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Secondary school students' understanding of circular economy and recycling at a small rural school

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ABSTRACT

Biology education plays a crucial role in bridging the gap between science and society. This is of high interest and relevance for several reasons helping students to become biologically literate and understanding basic biological concepts and principles as healthcare, environmental issues, and sustainability. The aim of this study was to investigate the understanding of the 9th grade and the 12th grade students regarding circular economy and recycling. To achieve the objectives, a study was conducted with the convenience sample, involving students from a rural school. The sample was made up of 27 students, including 17 students from the 9th grade and 10 students from the 12th grade. The prior knowledge of students was assessed by the tool of drawing on the topic of the circular economy and recycling. A two-hour training module was created and carried out, including several practical tasks followed by fulfilling the compliant worksheets. The effectiveness of the module was assessed by the questionnaire focused on the new information received during the module and the general feedback of the module was gathered from the students. The results were analyzed using qualitative content analysis and descriptive quantitative research methods. The findings revealed that the understanding of circular economy and recycling among the 9th grade and the 12th grade students was different, expressed in the categories of pre-knowledge and the secondary school students are aware of the importance and purpose of circular economy and recycling. The differences appaired in the students' obtained knowledge and changed attitudes of the 9th grade and the 12th grade students and the improvement of attitudes and willingness to behave in a sustainable way surpassed the increase of understanding of term "circular economy".

Keywords: education for sustainable development, students' conceptualization of circular economy, recycling, lower and upper secondary rural school

INTRODUCTION

The socio-economic situation in the peripheral rural districts of Estonia reflects a blend of challenges and steady developments within broader context of Estonian economy.

Estonia, as a whole, has experienced economic fluctuations, with a contraction predicted in 2023 followed by expected growth in 2024. The general economic environment features decreasing inflation and a complex labor market, where youth unemployment remains a significant concern (European Commission Directorate General for Economic and Financial Affairs, 2023). This broader economic landscape impacts the peripheral rural districts as they navigate their own unique challenges and opportunities.

Specifically, in peripheral rural areas economic activity is largely characterized by traditional sectors such as agriculture and industry, though these sectors have faced their difficulties. Agriculture, employing a small portion of the workforce, and industrial sectors such as food processing, electronics, and wood processing are prominent. However, these sectors have seen variability in output and productivity, which affects employment and economic stability in these regions (Economic and Political Overview in Estonia, n. d.).

Moreover, the population in these areas tends to experience lower income levels compared to urban centers, which impacts consumer behavior and economic opportunities. Access to services, including education and healthcare, can also be more limited in these rural districts, contributing to broader socio-economic disparities (European Commission Directorate General for Economic and Financial Affairs, 2023). Efforts to bolster economic activity, enhance connectivity and infrastructure, and support key industries are essential for fostering sustainable growth and development in rural regions, tackling with the main socio-economic problems like marginalization, depopulation, aging population, coupled with the outward migration of young people to urban areas, significantly impact the local dynamics.

Marginalization in these regions is evident as residents often face limited access to services and economic opportunities compared to urban centers (Heffner & Latocha, 2020). This can result in a lower quality of life and fewer prospects for personal and professional development (Binder & Matern, 2020), especially of young people. Depopulation is a major issue as younger individuals migrate to cities for education and employment, leaving behind an aging population. This shift not only affects the demographic structure but also places a strain on local economies and social services, which are often not equipped to handle the increasing needs of an older population (Dahs et al., 2021; Depopulation in Peripheral Regions of Eastern Poland–Determinants and Con, n. d.; Vaishar et al., 2020).

The aging population in these districts exacerbates the challenges of depopulation. As the younger workforce leaves, the remaining older residents may not be able to fully participate in the economy, leading to decreased economic activity and innovation (Kriisk, 2019), accompanied with outward migration of young people is driven by the search for better educational and job opportunities in urban areas. This migration pattern drains the rural regions of vital human capital necessary for economic development and innovation, further hindering their ability to compete with urban centers (Marksoo, 1999). As a consequence of these problems, the educational system and environmental activities face unique challenges and opportunities that reflect their socio-economic conditions and can be solved by enhancing the education for sustainable development (Tengecha et al., 2024) as the educational infrastructure in these rural areas tends to be less developed compared to urban regions. Schools may struggle with lower funding, fewer resources, and difficulty in attracting qualified teachers, which can affect the quality of education offered (Tampubolon et al., 2024).

Additionally, smaller student populations often mean limited course offerings and extracurricular activities, which can hinder student engagement and learning opportunities. Enhancing educational opportunities and promoting environmentally sustainable practices are key to mitigating the effects of marginalization and supporting the resilience of these communities (Bien et al., 2005).

While there are ongoing challenges, the push towards a circular economy and improved recycling practices in Estonia's peripheral rural districts is a positive sign of progress towards sustainability. Continuous efforts in policy, education, and community involvement are essential to further circular economy and recycling initiatives. These initiatives are often supported by educational campaigns to raise awareness about the benefits of circular economy and recycling (Tiippana-Usvasalo et al., 2023) but in rural districts, the implementation of circular economy practices is often at a smaller scale, focusing on local agriculture and waste management.

Recycling systems may be less efficient due to logistical challenges. Estonia, like its OECD counterparts, faces the dual challenge of ensuring economic viability and enhancing the quality of life in its rural districts, requiring tailored and innovative approaches in education system (Echazarra & Radinger, 2019).

Investigating students' perceptions about the circular economy and recycling in peripheral rural counties in Estonia is important for several reasons, as follows.

Education & awareness (Jitea et al., 2021): Understanding how students perceive recycling and the circular economy can highlight gaps in current educational curricula. It provides insights into how well concepts related to sustainability are being communicated and whether students grasp the importance of these practices. This can lead to more targeted educational initiatives that better address students' knowledge gaps and misconceptions (Adamowicz, 2021; Gaki et al., 2022).

Behavioral insights: Students' perceptions often reflect broader community attitudes towards recycling and sustainability (LeDrew, 2020) and as students represent the next generation of consumers, workers, and decision-makers. Understanding their attitudes towards recycling and sustainability can forecast future trends in consumer behavior and environmental policy support (Kioupi & Voulvoulis, 2019).

Education for sustainability is not just about acquiring knowledge, it is about equipping individuals with the tools they need to engage with and contribute to important discussions and decisions at the intersection of science and society (Kioupi & Voulvoulis, 2019). It plays a critical role in building a more informed, responsible, and engaged citizenry and that's why the topic of sustainable development is obtaining the increasing attention in biology curriculum, including circular economy and recycling (García-González et al., 2022).

Student awareness of circular economy and recycling is an emerging focus in sustainability education. Studies show that while there is increasing interest in these topics, students' understanding is still limited.

Innovative teaching methods, such as experiential learning through virtual enterprises, have proven effective in enhancing this understanding. However, educational practices and policies often fall short in fully supporting CE concepts, especially at secondary education levels (Keramitsoglou et al., 2023).

Incorporating the concepts of circular economy and recycling into environmental education is important for several reasons: Environmental awareness; real-world issues that directly relate to life science; the importance of conserving natural resources; waste reduction (Debrah et al., 2021) and adopting recycling habits; interdisciplinary learning and holistic understanding of environmental challenges; innovative problem-solving within the context of biology, ecology and sustainability; diverse career opportunities in fields like environmental science, conservation biology, and sustainable agriculture; the complexities of circular economy and recycling (Walshe, 2017).

Therefore, integrating circular economy and recycling concepts into science education not only aligns with environmental and sustainability goals but also equips students with knowledge and skills that are relevant to their future as responsible citizens and professionals (Korsunova et al., 2021).

The educational methodology behind the current study is a context-based teaching (Holbrook & Rannikmae, 2017), where the teacher introduces a topic or a lesson from a real-world context and relates this to the learning of conceptual interdisciplinary science ideas. The complicated problems of sustainability need transdisciplinary approach (Holbrook et al., 2020) using a four-stage teaching model (contextualization, de-contextualization, re-contextualization, and trans-contextualization) to promote active citizenry (Chowdhury et al., 2020).

The Estonian lower and upper secondary school national curricula do not extensively cover topics of the circular economy and recycling, despite their importance in preventing waste crises. To prepare future generations for crisis prevention, it is essential to teach the fundamentals of recycling and the circular economy from an early age. To make learning engaging and memorable, it is beneficial to use various modern teaching methods in natural sciences, such as role-playing, debate, frontal discussion, the flipped classroom, etc. (Jeronen et al., 2016). The curricula emphasize principles of sustainable development, environmental awareness, and responsible behavior, focusing on solving issues related to environmental questions (Zwiers et al., 2020). Through integrative themes, various fields such as biology, geography, chemistry, physics, and social sciences can be linked through practical problem-solving and project work, included into cross-cutting topic theme "environmental protection and sustainable development", the terms of circular economy and recycling are not used directly and it can be said that school textbooks do not cover circular economy and recycling themes as extensively as would be needed today (Basic Schools and Upper Secondary Schools Act–Riigi Teataja, n. d.).

According to the aim of the study, the following research questions were proposed:

RQ1. At what level are the students' perceptions of circular economy and recycling according to the learning outcomes expected in the curriculum?

RQ2. What are the sources of students' understanding of sustainable development and the circular economy?

METHODOLOGY

Sample & Data Collection

Convenience sampling was used for this study, involving 37 students from a small peripheral rural school. Five 45-minute lessons were planned for the survey.

The data of the study were collected in five stages:

1. Assessing the students' prior knowledge about circular economy and recycling by drawings about the circular economy and recycling.

2. A four-hour learning module on circular economy and recycling was conducted.

   a. An interactive lecture, including a short theoretical introduction and different learning materials from "interreg V-A Estonia-Latvia program 2014-2020" (PACKGDEPO–EstLat, n. d.)

   b. After the interactive lecture, the students were divided into groups of four. Then, each group was given a task called "letter scramble" to solve together. The scramble contained 19 words related to waste management. The students had to identify at least ten of these words and draw a circle around each word found. They had 10 minutes to complete the task.

   c. Circula game (Circula®, n. d.): Circular economy and entrepreneurship game familiarizes circular economy through creative teamwork. The gamified approach is suitable for many kinds of learners while the goals and instructions are adjusted according to the players' needs. Game master–teacher or other instructor–supports the cooperation and learning of the group.

   d. Creating a word cloud of obtained new concepts of circular economy and recycling (Hearst et al., 2020).

Textual information is inherently difficult to visualize quantitatively, due to its nominal nature. For at least a decade, a common method for showing textual information visually for lay people and scientists alike has been some variation of a word cloud (Hearst et al., 2020). students and user-friendly option for creating word clouds WordArt (Best Word Cloud Generator–25+ Templates, n. d.) was used to visualize the students' obtained concepts during the learning module.

3. The frontal analysis was conducted of the students' initially drawn posters and the possible additions to their posters after the intervention of the two-hour learning module and the additions to their initial posters were discussed; renewed circular economy and recycling concepts (Chintalapudi et al., 2021).

4. The questionnaire based on the new information received during the intervention was analyzed both quantitatively (Diéguez-Santana et al., 2021) and qualitatively (Lindgren et al., 2020).

5. Finally, the feedback of the learning module was gathered and analyzed using the qualitative content analysis method (Selvi, 2019).

Data Analysis

1. The prior knowledge of the students about the circular economy and recycling was assessed through qualitative analysis according to the method of drawing as a qualitative research tool from a social complexity perspective (Janis et al., 2020). The validity or the accuracy of the survey and the data collection was guaranteed by the three co-coders of the data–the initial drawings of the students were repeatedly revised to ensure that they were unambiguously understandable and reliable (Hayashi et al., 2019).

2. After a four-hour intervention of learning module on circular economy and recycling the knowledge assessment was fulfilled using the worksheets that were analyzed quantitatively and qualitatively (Almeida, 2018), using MS Excel and descriptive statistics due to small sample.

3. The feedback questionnaire that was analyzed by mixed method, i.e., quantitatively and qualitatively (Proudfoot, 2023).

Table 1. Results of qualitative content analysis of students' drawings of circular economy & recycling

Categories (codes)	9th grade students (n=17)	12th grade students (n=10)	All students (n=27)
Recycling (plastic, metal, textile, glass, & paper)	13 (76%)	8 (80%)	21 (78%)
Reusing (new product & reusing old clothes)	5 (29%)	7 (70%)	12 (44%)
Reducing (saving electricity, paper, cardboard, & fossil fuels)	6 (35%)	9 (90%)	15 (56%)
Renewable energy (solar panels, wind energy, hydro energy, & biogas)	15 (88%)	8 (80%)	23 (85%)
Waste management (garbage sorting, disposable dishes, cardboard, & paper sorting)	13 (76%)	8 (80%)	21 (78%)
Production (factories & emissions)	4 (24%)	5 (50%)	9 (33%)
Transport (electric cars, public transport, & bicycles)	10 (59%)	9 (90%)	19 (70%)
Consumption (habits & second-hand stores)	5 (29%)	8 (80%)	13 (48%)
Food (home-grown, organic, & organic farming)	13 (76%)	9 (90%)	22 (81%)

Validation of Research Results

Validating the results of a qualitative content analysis of students' drawings in the 1st stage a weighted kappa statistic was used to assess the level of agreement between two reviewers as weighted kappa statistic considers the degree of agreement beyond chance and is commonly used in inter-rater reliability studies. The agreement between two reviewers based on the calculated Cohen's kappa (0.78) indicated substantial agreement (Gläser-Zikuda et al., 2020). SPSS.23 statistical software package was used to compute Cohen's kappa according to test procedure in SPSS statistics (Everitt & Brian, 2003).

RESULTS

Students' Prior Knowledge About Circular Economy & Recycling

According to the qualitative content analysis of the students' drawings prior to the study, the information on the drawings was coded into categorized by two co-coders into nine categories.

The analysis presents the key findings extracted from **Table 1**, detailing the participation of the 9th and the 12th grade students across various sustainability categories. These results shed light on the extent to which students are engaged in environmentally conscious behaviors at different stages of their education.

According to the results, 78% of all students engage in recycling, with 76% of the 9th graders and 80% of the 12th graders participating. 85% of all students are involved in renewable energy practices, with 88% of the 9th graders and 80% of the 12th graders. Also 78% of all students participate in waste management practices, with equal participation from the 9th graders and the 12th graders. 48% of all students engage in conscious consumption habits, with 29% of the 9th graders and 80% of the 12th graders and 81% of all students are involved in sustainable food practices, with 76% of the 9th graders and 90% of the 12th graders.

In summary, **Table 1** reflects a strong inclination towards environmental sustainability among students, particularly in the areas of renewable energy, recycling, and waste management. There's an upward trend in participation from the 9th grade to the 12th grade, indicating increased environmental awareness with age. However, there's still room for growth in the areas of production, consumption, and some aspects of reducing and reusing and some aspects of circular economy and recycling are not mentioned by the students (e.g., hydropower, reducing water consumption, composting, food waste, e-waste, etc.).

After completing the module, the students were divided into groups of four. The groups had to solve word puzzle tasks together. There were 19 words related to waste management in the word puzzle (bio-waste, waste, waste station, waste management, compost, sea sludge, microplastics, plastic packaging, plastic bottle, litter, landfill, incinerator, landfill, recycling, textile waste, raw materials, single-use, recycling). The students had to find at least 10 of them and draw a line around each word they found.

The students had no difficulty searching for and finding the hidden words. Both classes solved the problem within the given 10 minutes. The results show that students in the 12th grade found more words than students in the 9th grade at the same time. Three groups of grade 12 students found all 19 words; one group found 18 words. Among the groups of grade 9 students, one group found 18 words, two groups found 17 words and the last group found 16 words.

Next, in the same groups, the students were asked 15 questions. The answers to these questions were cut out on sheets of paper and the correct answer had to be matched to the question. Students had 10 minutes to complete the task. After the carried through module of circular economy and recycling, the students had no difficulty in finding the correct answers to the questions in the 10-minute time allowed. All questions were answered correctly in both classes and in all groups.

After the completion of interactive tasks, the students were asked to give verbal feedback on the four-hour module and on their own performance. In summary, this group work approach was very well suited to the students, and they were keen to continue with this type of task in future lessons.

Questionnaire on New Information Received During Learning Module & Feedback

The students completed a questionnaire enabling them to assess their knowledge after the intervention. The general overview of the results revealed that there was still confusion about the concept of the "circular economy" among students, with only 29% of the 9th graders and 14% of the 12th graders understanding it correctly.

Fortunately, clear understanding appeared on the concept "recycling" among all students, with 100% accuracy from both grade levels. Strong support occurred for more focus on the

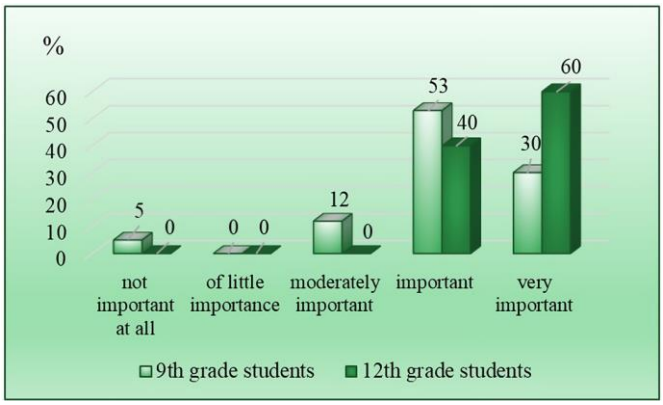

Figure 1. Students' ratings about seriousness of problems considering various environmental issues (Source: Authors' own elaboration)

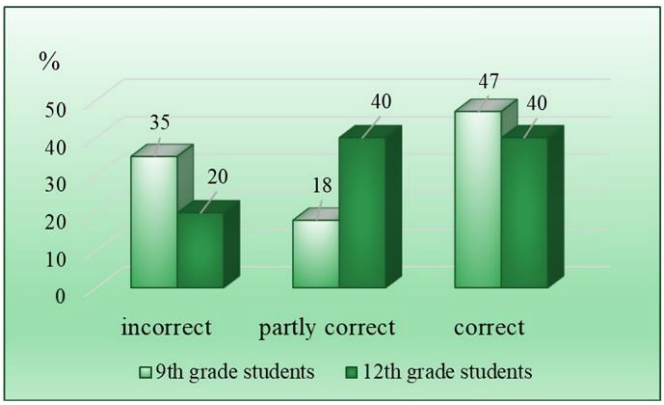

Figure 2. Answers to task "describe how you understand concept: Circular economy" (Source: Authors' own elaboration)

circular economy and recycling in science lessons, with 85% of students considering these topics very important. Biology and science classes were identified as the preferred subjects to cover circular economy and recycling. Many students (85%) reported that completing the module and worksheets changed their opinion about recycling and the circular economy. The results of the students' responses to rate the seriousness of sustainability issues for them are illustrated in **Figure 1**, showing that many students consider the topic to be important enough and very important.

The students' ratings on the seriousness of various environmental issues indicated that "waste management" was the most commonly cited concern, mentioned by 11 students (41%), with grade 9 students mentioning it eight times and grade 12 students mentioning it three times. "Recycling" followed closely, mentioned by a total of nine students (33%), with four mentions from grade 9 students and five from grade 12 students. "Reusing" was mentioned five times (19%), with grade 9 students mentioning it three times and grade 12 students two times. "Nature conservation" and "other" were each mentioned once (4%) by a grade 9 student.

To the question "how can you contribute to the functioning of circular economy and recycling systems?", majority of students (82%) answered that they would be willing to do something themselves to tackle environmental problems. 15% of students said that they would not be willing to do anything themselves to solve environmental problems and 4% of respondents had no opinion. The reasons given by the students were that they would rethink their consumption habits in the future and save the environment. It was also pointed out that they now know how to guide their family members to sort their rubbish and can talk to younger family members about the importance of sorting waste. Respondents also pointed out that they no longer wear cheap clothes.

Schools and teachers were most cited in the responses to the question "from whom have you received information about the circular economy and recycling", also using the Internet to find information from parents were mentioned. In addition, the website of environment agency. The main point made by respondents was that this topic should be introduced already in kindergarten. In addition, schools, students, and young people were also mentioned. It was also pointed out that sustainability education should be targeted at older people, who are not very aware consumers.

To summarize the feedback of students we can conclude that the students plan to change their consumption habits, educate family members about waste sorting, and avoid buying cheap clothing. Most respondents gained knowledge about circular economy and recycling from schools, teachers, and the Internet, there is a strong suggestion that education on sustainability should begin in kindergarten and also target older people who may lack awareness about sustainable consumption.

Figure 2 compares the percentage of the 9th grade and the 12th grade students' understanding of the circular economy, categorized into "incorrect," "partly correct," and "correct" responses.

A higher percentage of the 9th grade students (35%) had an incorrect understanding of the circular economy compared to the 12th grade students (20%). This suggests that younger students may have less exposure or more difficulty grasping the complex aspects of the concept.

Both the 9th grade and the 12th grade students showed similar levels of partly correct understanding, with 18% of the 9th graders and 40% of the 12th graders falling into this category. The significant difference here indicates that while students are progressing, they gain a better but still incomplete grasp of the concept.

The 12th grade students displayed a notably higher correct understanding of the circular economy at 40%, compared to 47% among the 9th graders. This pattern demonstrates a substantial improvement and deeper comprehension as students mature and progress through their education.

These results indicate a clear developmental trend in understanding the circular economy, with comprehension improving significantly from the 9th to the 12th grade. The data suggests that educational strategies might need to focus more intensively on younger students to build a solid foundational understanding early on. Additionally, the high rate of partly correct answers among the 12th graders suggests that while older students are advancing, there is still room to enhance clarity and depth in teaching this complex topic, possibly through more integrated and practical applications in the curriculum.

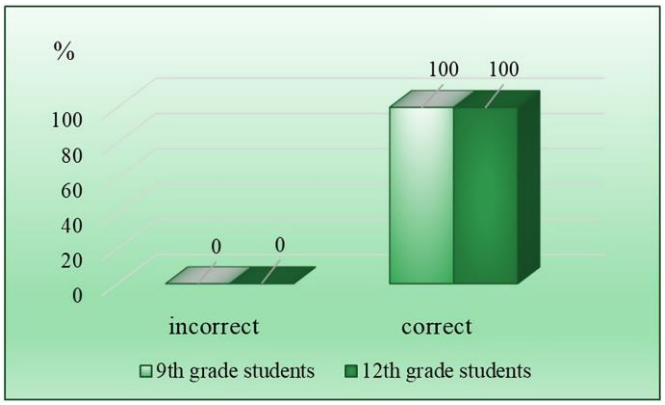

Figure 3. Answers to task "describe how you understand concept: Recycling" (Source: Authors' own elaboration)

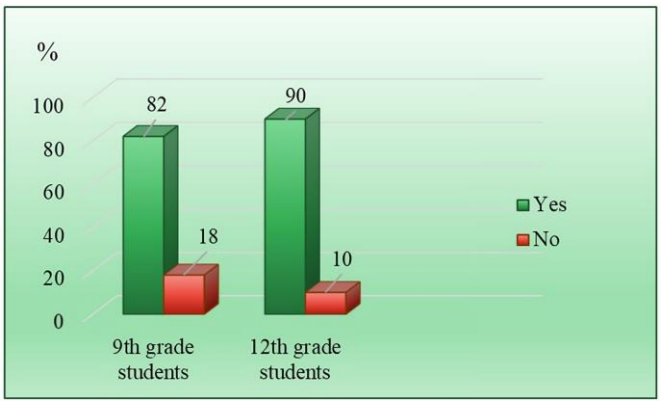

Figure 4. Answers to question "should school science classes address more topics on circular economy and recycling?" (Source: Authors' own elaboration)

Figure 3 displays comprehension levels of the 9th grade and the 12th grade students regarding to the concept "recycling", categorized into "incorrect" and "correct" responses.

Both the 9th grade and the 12th grade students show 0% incorrect understanding in the topic of recycling. This implies that no students from either grade level held misconceptions or completely wrong ideas about recycling, indicating a universally solid foundational knowledge in this area.

Remarkably, both age groups–the 9th graders and the 12th graders–achieved a 100% success rate in demonstrating correct knowledge about recycling. This suggests that every student surveyed correctly understands what recycling involves and its importance. The outcomes indicate an exceptionally successful comprehension of recycling across both surveyed grade levels. The 100% correctness in understanding among all students suggests that the educational approaches to teaching recycling are effective, ensuring that students grasp both the concept and practice of recycling thoroughly. This uniform success across different age groups points towards consistent and effective educational messaging and methods throughout the students' studies.

Figure 4 illustrates student responses to the question, "should school science classes address more topics on circular economy and recycling?" across two grade levels: the 9th grade and the 12th grade.

82% of the 9th grade students believe that school science classes should include more topics on circular economy and recycling. This indicates a strong interest in and perceived importance of these topics among younger students. 18% of the 9th grade students do not think it is necessary to address more topics on circular economy and recycling in science classes. This minority may feel that the current curriculum is sufficient or may prioritize other subjects or topics. An even higher percentage, 90%, of the 12th grade students responded affirmatively, suggesting that as students advance through their studies, they recognize an increasing need or value in expanding education on these environmental topics. Only 10% of the 12th graders oppose the inclusion of more topics on circular economy and recycling. This reduced opposition compared to the 9th graders could indicate a deeper understanding or appreciation of these topics' relevance, possibly influenced by their closer proximity to entering higher education or the workforce.

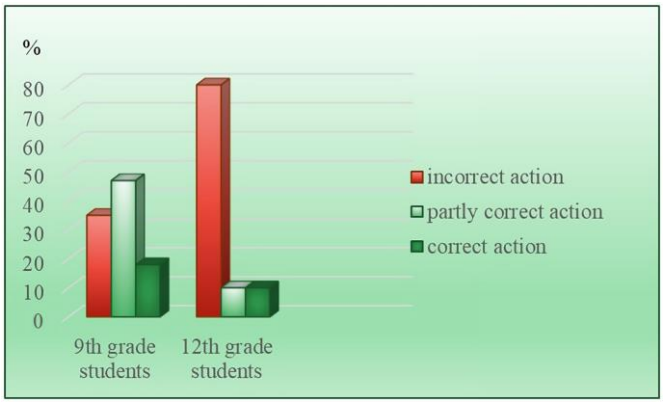

Figure 5. Answers to question "how can you contribute to functioning of circular economy & recycling systems?" (Source: Authors' own elaboration)

These results reveal a strong and increasing support for more extensive coverage of circular economy and recycling topics in school science classes as students are progressing from the 9th grade to the 12th grade. The high percentages of affirmative responses (82% and 90%) underscore the importance students place on these subjects, likely reflecting their growing awareness of environmental issues and the relevance of sustainability in education. The data suggest that students are keen on integrating these critical global challenges into their learning to better prepare for future societal and environmental challenges. **Figure 5** presents the results of responses from the 9th grade and the 12th grade students to the question "how can you contribute to the functioning of circular economy and recycling systems?"

A relatively small portion of the 9th graders responded with incorrect actions, representing about 20% of the cohort. This indicates some misconceptions or lack of understanding about how to contribute effectively to the circular economy and recycling systems. The largest group of the 9th grade responses fell into the partly correct category, around 40%. These responses likely contain elements of correct actions but may lack completeness or full understanding of how to implement these practices effectively. Approximately 40% of the 9th graders provided responses that were classified as correct actions. This suggests that a significant portion of these

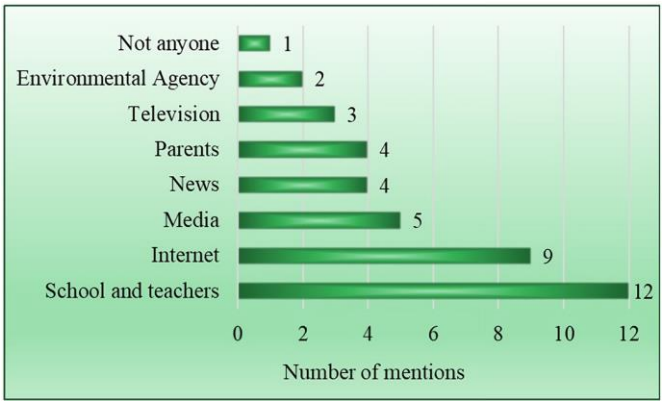

Figure 6. Answers to question "where have you learned about circular economy & recycling?" (Source: Authors' own elaboration)

younger students have a good grasp of applicable actions to support the circular economy and recycling.

The percentage of the 12th graders providing incorrect actions significantly increased to about 70%. This unexpectedly high rate might indicate either a misunderstanding of the question, a shift in perception about what constitutes effective actions, or possibly a more critical view of what truly supports the circular economy and recycling. Only a small percentage, about 10%, of the 12th graders fell into the partly correct category. This lower value compared to the 9th graders might reflect a polarization in understanding as students age, moving towards either largely incorrect or wholly correct understandings. Approximately 20% of the 12th grade responses were considered correct. This is a significant decrease from the 9th grade level and could reflect more sophisticated criteria for what students consider to be truly effective actions as they mature or an indication of gaps in educational reinforcement at higher grade levels.

These results show a complex picture of understanding and misconceptions about contributing to the circular economy and recycling systems among the 9th graders and the 12th graders. While the 9th graders displayed a balanced understanding with a good proportion achieving correct actions, the 12th graders showed a significant increase in incorrect actions, suggesting a need for educational interventions to correct and deepen understanding as students are progressing. The disparity between the grades could also suggest different interpretations or understanding of what actions are effective or necessary for contributing to the circular economy and recycling, highlighting the need for clearer education on practical environmental actions.

Figure 6 shows the results from the task, where students were asked, "where have you learned about the circular economy and recycling?" The data presented in the bar chart lists various sources of information, with the number of times each was mentioned by students.

The most frequently mentioned source, where students learned about the circular economy and recycling is through school and teachers, indicating a strong educational influence on these topics in the academic environment. The Internet is the second most common source, highlighting its role as a significant platform for educational content outside traditional classroom settings. Various forms of media (possibly including both digital and print media) rank third, suggesting that media outlets play a notable role in disseminating information related to environmental topics. Both news outlets and parents are cited equally, indicating that students also receive information from current events and family discussions. Television is less mentioned but still serves as a source of information, possibly through documentaries, news broadcasts, or educational programs. Direct information from environmental agencies is less commonly mentioned, which might reflect less direct engagement with these agencies by the general student population. Interestingly, one student mentioned not learning about these topics from anyone, which might indicate either a lack of interest or a lack of exposure to these topics outside formal educational settings.

The data reveals that schools and teachers are the primary sources of information about the circular economy and recycling, underscoring the critical role of formal education in environmental awareness. The Internet also serves as a key resource, reflecting its importance as a tool for self-education and information dissemination. While traditional and new media forms contribute to awareness, there is a relatively lower engagement with direct sources like environmental agencies. This distribution of sources suggests that enhancing collaborations between schools, media, and environmental agencies could further improve the breadth and depth of student education on these critical topics. The mention of not learning from anyone highlights a potential gap that needs addressing to ensure all students have access to information about sustainability practices.

The results from **Table 2** present a breakdown of responses from the task, where students were asked, "who else do you think should talk about these topics and why?"

The students' suggestion to include everyone underscores the universality of environmental issues. Respondents believe that broad-based education and information dissemination are crucial because these topics affect all members of the community, impacting societal well-being and requiring collective action.

Engaging young children and youth is considered vital because they are often less aware of environmental impacts and their responsibilities. Early education on these topics is seen as essential for instilling sustainable values and behaviors that can influence their future actions and attitudes toward environmental stewardship.

There is a recognition that students are at a critical phase of learning and development. Discussing circular economy and recycling within educational settings ensures they become informed and capable individuals who can contribute positively to societal changes. The goal is to arm them with knowledge that empowers them to make informed decisions.

Adults are influential in both community and family settings. Educating adults is seen as a way to change entrenched worldviews and promote contemporary values that include sustainability. Adults have the capacity to implement changes at the community or policy level and influence younger generations through their actions and decisions.

Table 2. Answers to question "who else do you think should talk about these topics & why?"

Category	Code (who to talk to)	Why?
General audience (broad)	Everyone, all, people, our brothers, & community members	To all people, so they would know more about it. Information & education about certain topics are relevant to everyone, as societal issues affect all members of community.
Children & youth (age-specific)	Young children, little ones, children of all ages in schools, starting from kindergarten, children from kindergarten onwards, school children, & youth (mentioned twice)	To little ones, as they usually do not know much about such things & who constantly throw candy wrappers on the ground. Engaging children & youth in conversations about important issues is crucial for early education. It helps instil values & knowledge that shape their future actions & attitudes.
Students (educational level)	Students in schools at all educational levels & students at school	To students, so they would know. Students are in a pivotal phase of learning & development. Discussing these topics in educational settings ensures they become well-informed individuals who can contribute positively to society.
Adults & special groups	Parents, elderly, & primarily adults	To change their worldview to be more contemporary. Adults often have power to make changes at community or policy level. Educating adults, including parents & elderly, can have a ripple effect, influencing their decisions & upbringing of next generation.
Environmental awareness (context-specific)	People, especially those who live in cities	Rural areas face significant challenges with waste management. Targeted awareness campaigns in cities can lead to better practices, such as recycling & reduced consumption, that are critical for sustainability.

Rural areas face significant environmental challenges, particularly in waste management. Targeting city dwellers for awareness campaigns can lead to better practices, such as effective recycling and reduced consumption, critical components for sustainable rural living.

These data highlight a comprehensive approach to environmental education, emphasizing the need to involve various groups in the conversation about circular economy and recycling.

By engaging a wide spectrum of the population–from the very young to the elderly–the respondents recognize that effective communication and education about environmental issues must be inclusive and widespread, tailored to specific needs and contexts. This approach not only enhances awareness but also fosters a culture of responsibility and proactive engagement across all levels of society.

DISCUSSION & CONCLUSIONS

This study focused on understanding circular economy and recycling concepts among secondary school students in a peripheral rural setting. Utilizing both qualitative and quantitative methods, the research aimed to assess and enhance students' comprehension through educational module of circular economy and recycling.

The importance of teaching circular economy and recycling concepts in educational settings, particularly in peripheral rural districts cannot be underestimated (Bien et al., 2005; Debrah et al., 2021) as there are the unique challenges and opportunities in these areas (Depopulation in Peripheral Regions of Eastern Poland–Determinants and Con, n. d.; Heffner & Latocha, 2020; LeDrew, 2020; Vaishar et al., 2020).

The findings revealed a significant improvement in understanding from the 9th grade to the 12th grade, indicating a clear developmental trend in the comprehension of the circular economy. The data suggests a need for targeted educational strategies for younger students to establish a solid foundational understanding early on (Walshe, 2017). Furthermore, the high rate of partly correct answers among the 12th graders suggests the necessity for enhanced clarity and more integrated, practical applications in the curriculum to address complex topics effectively (Zwiers et al., 2020).

For recycling, the results showed an exceptionally successful comprehension across both grade levels, with a 100% correctness rate, reflecting highly effective educational approaches that ensure thorough understanding of both the concept and practice of recycling. This success points towards consistent and effective educational messaging and methods throughout the students' education (Tiippana-Usvasalo et al., 2023).

Peripheral rural districts offer unique experiential learning opportunities that can significantly enhance environmental education. These areas serve as real-world activities, where students can directly observe and engage with sustainability practices, which is reflected in the high student readiness to involve in activities like "waste management" (Adamowicz, 2021).

The shift in student attitudes towards sustainability and recycling, particularly noted in post-intervention questionnaires, indicates that increased awareness can lead to significant behavior change and potentially influence community (Chodkowska-Miszczuk et al., 2021). This is further supported by strong student support for expanding coverage of circular economy and recycling topics in school science classes, as indicated by high affirmative responses (82% and 90%) of participating students.

The effectiveness of the educational module in changing student perceptions highlights the importance of interactive and participatory teaching methods (Rodríguez Aboytes & Barth, 2020). The study suggests further improvements and adaptations based on student feedback to enhance engagement and understanding in less comprehended areas such as "production" and "consumption" (García-González et al., 2022).

Limitations of Study

The study's limitations include its small, rural-focused sample, which might limit the generalizability of the findings. Moreover, the specific demographic focus might not accurately reflect urban students' perspectives or challenges.

Recommendations for Future Research

Future research should explore these educational topics across diverse demographic settings and age groups. It's recommended to examine different innovative pedagogical approaches (Reynolds et al., 2018) to deepen the understanding of sustainability issues of circular economy and recycling, particularly in areas, where misconceptions persist. Focus should be put on long-term impacts of environmental education on societal and individual levels (Liu et al., 2019).

This study underscores the critical role of education in promoting sustainable behaviors and attitudes towards the circular economy and recycling. The findings advocate for beginning environmental education as early as kindergarten and extending it to older populations to ensure comprehensive community engagement. The importance of schools and teachers as primary information sources is evident, and there is a potential for enhancing collaborations between educational institutions, media, and environmental agencies to broaden the scope and depth of student education on these crucial topics. By engaging a wide spectrum of the population, effective communication and education about environmental issues can be achieved, fostering a culture of responsibility and proactive engagement across all levels of society.

In summary, there is a strong inclination towards environmental sustainability among students, particularly in the areas of renewable energy, recycling, and waste management. Also, there is an upward trend in participation from the 9th grade to the 12th grade, indicating an increased environmental awareness with age. However, there is still room for growth in the areas of production, consumption, and some aspects of reducing and reusing.

The survey highlights a significant willingness among students to engage in environmentally friendly practices. It emphasizes the importance of early and inclusive education on sustainability, suggesting that such initiatives should start from a young age and address older generations. The role of schools, teachers, and digital resources in spreading awareness about the circular economy and recycling is notably significant.

This distinction in learning outcomes underscores the relevance of targeting rural districts with educational initiatives that bridge science education with practical environmental and sustainability applications. Such efforts are vital for empowering students in rural communities to become proactive inhabitants of their environment, leveraging their knowledge for the betterment of their local and the global ecosystem.

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