. Additionally, creating support systems and communities of practice can help teachers share resources and strategies, fostering a more uniform and effective approach to sustainability education across schools and regions.

Nonetheless, limited research develops limited outcomes. The present study aimed to broaden the scope outside tertiary education and to propose a precise demarcation and first acquaintance with the more critical social category of schoolteachers and primary education students. By opting to survey in a typical region of an average economy in an average educational standard country such as Greece, average results may illuminate anchor standards regarding possible further research in the field. In turn, this study may inform policymakers and other leaders to act in the direction of advancing the circular policy agenda in schools. The primary school teachers who participated in this study showed interest and sensitivity in environmental protection and recycling. They were attuned to value systems, which are apposite to sustainable development and circular policy. Their positive stance was further reflected in their inclination toward the curricular inclusion of CE projects. They and their students and communities would benefit from lifelong, continuous training in CE and sustainable development theory and practices.

Keramitsoglou and Tsagarakis (2011) emphasize the positive effects of school environmental education not only to students but also to their parents. Thus, educators can play an essential role in facilitating progress toward a more sustainable world through instruction. However, for this to occur institutions focused on teacher education and teacher educators themselves must overtly integrate SDGs, subject matter, and tactics into their respective programs (Valter and Costa, 2020). This is also clearly seen in our research as the teacher's personality determines the method and subject matter of the training they offer.

According to the literature review, "Refuse" is the most important CE concept in product chains, followed by "Rethink," "Reduce," and "Reuse" (Wanaguru et al., 2022). Nevertheless, in our study, teachers prioritize the "Recycling" aspect of the CE, possibly due to their extensive training and familiarity with it, and "Refuse" takes a secondary position.

The respondents posit that the 6th grade represents a more optimal juncture for its introduction in the curriculum, obviously considering it more sophisticated than other abstract terms when other research involving the implementation of novel concepts in primary education suggests that the 4th grade is deemed more suitable (Kosta and Tsagarakis, 2019).

Overall, the originality of the present survey consists of a focus on locating the educational needs of primary school teachers as key factors in introducing sustainability and circularity values and principles to young generations. The results revealed the need for special training and continuous education to clarify concepts and misunderstandings and integrate all the SDGs and the 9Rs of waste management in the teaching-learning process.

The limitations of this study are closely intertwined with its merits. The limited range of available literature on the subject restricted the scope for comparative analysis, but this scarcity underscores the importance of initiating research in this emerging field. The study also faced geographical and demographic limitations as the sample was drawn primarily from a provincial population. While this specificity restricts the generalizability of the findings to

more urban or demographically diverse settings, it also provides a valuable foundation for future research. A localized, bottom-up approach can offer unique insights and serve as a meaningful point of departure for expanding into broader, more varied populations, rather than assuming that urban findings are universally applicable to rural contexts as well as face to face data collection. These limitations highlight opportunities for future research. Expanding the sample to include participants from diverse geographical regions, socioeconomic backgrounds, and cultural contexts would enhance the applicability and robustness of the study. Such an approach would not only validate the findings but also ensure their relevance to a wider audience. Furthermore, the bottom-up principle explored here carries broader implications. If its validity holds in geopolitical terms, it logically applies across other dimensions such as age groups, economic strata, and social systems. This perspective is especially pertinent in the CE context, which embodies a political and economic ideal aimed at sustainability and benefiting future generations. Starting at foundational levels, both geographically and demographically, research can more effectively capture the nuances required for a comprehensive and inclusive understanding of this evolving paradigm.

5 Conclusion

The present study sheds light on various aspects of introducing sustainable development and circular economy concepts in primary education. The analysis reaches several critical conclusions based on the sixty-one teachers' responses to a structured questionnaire.

First, whether the teachers adopt innovative teaching practices and implement environmental programs is strongly influenced by their level of information and awareness of SDGs and circular economy strategies. This underscores the need for comprehensive professional development programs, which enhance teachers' knowledge and skills in these areas. Teachers associate quality education with sustainability and circularity values, principles, and related attitudes and behaviors, highlighting the importance of embedding these concepts into the curriculum to foster a holistic understanding among students.

For the moment, the Greek primary education system inadequately integrates the concepts of circularity and sustainability across most disciplines in all six grades. This gap presents a significant opportunity for educational reform. Teachers unanimously agree that theoretical knowledge to raise pupils' awareness of the abstract and evolving concepts of sustainability and circularity should be integrated into the primary education level, with preference in the sixth grade. They suggest introducing these concepts within environmental studies and other subjects connected to practical and innovative methods such as learning by doing, problem-solving, and experiential learning, including Flexible Zone or Physics classes.

There is a clear need for lifelong, continuous, and repetitive education and training for primary school teachers about sustainable development and CE. Professional development programs should focus on empowering teachers with the necessary theoretical knowledge and practical skills to integrate these concepts into their teaching practices effectively and efficiently. Policymakers should recognize that promoting and implementing SDGs and circular strategies requires both, a solid theoretical foundation, and practical competencies, as these are best acquired from an early age.

Comprehensive educational reforms are necessary, including a standardized curriculum, which incorporates sustainability and CE concepts, teacher training programs, resource provision, and essential institutional support for schools.

The timescale for furthering this study is critical; to compare data from similar surveys accurately, the smaller the time window, the more precise the comparative analysis. Longitudinal studies should be conducted to monitor the progress and impact of integrating sustainability and CE concepts over time. Furthermore, expanding this research within an interdisciplinary and international framework could provide broader perspectives and enhance the generalizability of the findings. The present study may serve as a preamble to a wider, more systematic research structure, focusing on identifying best practices for integration, evaluating different teaching methods, and exploring the long-term impacts on students' knowledge, attitudes, and behaviors.

In conclusion, integrating sustainable development and CE concepts into primary education is essential for preparing future generations to address global environmental challenges. Enhancing teachers' knowledge and skills, reforming the curriculum, and fostering international collaboration can create an educational framework that promotes sustainability and prepares students for a sustainable future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. KK: Conceptualization, Formal analysis, Methodology, Supervision,

Validation, Writing – original draft, Writing – review & editing. KT: Conceptualization, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2025.1414055/full#supplementary-material>

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