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# Raising effective awareness for circular economy and sustainability concepts through students' involvement in a virtual enterprise

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**Introduction:** Despite increasing research on the transition of a well-established linear-oriented economic system toward the circular economy (CE) model, existing literature on the adoption and implementation of educational approaches that reinforce CE concept in secondary education seems to be limited. In light of the current challenges and the critical role of education in empowering students to explore new paths of sustainable development and grow into active citizens, conscious producers, and consumers, this study focuses on experiential learning as an effective tool for teaching CE and sustainability concepts. The literature review has revealed a research gap as regards the formulation of educational approaches to support CE concepts for secondary education students effectively, particularly in Greek vocational education. The present study describes and critically discusses how a virtual enterprise could introduce secondary-level students to the circularity and sustainability perspective, prepare them to build prosperity, and act circularly in the future.

**Methods:** Drawing on the activities of 32 students coming from different disciplines and participants in a virtual agri-business, we recommend practical educational strategies expecting (i) to encourage teachers to adopt innovative teaching methods and share good practices of CE teaching and (ii) to urge education policymakers to integrate the CE vision into school curricula.

**Results and discussion:** Furthermore, the students' responses to a structured questionnaire before and after the programme implementation indicate that experiential learning should be supported by the teaching of theoretical aspects for a better consolidation of abstract concepts such as CE and sustainability. The implementation of a circular enterprise by a student team consists of a positive prospect for the community and economy.

KEYWORDS

**circular economy, circular business model, education policy, sustainability, virtual enterprise**

## 1. Introduction

During the last few decades, the concepts of circular economy (CE) and sustainability have attracted the increasing attention and interest of researchers, governors, policymakers, practitioners, entrepreneurs, and citizens. The CE model challenges the current traditional linear model of production and consumption, which follows the process of exploiting the planet's raw resources, manufacturing, using, consuming the products, and finally, disposing of waste. The linear model has created an economy that largely depends on energy consumption, virgin sources, and wastefulness of raw materials, thus resulting in climate change, pollution and depletion of natural resources, biodiversity loss, economic instability, and social inequality. On the contrary, the CE has been promoted as a tool or a condition for acting toward sustainable development (Geissdoerfer et al., 2017).

However, both concepts remain unclear and ambiguous (Kirchherr et al., 2017; Geisendorf and Pietrulla, 2018; García-Barragán et al., 2019; Millar et al., 2019).

Moving toward a CE model, which signifies a closed-loop production–consumption process and system, and its implementation requires systemic thinking, top-down and bottom-up approach, initiatives and action, and the active involvement of various stakeholders, including the public and private sectors, and civil society (Kyriakopoulos et al., 2019; Calisto Friant et al., 2020; Desing et al., 2020). Various roles of citizens, individual engagement toward this transformation, and gaps in the existing knowledge highlight the need for bringing about changes in everyday life attitudes and behaviors for adopting a new way of thinking and for developing new competencies and skills (Milios, 2022). Furthermore, the European Union's (EU's) relevant policy framework includes the citizens' empowerment by providing trustworthy information (EU, 2020).

New theories on how the CE perception can be applied to promote sustainability should be developed, reflecting a conceptual change in education. Prior research indicated that education could decisively contribute to a change in behavior and culture, thus condensing the time for implementation of circularity and sustainability and posing them as the highest priority in the economy and society (Pandey and Vedak, 2010; Changing Public Behavior, 2015a; Graaf, 2021b). Education is considered the starting point of every effort to achieve social, political, and economic growth in the modern world and a prerequisite for connecting theory and practice (Bakken et al., 2017; Suárez-Eiroa et al., 2019). Nevertheless, the need for further investigation of education policies and practices toward circularity has been ignored so far (Martinho and Mourão, 2020).

In the present study, focusing on the education for CE and sustainability at the secondary education level, we present a case study of a student's virtual enterprise as an innovative method for teaching–learning their principles and values. After highlighting the gap in the relevant existing knowledge with a literature review, we describe the case study in detail, present the research results, critically discuss themes to locate strengths and weaknesses, and draw conclusions for practical and theoretical implementation of CE and sustainability.

## 1.1. Literature review

Given the nature of research topic and its objective, the presentation of a circular virtual business at the secondary education level, the bibliographic review covers both (a) previous research results of innovative methods in the teaching–learning of CE and sustainability and (b) the implementation of circular entrepreneurship.

Raising effective education at all school levels and beyond that for off-school adults through continuing education interventions and including formal, informal, and non-formal education as a distinct field of research continues to be nascent. In addition, teaching and learning methods could develop in line with the United Nation's (UN's) recent definition of the 17 Sustainable Development Goal (SDG) and the 10 R (Refuse, Reduce, Reuse, etc.) strategies based on the hierarchy of waste management, adding value to both the theoretical and the practical levels and, therefore, facilitating the CE implementation (UN, 2015; Campbell-Johnston et al., 2020). Education for SDGs without including CE has been criticized as anthropocentric, concentrating on economic growth rather than environmental ethics and climate change (Kopnina, 2020).

Recent research has emphasized the need for education for the successful transition to CE; however, it focuses only on the higher education and academic level (Kopnina, 2012, 2018b; Kirchherr and Piscicelli, 2019; Luna and Arce, 2022; Qu et al., 2022). The need for fine improvement in educational curriculum toward CE was first identified in design schools, where circular practices were adopted and new products and services were devised, reflecting a bottom-up approach and initiative (Andrews, 2015; Leube and Walcher, 2017; Kozlowski et al., 2019; Wandl et al., 2019; Vicente, 2020; Troiani et al., 2022). Moreover, good internships in the design for CE have been tested successfully in the context of a European project (Sales et al., 2019).

The CE and its sustainability vision also provide alternatives for creating circular entrepreneurship, promoting innovative development, and supporting current enterprises to adopt the new model and encounter the less prevalent practices. Green entrepreneurship arises forcefully as a modern form of economic activity that responds to the business needs for profitability and growth while focusing on the environmental dimension, deeming it more as an opportunity rather than an obstacle. An increasing number of modern enterprises are seeking to assist toward environmental protection and inhibiting climate change by investing in further research and development of green technologies and practices (Masi et al., 2018; Ranta et al., 2018; Hofmann, 2019; Geissdoerfer et al., 2020; Cullen and De Angelis, 2021; Ferreira and Matias, 2021). However, while on a theoretical level, research has established guidelines and strategies for companies to adopt a circular model, but on a practical level, there is still a long way to go (Bocken et al., 2016; Lewandowski, 2016). Despite the barriers to be investigated for the transition from theory to practice, cases mainly pertaining to agri-businesses, which managed to bridge the gap (Chinnici et al., 2019; Cullen and De Angelis, 2021; Bentivoglio et al., 2022), are prevalent.

The designing of new business models for circular economic development, the closed-loop resources, and the cradle-to-cradle biomimetic approach to production could be interpreted as having the potential for employment creation as well (Kunapatarawong and Martínez-Ros, 2016). Future green occupations, serving the new vision for the society and economy, require high cognitive and social skills and training, thus designating education as a crucial factor that presupposes revisiting the current practices starting from early childhood (Deschenes, 2013; Consoli et al., 2016; Bakken et al., 2017; Fauske et al., 2022). Focusing on adolescence and the secondary level of education, a critical period of study for professional orientation, and given that the young are close to growing into active citizens, future producers, scientists, practitioners, entrepreneurs, policymakers, or researchers, integrating circularity, and sustainability vision into the school curriculum and the adoption and encouragement of active and innovative methods of teaching–learning are vitally important.

However, innovative educational theories, teaching–learning methodologies and approaches, such as constructivism, student-centered teaching, real-world problem-solving, collective working, and social interaction for a CE, have been applied only at higher

education levels, particularly in the engineering sector. Strategies, such as gamification (gameplay), challenge-based learning, flipped classrooms, and case studies, have been examined successfully at the higher education level as well (Bada and Olusegun, 2015; Whalen et al., 2018; Kopnina, 2019; Rodríguez-Chueca et al., 2020; Luna and Arce, 2022). Simulation and embedding learning in a realistic context also proved to be powerful interactive tools for teaching–learning and for promoting circularity and sustainability (De La Torre et al., 2021).

In Greece, research showed the positive effect of learning on the integration of multimodal educational materials in science, technology, engineering, and mathematics (STEM) in early childhood and the adaptive gamification in the teaching of science at the preschool and elementary education levels (Zourmpakis et al., 2020; Tsoukala, 2021). Similarly, gameplay experience enhanced students' learning ability for circular business (Lange et al., 2022). The serious game *In the Loop* facilitated the educational process for engineering students to adopt CE strategies (Whalen et al., 2018). Nevertheless, recent review research in the field of engineering education identified the lack of systemic research and a holistic approach to CE and sustainability globally, and therefore, deficiencies in the generation of new knowledge and the acquisition of relevant competencies need to be removed (Mesa and Esparragoza, 2021).

Higher education institutions (HEIs) provide guidelines and the framework for the implementation of CE in practice, but they are restricted only to campus operations (Mendoza et al., 2019a,b). Dissemination of information relevant to CE and sustainability improved the students' behavior and reduced their impact on campus (Bugallo-Rodríguez and Vega-Marcote, 2020). Latin American HEIs recommend the Life Cycle Assessment perspective as an innovative educational tool toward a CE future (Maruyama et al., 2019). In Europe, educational initiatives for CE were launched from the entrepreneurship perspective at the university level (Del Vecchio et al., 2021).

Given the previous limited performance of research in serving as the educational pillar for CE (Romero-Luis et al., 2021), which should be a priority for serving and applying the new vision, and that the research seems to have been underestimated so far, the current study pursues to share an innovative practice of teaching–learning, simultaneously initiating and encouraging a critical discussion on this issue. Building on a virtual business case at the secondary level of formal vocational education and presenting the relevant activities and the results derived from this case study, we aspire to contribute effectively to covering the gap in the existing literature and create innovative paths for future investigation.

According to research, the virtual enterprise as an innovative, multidimensional, complex, and experiential teaching–learning method inspires students' creativity, promotes mental ability, and expands not only their knowledge but also their skills (Borgese, 2011; Riebenbauer and Stock, 2015; Ping and Yinghong, 2018).

# 2. Methodology approach

## 2.1. Research method

The case study is a frequently applied research method in education appropriate for empirical and descriptive as well as qualitative and quantitative research addressing "what," "why," and "how" issues. Thus, the researchers posed the questions: "What strategy does lead to more effective learning and teaching of CE and sustainability concepts through a virtual enterprise?," "How do students involve in the learning process of these concepts through a virtual enterprise?," and "Why does a virtual enterprise can affect the participants' learning about CE and sustainability concepts?" (Yin, 2009; Cronin, 2014; Mahadi and Husin, 2021). The researchers served as coordinators and participants in a virtual enterprise, observing the actions of a group of participating students and their procedures of problem-solving and decision-making in real-life situations, describing, interpreting, and understanding their learning and behaviors. They also collected data from multiple sources of evidence apart from observations, such as documentation from the final products of the planned activities of the educational intervention, through interviews and a complementary structured questionnaire (Woodside, 2010).

## 2.2. The case study

The student virtual enterprise started up in the 1st Vocational Lyceum Didimotichou "Evgenios Evgenidis" (https://blogs.sch.gr/1epal-didym/), in Didimoticho, a small provincial town located on the northeast edge of Greece, with a total of 170 students aged between 15 and 18 years, under the mentorship of the Junior Achievement SENJA, a youth-serving non-governmental organization (NGO) for promoting youth entrepreneurship (https://www.jaworldwide.org/, https://jagreece.org/). The business idea was proposed initially by the teachers (authors of this study) who were specialists in the fields of Agriculture and Economics and received its final form with the contribution of the participating students in the programme. The idea of producing animal feed from food waste as well as compost from the waste generated during the feed production process and applying the principles and values of CE arose from: (i) the specialized knowledge acquired gradually through the teaching of subjects at the Vocational Lyceum, (ii) the need for sustainable management of food waste produced during the school laboratory exercises, (iii) the comprehension of eminent climate change occurring at a local, national, and global level and the major contribution of agriculture (Krajick, 2015), (iv) the waste of available natural resources, which increase the production costs of agricultural/livestock farms in the region, and (v) the food waste produced by the households and companies active in the food sector in the town and the district. The programme lasted 5 months during the school year of 2021–2022. Thirty-two students (18 boys and 14 girls) participated in the activities of the virtual enterprise under the coordination of three teachers. The only criterion for participation was attending the school curriculum as an active student in the fields of Agriculture, Food, & Environment (25 pupils) and Administration-Finance (7 pupils), which provide relevant teaching subjects and access to the food processing laboratory.

It should be noted in the case study that food waste was defined "from field to fork" throughout the food life cycle as: "*raw food materials lost during production, post-harvesting, and processing (food loss) and inedible part of food or cooked food cut off from the food supply chain, manufacturing, distribution, retail, and service activities or leftovers discarded by households*." The causes of food waste could be expiry, overmaturity, inadequate storage conditions, improper use

of food, and lack of consumer awareness (Supplementary Figure 1; EC, 2010; Gustavsson et al., 2014; Garcia-Garcia et al., 2015).

### 2.2.1. The business model

First, the teachers designed a fully structured questionnaire to explore the school students' knowledge, attitudes, and behavior toward CE, sustainability, and zoophilia due to the topic matter. Almost simultaneously, they organized a team of participating students who determined the final business idea, shared roles according to their interests and skills, and previously canvassed using the JA questionnaire. They also designed two surveys, one for locating potential suppliers and a second for conducting a local-scale marketing research (Figure 1). During the founding meeting of the members and after a thorough discussion, the distribution of members to the respective company's departments was unanimously decided and the first organizational chart was drawn up. It is noteworthy that female students were chosen for key management positions (Supplementary Figure 2). Moreover, the enterprise vision statement was defined: "*to develop into a pioneer company in the field of producing innovative, qualitative and healthy animal feed, with ethical, environmental and social responsibility following the legislative ties and adopting the values of sustainability and the principles of the CE model*" (EC, 2002; L/4235, 2014).

Second, two online polls in the school community brought up the business name "Zooboukitses Evrou" and the official logo (Figure 2A) among three, reflecting the milestone in the business concept, the commitment of the founding members to the principles of democratic governance, the equal participation in the decision-making process, and the operations and the activities of the enterprise. A skilled student in painting designed the logos based on the team's suggestions and drafts, which were later put to vote. After the selection of the enterprise name and logo, a group of students from the economic specialty proceeded to write the articles of the charter while others conducted the surveys. The legal form of the newly established company was that of a Société Anonyme (S.A.), with the participants as founding shareholders. In total, 100 equity shares, with a nominal value of €1, were issued (Supplementary Figure 3). As regards the results of the surveys, drawing on the valid responses to a structured questionnaire of 81 regional inhabitants and animal owners, their analysis indicated that (i) it seemed possible for our products to enter the market successfully and gain regular customers as a sufficient number of consumers were young and interested in the quality and environment-friendliness of the products and, therefore, would turn to a new innovative product, (ii) prices should be kept low due to the high percentage of low-income and unemployed consumers, (iii) the consumers' preference toward local markets would favor our business, and (iv) dog feed should account for most of the production (Supplementary Figures 4–6). Locating potential suppliers was achieved by distributing a semi-structured questionnaire and by conducting face-to-face interviews with business owners in the district. Key sponsors and primary suppliers, convinced by our business proposal and committed to the development of mutually beneficial relationships, consisted primarily of local small enterprises, butchers, bakeries, fish shops, small supermarkets, and catering businesses, motivated by the fact that they would be freed from the process of sorting, transporting, discarding, and destroying non-marketable food as well as their residues and leftovers. The reluctance of the supermarket chains to cooperate, whose managers stated that they follow a certain unpublished protocol for the management and destruction of unmarketable food, should be noted. In addition, the school provided free of charge, without rent, the necessary premises and equipment. In return, we intend to open the laboratory spaces to the school and local community for dissemination of the principles of CE and the values of sustainability. The cognitive results of the production process, measurements, analyses, and calculations will remain at the disposal of the school community as a repository of knowledge for future use and dissemination and its utilization in professional orientation. Finally, a strengths, weaknesses, opportunities, and threats (SWOT) analysis enhanced students' strategic thinking and planning and assisted in identifying internal (strengths–weaknesses) and external factors (opportunities–weaknesses) influencing the enterprise operation and management (Figure 2B).

It is worth mentioning that the students succeeded in illustrating the CE and sustainability concepts on the logo without being able to explain them clearly. The logo composition and the circular shape symbolize (i) the sustainable flow of the production process, Production–Reuse–Recycling; (ii) the handwritten font depicts the personal passion and special care of the company members for the products and, at the same time, highlights their qualitative differentiation from similar competitors. The latter lies in the quality of raw materials used and the handmade nature of the products; and (iii) the white background reinforces the concept of purity, especially materials' purity, while, (iv) the predominant green and brown color suggests the inseparable relationship of the enterprise with the nature and environment as well as its non-negotiable commitment to the conservation of natural resources, (v) the footprint of a small animal foot shows the pet feed products and at the same time, the commitment in an effort to minimize the environmental footprint of the production process, zero waste, saving resources and energy, and the long-term vision of maximizing the social footprint of the business, quality innovative products, jobs' creation, and providing sustainable solutions to animal owners and small farmers, and (vi) the outline of the Evros prefecture reflects the traditional values and principles that the place has instilled in students.

### 2.2.2. Production and marketing

Third, after the information gathering and data analysis, students from the agricultural sector initiated the designing of the production process, while those of the economic speciality drew up the business plan (Figures 1, 2B, 3). A challenge they had to solve was the quality control of food waste provided by the suppliers, its categorization, and the creation of animal feed recipes while taking into account the nutritional needs and rules of domestic animals and the available raw materials, and their preparation. Therefore, our company entered the packaged animal feed market with a dozen types of dry and cooked animal feed (of 300 and 600 g), five for dogs, five for cats, pellets for rabbits, and frumenty for poultry. Glass containers, as the primary packaging material, were chosen because of their reusing possibility and environment-friendliness. In addition, the glass utensils can be filled with hot liquid and be pasteurized after filling in (72°C), protecting the product and extending its life cycle without allowing substances to migrate from the package to the product. Plastic packaging was avoided. We also intend to constantly inform our customers not to throw away the glass packages but to

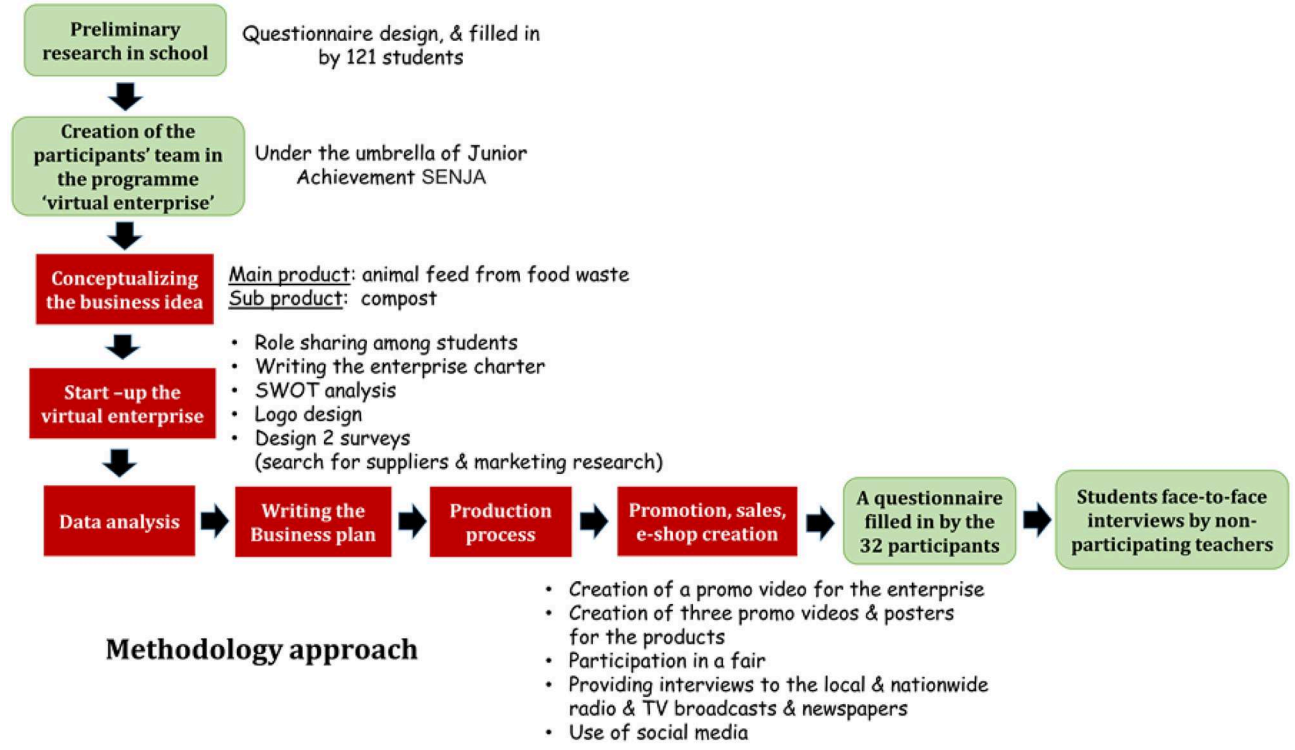


FIGURE 1
The methodology approach.

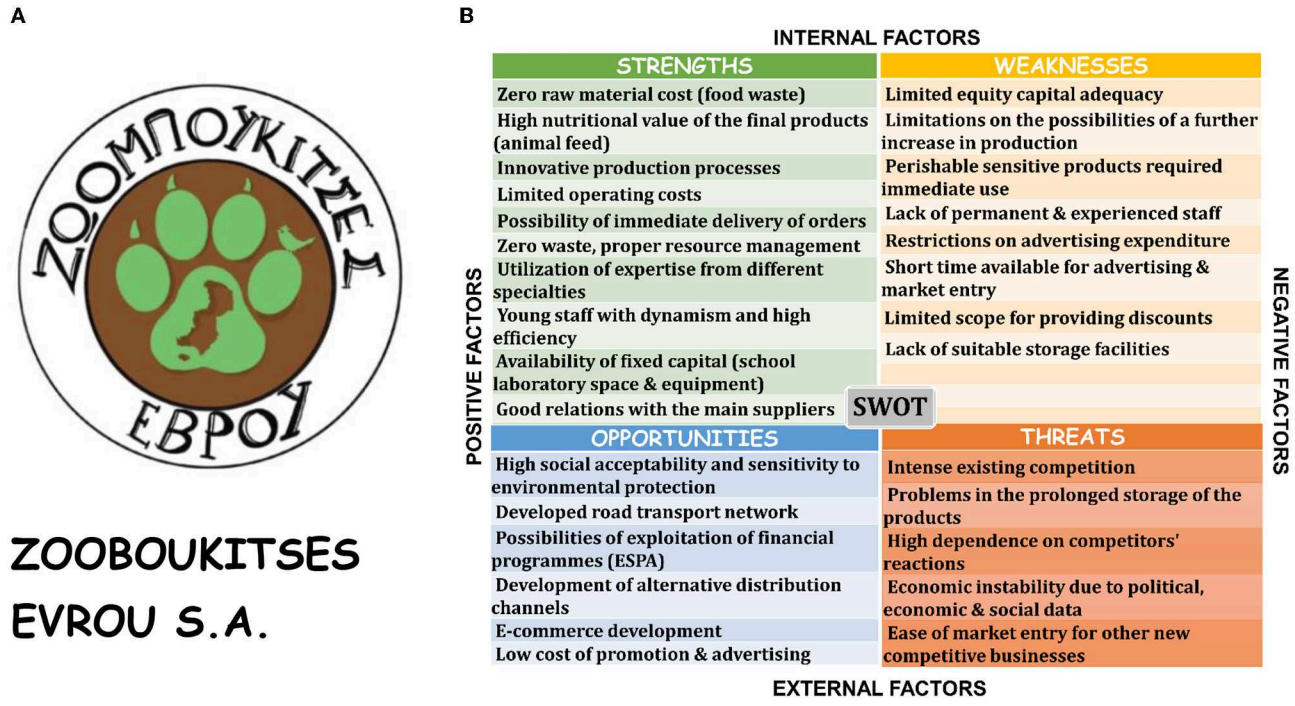


FIGURE 2
**(A)** The brand name and logo of the enterprise **(B)** of the strengths, weaknesses, opportunities, and threats (SWOT) analysis.

return them with each new purchase so that we can reuse them and decrease the product price. Other challenges the students had to face pertained to the calculation of the nutritional value of each product and the design of labels, which should provide the client:

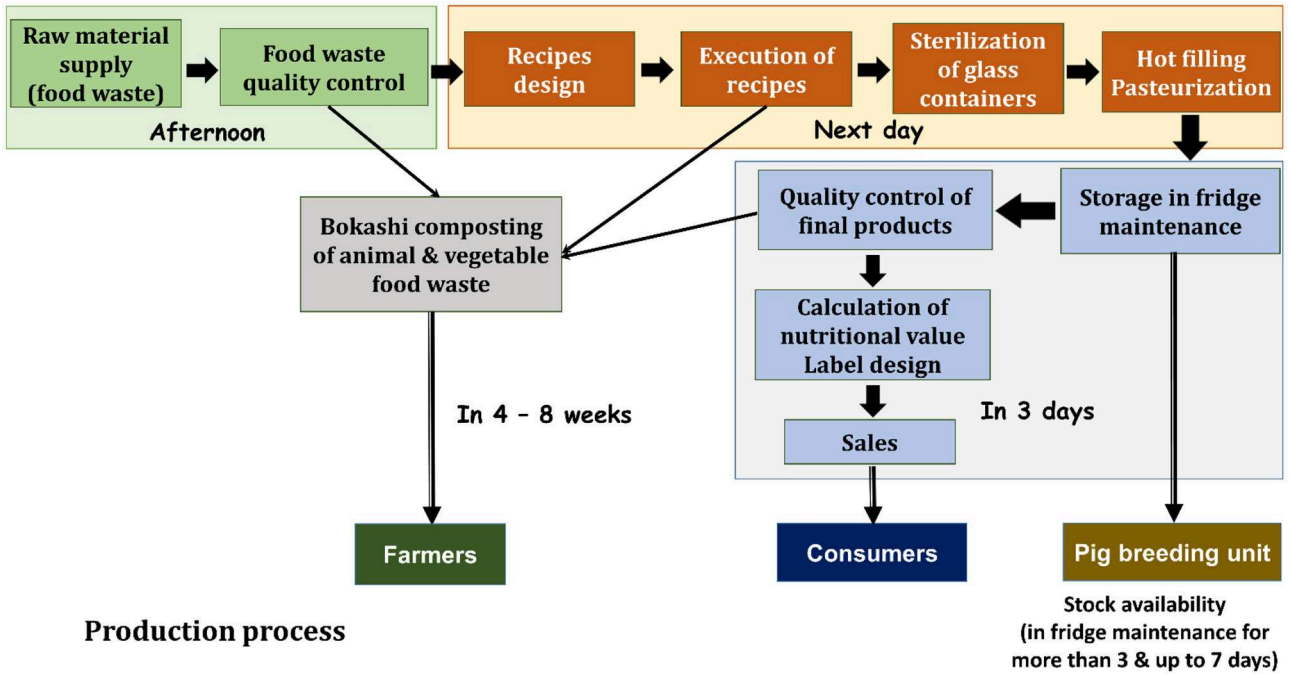


FIGURE 3
The production process.

(a) immediate and quick information on the composition of feed, the net weight, its expiry date, its maintainability after opening the package, the brand name of the producer, and the place of production, (b) easy reading of the nutritional and energy value of the product, and (c) a composition and colors that attract and immediately demonstrate the kind of animal feed. The production process waste of animal and vegetable origin was composted and anaerobically fermented with the Bokashi method (compost bins and fermentation microorganisms) to produce organic fertilizer in 1–2 months for farmers. The investigation proved that the anaerobic digestion of food waste has the lowest environmental impact compared to other treatments (Slorach et al., 2019). A cooperation agreement was also signed with a local breeder and owner of a pig breeding unit to provide the unsold packaged preparations immediately and shortly before their expiry. Thus, we succeeded in closing the loop with zero waste production, minimizing the environmental impact of the enterprise. Additionally, the exact costing of the products to ensure the required profitability that would determine the long-term viability of the business and the break-even point calculation were particularly puzzling for the students. Consequently, if our company disposed of 180 pieces at the weighted average price of € 2.14 in the market, it would show no profit or loss.

Fourth, the marketing mix consists of inextricably linked variables, the 4 Ps, product, price, place, and promotion, which satisfy the consumer's needs and serve the goals of the enterprise (Al Badi, 2018; Thabit and Raewf, 2018). All products were processed naturally and with the least possible heat treatment to preserve all the nutrients. The price factor emerged as a decisive item in the decision-making process of consumers for choosing a product. We decided not to compete on price with industry competitors, multinational giants activating in the existing market for decades, as that act would jeopardize the company's viability and growth conditions. The pricing (in €) of the product per 250 g was above the market average and was intended to provide the company with profit margins of around 10% per unit of product. Large firms can benefit from economies of scale, so a start-up can be difficult to compete on price. For that reason, the company's strategy focused on increasing the quality of all its products and on their continuous improvement. The school facilities allowed the place of production, storage, and administrative functions to be in direct connection with one another, facilitating the development of cooperative relationships with local suppliers. The raw materials entered the production process directly, a necessary condition for receiving fresh products. In addition, the company's location assisted in establishing a direct contact with the town's center market and the urban complex of the municipality and at a distance of fewer than 500 m from the bus station and courier companies, which could facilitate its expansion to new markets and directly support the company's online sales in the future. Thus, the ecological footprint from transport emissions is kept low. Emissions amount to 0.01 kg $CO^2$e/ a local product, while almost doubling for longer distances of 10 km.[1] As regards the promotion of a range of innovative, low carbon impact, and natural nutritional formulations for pets and domestic animals, the students created a promo video for the enterprise, established an official website and e-shop (zooboukitses), utilized official accounts through various social networks, launched three promo videos and posters to enhance customer's awareness for the company's products (S10), participated in a fair, and raised publicity through interviews to local and nationwide radio and TV broadcasts, websites, and newspapers (kathimerini).

Finally, the participants filled in the same preliminary survey questionnaire, and non-participating teachers videotaped students'

1 Carbon Emissions Calculator.

interviews describing their experience and impressions about their involvement in the virtual enterprise activities as a final product and evidence for the programme needs with a smartphone. They also presented the programme to the school and the local community at an event at the schoolyard. The Statistical Package of SPSS was used for analyzing data collected through the questionnaires.

## 3. Results

Only 21.5% (26 out of 121) of the exploratory survey respondents (58.7% male students and 41.3% female students) stated that they knew the CE principles and sustainability values (16.5% "well" + 5% "absolutely" informed), 38.9% stated that they often recycle, 36.3% stated that they take care of stray animals, and 75.2% stated that they often eat meat. The majority (70.3%) of them stated their belief in the values of zoophilia, and 62.0% were pet owners. The always overflowing recycling bins were the first cause for discouragement of recycling (36.3%). The students' responses to a series of attitudes, which connect with the circularity and sustainability principles in real life are presented in Table 1 in detail, what discourages them from recycling in Table 2, practices they have adopted for waste management, saving water, and energy sources in Table 3, and the responses to a series of zoophilia values in Table 4.

The measurement of the reliability level of the 5-point Likert questions (Tables 1, 4) indicated Cronbach's alpha values of 0.885 and 0.894, respectively, allowing the addition of variables and the creation of two new variables. The non-parametric Spearman's correlations revealed a positive correlation at a statistically significant value between the level of information about the CE principles and sustainability values and between the level of significance of 13 added sustainable practices ($r_s = 0.300$, $p = 0.001$), the frequency taken by the students to recycle ($r_s = 434$, $p < 0.001$), the level of information about the values of zoophilia ($r_s = 0.221$, $p = 0.015$), between the level of significance of 13 added sustainable practices and the frequency of recycling ($r_s = 0.386$, $p < 0.001$), the information level about the values of zoophilia ($r_s = 0.250$, $p = 0.006$), the frequency of stray care ($r_s = 0.246$, $p = 0.006$) and the level of significance of eight added values of zoophilia ($r_s = 0.633$, $p < 0.001$), between the added values of zoophilia and the level of information about the values of zoophilia ($r_s = 0.387$, $p < 0.001$), the frequency of recycling ($r_s = 0.212$, $p = 0.020$) and the frequency of stray care ($r_s = 0.464$, $p < 0.001$), between the information level about the values of zoophilia and the frequency of stray care ($r_s = 0.292$, $p = 0.001$), and between the frequency of stray care and pet ownership ($r_s = 0.194$,

TABLE 1 Students' attitudes toward a series of circular and sustainable practices in percentage ($N = 121$).

| | Not important | Little important | Neither important not unimportant | Important | Very Important | Importance rank |
|---|---|---|---|---|---|---|
| Products reuse and redistribution (glass packaging, cloths, etc.) | 12.4 | 9.1 | 14.9 | 41.3 | 22.3 | 63.6 (1) |
| Promotion of research & innovation in matters of environmental protection and tackling climate change | 8.3 | 12.4 | 23.1 | 33.1 | 23.1 | 56.2 (2) |
| Economic benefits for the local community and country | 9.9 | 10.7 | 24.0 | 28.1 | 27.3 | 55.4 (3) |
| Waste recycling and production of new products (e.g., using glass to produce asphalt paving material or paper to produce egg cups) | 8.3 | 12.4 | 24.8 | 26.4 | 28.1 | 54,5 (4) |
| Sustainable management of natural resources (water, fossil fuels, etc.), reducing their waste during production process | 14.0 | 10.7 | 24.0 | 34.7 | 16.5 | 51.2 (5) |
| Limiting air, land & water pollution, & addressing climate change (e.g., limiting car use & use of cycling) | 10.7 | 11.6 | 27.3 | 24.8 | 25.6 | 50.4 (6) |
| Keeping goods in good condition for a long time with the help of good maintenance & repairs (e.g., electronic & electrical appliances) | 9.1 | 14.0 | 29.8 | 28.1 | 19.0 | 47.1 (7) |
| Utilization of renewable resources, plant and animal waste (e.g., for the production of organic fertilizer) | 10.7 | 16.5 | 27.3 | 29.8 | 15.7 | 45.5 (8) |
| Empowering local communities, reducing inequalities and discrimination through new job opportunities that the circular economy can offer | 7.4 | 21.5 | 27.3 | 22.3 | 21.5 | 43.8 (9) |
| Designing new products using smaller amounts of raw materials, less energy, and easily recyclable | 9.1 | 13.2 | 38.0 | 17.4 | 22.3 | 39.7 (10) |
| Environmental benefits of sharing services with others (e.g., car, motorbike to travel to the same destination) | 14.0 | 14.0 | 33.1 | 26.4 | 12.4 | 38.8 (11) |
| Utilization of waste production processes for energy production (e.g., biogas production from manure) | 5.0 | 17.4 | 41.3 | 24.8 | 11.6 | 36.4 (12) |
| Environmental benefits of renting the services of a good instead of owning it (e.g., using public transport instead of owning a private car) | 14.0 | 25.6 | 37.2 | 17.4 | 5.8 | 23.2 (13) |

TABLE 2 Reasons for the discouragement of recycling in percentage ($N = 121$).

| | |
|---|---|
| The always overflowing recycling bins | 36.4 |
| I don't believe in the value of recycling | 33.1 |
| The lack of space at home to collect the separated materials in different bins | 30.6 |
| The process of separating garbage requires effort and time | 29.8 |
| I do not trust the agency that undertakes the collection, transport and processing of the materials | 28.1 |
| The distance from the residence to the points of collection of recyclable materials | 27.3 |
| The difficulty of finding in which bin each material should be deposited | 18.2 |

$p = 0.033$). Even though some of these findings sound clear, they indicate that (i) the various values are interconnected in the students' consciousness and (ii) the values, beliefs, information, and awareness level influence their attitudes toward circularity and sustainability. A closer examination of Tables 2, 3 and their low performance of behaviors related to waste management and of energy and water saving indicate that (iii) they avoid adopting practices that require personal sacrifice and effort. A comparison of participants' responses before and after the implementation of the programme demonstrated no statistically significant results.

In their interviews provided to mass media and teachers, the participants stated that the programme enabled them to approach the world of business, meet and cooperate with entrepreneurs, citizens, and freelancers, acquire multifaceted knowledge, and develop numerous abilities and skills such as cooperation and teamwork, communication, designing and conducting research, information management, flexibility to the challenges arising, solving practical problems, creativity, self-control, familiarization with new technologies, development of integrity, and honesty during labor and customer service. Their circular business was an opportunity to open the school to the local and national community and communicate circularity and to sustainability principles and values. The participating students also emphasized the qualitative time spent with their schoolmates and teachers during the activities collaborating and working as a team. The latter proved to be accurate as seen from the final materials and products and the successful realization of all activities of the enterprise (Supplementary Figures 7–10).

## 4. Discussion

The present case study describes in detail the establishment and operation of a virtual enterprise, with the vision to add value to food waste by transforming it into animal feed and compost, indicating the possibility of income generation and entrepreneurship activity based on the principles of CE and the values of sustainability. Food loss and waste have become a priority globally, reaching one-third of the food produced for human consumption, about 1.3 billion tons per year, which increases continuously per capita following the increase in per capita gross domestic product (GDP). The aforementioned fact indicates that the immense wastefulness of natural sources is threatening global sustainability, particularly when the assessment of the impact of food waste on economic, social, and environmental dimensions has failed (Xue et al., 2017; Goossens et al., 2019; Ravandi and Jovanovic, 2019; Xue and Liu, 2019; FAO, 2022). Data for Greece point to ∼142 kg of food waste per capita related to households, the largest in Europe, and 5,672.5 Gg of $CO_2$ eq emissions annually generated due to food waste (Abeliotis et al., 2015; UN, 2021). Furthermore, the case study suggests a circular business based on food waste management not previously investigated (Dragomir and Dutescu, 2022), while, in parallel, highlighting the critical role of education (Rezaei and Liu, 2017; Graaf, 2021a) and the employment perspective for the young people locally (Stahel, 2016).

The introduction of innovation for creating circular models in the agri-food sector is fraught with various obstacles, such as the lack of private and public financial sources and markets for new products and byproducts and weaknesses in technical, cognitive, and educational aspects. Moreover, multiple stakeholders involved in food loss and food waste management, who originate from both production and consumption systems, should accept the CE model and undertake responsibilities and obligations for cooperation and coordination (Hamam et al., 2021, 2022). The present case reveals that the coordination of various stakeholders plays a crucial role in a CE agri-enterprise to flourish, which was undertaken successfully by a team of students. The interdisciplinary approach, another critical aspect, supports and facilitates the transition to the CE model (Ghisellini et al., 2016). The osmosis of knowledge and skills between the two specialities assisted in achieving profitable results and completing all programme activities. Despite the limitations of turning to circular entrepreneurship, as companies claim and the literature demonstrates, this case sends an optimistic message, especially to the local community and the entrepreneurship world, that CE can be made feasible and implementable (Cristoni and Tonelli, 2018; Korhonen et al., 2018).

As regards the findings of the preliminary survey and despite the limited sample size, figures indicate a lack of adolescents' awareness, knowledge, and interest in circularity and sustainability. Even though they demonstrate positive attitudes toward a series of circular and sustainable practices that do not translate into adopting related behaviors when the latter requires personal effort, change, and sacrifice; for instance, while a high percentage (63.6%) state significance toward products' reuse and redistribution, only 5.8% buy secondhand clothes; while 54.5% state significance toward recycling, a low percentage of students often recycle (36.3%) or they are unwilling to leave their motorbike for recycling, take care of separating and composting organic waste, or change their dietary habits reducing the meat consumption (Tables 1, 3). They also transfer the responsibility to other actors or external factors for their discouragement of recycling (Table 2), which is in line with previous research on underestimating personal responsibility for environmental action (Truelove and Parks, 2012; Rosentrater et al., 2013). According to behavioral theories and research, intrinsic variables, beliefs, values, knowledge, and attitudes can influence environmental action and behavior change. However, the latter requires time, is a long-term process, and depends strongly on extrinsic determinants, as the students' responses reflected (Ajzen, 1991; Stern, 2000; Changing Public Behavior, 2015b). The evaluation of educational programmes and interventions indicates a positive

TABLE 3 Students' behaviors toward waste management, energy, and water saving in percentage ($N = 121$).

| Waste management practices | | Energy saving practices | |
|---|---|---|---|
| I don't usually throw rubbish in the environment and I always look for a bin | 53.7 | I usually turn off the lights when I leave a room | 60.3 |
| I utilize old clothes and fabrics for other uses or offer them to who need them | 49.6 | I try not to leave electrical devices on standby (computer, TV) | 57.0 |
| I often use refillable product packaging (e.g., cream soap) | 40.5 | I often avoid unnecessary rides with the motorbike | 27.3 |
| I usually refuse plastic bags at the supermarket and take reusable bags from home | 36.4 | I prefer to use a bicycle instead of a motorbike to get around the city | 21.5 |
| I often make sure to separate the caps from the plastic bottles & recycle them separately | 31.4 | We use energy-saving light bulbs in my house | 20.7 |
| I often recycle batteries, lamps or electrical and electronic devices (old technology mobile phones) | 31.4 | A criterion for buying an electronic or electrical device is & how much energy it consumes | 13.2 |
| I often avoid using disposable products (plastic cups, plates, straws, etc.) | 33.1 | Water saving practices | |
| I usually reuse boxes, papers, bottles, containers & other old plastic or glass packaging | 33.1 | I usually turn off the tap while brushing my teeth or shaving | 68.6 |
| I usually try not to have any leftover food on my plate that ends up in the trash bin | 33.1 | I usually turn off the tap while washing my hands, face & dishes | 41.3 |
| I usually buy soft drinks & drinks in returnable glass containers | 25.6 | I usually only run the dishwasher & clothes washer when they are fully loaded | 38.8 |
| I don't usually pour cooking oils down the sink & collect them in containers for recycling | 22.3 | I often pour the excess water of my bottle or glass into the pots or nature | 28.1 |
| I print on both sides of the paper and choose economy printing (less ink) | 19.0 | I usually prefer a shower to a bath | 28.1 |
| I usually only use the necessary amount of cleaning products | 19.0 | I make sure not to use the hose often to water, wash the balcony or the car/motorcycle | 26.4 |
| I often prefer products that come from recyclable materials | 16.5 | On the dual flow flush, I make sure to push the button for half or full water as the case may be | 20.7 |
| I usually choose the products with the least packaging | 10.7 | | |
| I often separate organic scraps to compost in the yard | 8.3 | | |
| I tend to buy clothes in good condition, second hand | 5.8 | | |

TABLE 4 Students' attitudes toward certain zoophilia values in percentage ($N = 121$).

| | Not important | Little important | Neither important nor unimportant | Important | Very Important | Importance rank |
|---|---|---|---|---|---|---|
| Respect for animal rights | 6.6 | 9.1 | 10.7 | 20.7 | 52.9 | 73.6 (1) |
| Caring for a pet contributes to better mental health and reduced stress | 6.6 | 5.8 | 18.2 | 33.9 | 35.5 | 69.4 (2) |
| Caring for the welfare of production animals and pets | 4.1 | 6.6 | 23.1 | 24.8 | 41.3 | 66.1 (3) |
| A pet offers opportunities for recreation (opportunities for recreation and activities in green spaces in the city) | 8.3 | 5,8 | 24.0 | 31.4 | 30.6 | 62.0 (4) |
| Conservation of biodiversity (the rich variety of organisms, plants, and animals in nature) | 5.8 | 9.9 | 26.4 | 30.6 | 27.3 | 57.9 (5) |
| Caring for a pet contributes to better physical health through the need for walking and exercise | 5.0 | 14.9 | 23.1 | 27.3 | 29.8 | 57.1 (6) |
| All creatures have an inherent value or quality (rarity, representativeness) | 10.7 | 12.4 | 23.1 | 23.1 | 30.6 | 53.7 (7) |
| A pet provides opportunities for socialization (opportunities to communicate with other pets owners) | 7.4 | 12.4 | 27.3 | 24.8 | 28.1 | 52.9 (8) |

effect on students' attitudes but not on behaviors at the preliminary-education level (Collado et al., 2020). Moreover, these interventions impact students' orientation toward sustainability (Kiely et al., 2021) and their water-saving practices independent of external factors at

the secondary-education level (Keramitsoglou and Tsagarakis, 2011). Systematic and repetitive theoretical and practical interventions and the creation of an appropriate social context in school could allow the building of behaviors toward a circular and sustainable future (Carbonell-Alcocer et al., 2022; Kosta et al., 2022).

Concentrating on the teachers' observations of students' actions and how they solve problems by thinking creatively, the documents, the final products of students' work in the context of the virtual circular enterprise, and what they expressed orally in the interviews, the acquisition of soft skills and particularly the development of collaboration, cultivation of creativity, and the interdisciplinary approach were considered core gains. Relatively recent research demonstrates collaborative skills and critical thinking as central factors toward CE transformation (Marouli, 2016) and supports collaboration among stakeholders as a prerequisite for successful circular business (Halloran et al., 2014; Witjes and Lozano, 2016; Ghinoi et al., 2020; Kleine Jäger and Piscicelli, 2021). Moreover, higher education could be the main collaborator stakeholder (Luna and Arce, 2022; Serrano-Bedia and Perez-Perez, 2022) and contributor to entrepreneurship for adopting CE principles and achieving behavior change (Mehrotra and Jaladi, 2022). In this case, and contrary to problems caused by COVID-19, adolescents accomplished the coordination of different stakeholders toward circularity by saving food waste from disposal.

However, no anticipated alteration in the participants' knowledge, attitudes, and behaviors was observed according to their responses to the second questionnaire. Disregarding the short length of the programme and building on the research questions, proven evidence indicates students' deep consciousness of the ethical dimension of circularity and sustainability as ideas and values were illustrated in the enterprise logo, the collaborative working framework establishment, the resolution of conflicts, or the democratic decision-making process. The internalization of concepts through practice and experiential activities did not translate automatically into the ability to consciously express and explain them, which is the evidence of learning and understanding in the context of formal schooling. The weakness of translating practice into theory, the rationalization of attitudes, beliefs, and behaviors, and the lack of connection between the theoretical concepts and how they were practically applied could be considered a failure of the programme. Previous research at the university level recommends the combination of theoretical and practical strategies in teaching CE (Kopnina, 2018a). Additionally, teaching SDs' goals and Rs framework through analysis of their application in the production process could be an effective strategy. Paying attention to extra-curricular activities, the theoretical aspects were underestimated. Enabling effective awareness and knowledge, theory and practice should be interconnected, including the process of teaching and learning analysis (Khamidov, 2019; Asplund and Kilbrink, 2020; Nepal and Rogerson, 2020). Education practice based on the bottom-up approach could facilitate action from the top-down approach by curriculum integration of the circularity and sustainability vision and providing a greater focus on their concepts through cross-disciplinary and various educational materials, enabling students to collaborate and provide viable solutions (Pászto et al., 2021). Finally, taking the narrow approach of a small secondary school in this case study could serve as an example of a broader holistic approach, as a teaching tool and source of inspiration for educators. Utilizing a virtual enterprise as an educational method creates an innovative educational environment (Trummer, 2004) and establishes a theoretical framework for further investigation and discussion.

## 5. Conclusion

This study brings to light various aspects of teaching and learning both circularity and sustainability concepts at the secondary level of education, leveraging a case study of a virtual enterprise applying a circular model of food waste management. From this perspective, education should be viewed as a vehicle for conveying the requisite theoretical background and acquiring the appropriate practical competencies for molding individual and collective ecological awareness and promoting CE and consequently contributing to the generation and applicability of a sustainable entrepreneurship model. Furthermore, the present analysis provides insights into future practical implementation:

(i) Applying virtual business and simulated entrepreneurship as an innovative teaching method, particularly through interdisciplinarity, can positively contribute to the development of various soft skills, group creativity, experiential learning, and problem-solving in a real-life context;
(ii) Practice should be paired with theory for raising effective awareness about unclear concepts such as CE and sustainability;
(iii) Students need time and repetition to consolidate abstract concepts and be able to express their views on these concepts consciously;

and into theoretical implementation:

(iv) The role of education policymaking is crucial for promoting circularity and sustainability concepts, which should be included in the school curriculum of all education levels;
(v) A coordinator is needed among different stakeholders in the food supply chain for effective food waste management; and
(vi) Circular entrepreneurship could be an effective and profitable prospect.

Limitations in the implementation of the current programme, its short duration and the small group of participants, the absence of participating teachers and students for a long time due to coronavirus 2019 (COVID-19) illness, the focus on practical activities rather than the development of a supporting theoretical framework, and the weakness of repetition of intervention with the participation of the same students' team for evaluating differences in their environmental behaviors are worth noting. Education for CE and sustainability requires further investigation for carving innovative paths of creative discussion on the challenge of teaching–learning of these ambiguous concepts and their implementation. The individual grows environmental consciousness from early childhood through the potential of educational curricula that are intended to correspond to the experience and the needs of society. The befitting education courses or modules aimed at reducing the daily use of plastic, adopting energy conservation, bridling overconsumption, favoring environment-friendly means of transportation, reusing and recycling consumer goods, and preserving natural resources constitute a promising prosperity. Additionally, in light of the global concern

about food waste, academic research for improving its management should be a priority.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

## Ethics statement

Written informed consent from the participant's legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

## Author contributions

KK conceived the idea, coordinated the programme activities, and wrote the article. TL inspired the students, coordinated the programme activities, and helped students to write the business plan. AK inspired the students and coordinated the programme activities. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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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.2023.1060860/full#supplementary-material

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