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Factors affecting social attitude and behavior for the transition towards a circular economy

Irene Voukkali [a], Iliana Papamichael [a], Florentios Economou [a], Pantelitsa Loizia [a], Eleftheria Klontza [b], Demetris F. Lekkas [b], Vincenzo Naddeo [c], Antonis A. Zorpas [a, *]

[a] Open University of Cyprus, Faculty of Pure and Applied Sciences, Laboratory of Chemical Engineering and Engineering Sustainability, Giannou Kranidioti 89, Latsia, 2231, Nicosia, Cyprus

[b] Waste Management Laboratory, Department of the Environment, University of the Aegean, 81100, Mytilene, Greece

[c] Sanitary Environmental Engineering Division, Department of Civil Engineering, University of Salerno, via Giovanni Paolo II, 84084, Fisciano, SA, Italy

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ABSTRACT

Environmental obligations of scientists, engineers and members of the research community have evolved further than the quantifiable control of emissions and waste of production. The environmental consciousness of communities as well as individual responsibility for the development of sustainable waste management strategies increased in demand, from urban planners and stakeholders to industries and business model developers. Despite this growing interest, the principal barrier to the implementation of sustainable waste management plans for the promotion of responsible production and consumption as well as the integration of Circular Economy into urban, industrial or otherwise environmentally compromised settings, remains the lack of knowledge and awareness of the benefits of sustainability as well as the active participation on behalf of the public, leading to a limited responsiveness to the individual social, economic and environmental responsibilities. The aim of this short communication is to explore the social factors that affect the transition towards circular economy. As social influence is in many cases overlooked, observation, identification, evaluation, and monitoring of social factors that have the potential to aid or delay circular transition is of imminent importance. At the same time, in line with the digital transition of today's society, the authors explore how digitalization can help with influencing the public in terms of environmental and sustainable education, social responsibility and other main areas of interest. The combination of existing educational models (i.e. gamification) where digitalization is also promoted is deemed very helpful to promote a sustainable way of thinking.

1. Introduction

Population expansion, urban development, industrial evolution, and economic growth has been identified as the main factor of the emergence in solid waste production. Waste generation has exploded in recent years, with no signs of slowing. In a yearly basis, the world produces 2.2 billion tons of solid waste, with at least 33% of that not handled in an environmentally safe manner. Globally, waste production equals to 0.74 kg/day/capita but varies greatly, ranging from 0.11 to 4.54 kg (Statista, 2023). Simultaneously, it is

* Corresponding author.
E-mail addresses: voukkei@yahoo.gr (I. Voukkali), iliana.papamichael@gmail.com (I. Papamichael), florentios.eco@hotmail.com (F. Economou), pantelitsaloizia@hotmail.com (P. Loizia), rklontza@gmail.com (E. Klontza), dlekkas@aegean.gr (D.F. Lekkas), vnaddeo@unisa.it (V. Naddeo), antonis.zorpas@ouc.ac.cy, antoniszorpas@yahoo.com (A.A. Zorpas).

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expected that global waste will reach 3.88 billion tons by 2050, more than doubling population growth during the same period (Fig. 1).

Based on the amount of waste produced, it is predicted that solid waste treatment and disposal generates 1.6 billion tons of carbon dioxide (CO_2) equivalent greenhouse gasses (GHGs) emissions, accounting for 5% of global emissions (The World Bank, 2018). This is especially noticeable in contexts where there are still issues with improper organic waste management (Di Fiore et al., 2022). Nearly 40% of global waste is disposed of in landfills, 19% recovered through recycling and composting, and 19% is treated through modern incineration (Fig. 2). Although, 33% of waste is still dumped openly globally. Waste disposal practices vary greatly depending on income level and region. Open dumping is common in low-income countries where landfills are not yet useable. In low-income countries, approximately 93% of waste is burned or dumped on roads, open land, or waterways, while only 2% of waste dumped in high-income nations (The World Bank, 2018).

The European Union (EU) has established an extensive regulatory action to transition waste management forward into sustainable waste management (Fig. 3). The Waste Framework Directive (WFD) (2008/98/EC) developed the concept of sustainable waste hierarchy. The purpose of Sustainable Waste Management is to strengthen the link between waste management materials and circularity (Official Journal of the European Union, 2008). WFD prioritizes waste prevention, secondly improving waste residual treatment through reuse, remanufacturing, recycling, and thirdly reducing waste diverted to landfills (Chioatto and Sospiro, 2023; Zorpas, 2020). This framework will contribute to lowering emissions caused by waste production and therefore will enable for 17%–24% resources savings, which equates approximately €630 million savings and a 3.9% rise in EU Gross Domestic Product by 2030. The EU revised its WM directives following the Circular Economy Package of 2015.

The circular economy concept seeks to shift traditional production and economic growth practices, which thought to be linear systems where raw materials are collected and converted into products used by consumers before being discarded as waste, into circular dynamics that link resource use and waste production in order to decrease waste (Wang et al., 2020). Global material consumption could rise from 92 billion tones to around 190 billion tones by 2060, while GHGs may increase by 43%. Aside from the environmental consequences, this will create dependency, scarcity, and expense inflation issues for communities to deal with (Domènech, 2018). The first circular plan was completed in 2019 and its 54 actions have been finalized. Afterward, a new Circular economy plan was developed with 35 additional actions. In March 2022, the European Commission proposed the first package of measures to speed up transition towards a circular economy.

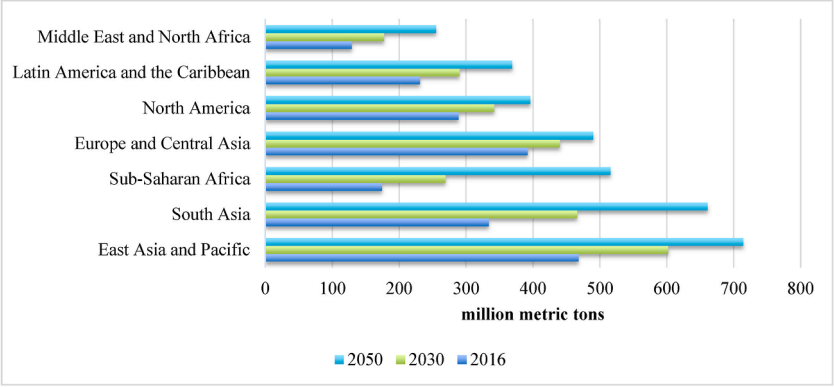

Fig. 1. Projection of waste generation worldwide in 2016, 2030, and 2050, by region (in million metric tons) (Data from Statista 2023).

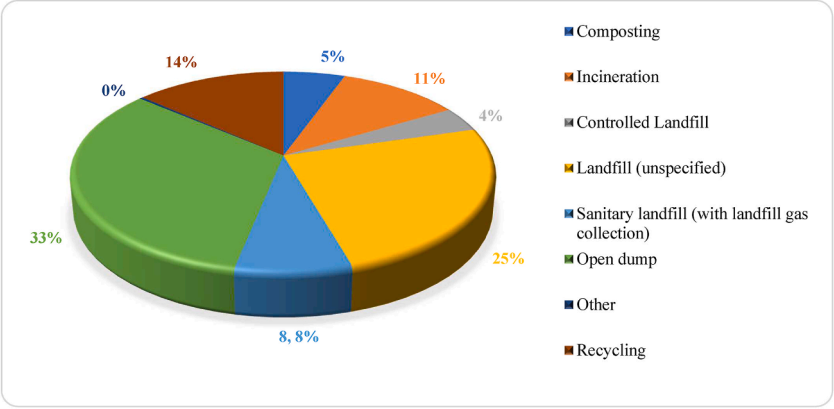

Fig. 2. Global waste treatment and disposal (%) (data from The World Bank, 2018).

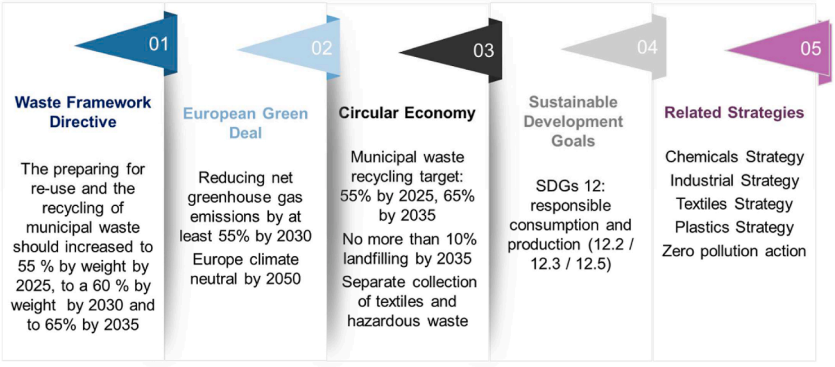

Fig. 3. Legislative and non-legislative initiatives and targets for waste production and management (figure created by the authors).

Alongside to the Circular economy model, in 2015, the United Nations (UN) released the 2030 Agenda for Sustainable Development, which encompasses 17 Sustainable Development Goals (SDGs) and 169 targets that can be measured using 230 qualitative and quantitative indicators (Fuldauer et al., 2022). Related to waste production and management, SDG 12 (sustainable consumption and production) sets a specific deadline of 2030 to reduce losses and generation of waste through the implementation of prevention, reduction, recycling, and reuse (United Nations, 2015) (Fig. 4). In addition, SDG 11 (Sustainable Cities and Communities) and SDG 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development), are directly related with solid waste management (i.e. sustainable waste management practices, plastic and microplastic marine pollution etc.) (Chatziparaskeva et al., 2022). Additionally, to the above strategies, in 2019 the European Green Deal (EGD) was launched as a guideline designed to make the EU's economic system more sustainable by transforming climate and environmental concerns into opportunities across all policy priorities. The goals include, among other things, (i) a 90% reduction in transportation emissions (ii) a GHG reduction target for 2030 of at least 50% and up to 55% in comparing to 1990 levels (c) zero-carbon steel by 2030 (iv) the endorsement of a circular economy (European Commission, 2019).

In order for such legislations, strategies and directives to be implementable and viable in the timeframe given by each one, social acceptance and independent responsibility in matters of sustainability and circularity are vital. The last few decades, the scientific community has emphasized the significance of social acceptance and behavior in waste management strategies (Di Fiore et al., 2022; Kwon and Silva, 2019; Loizia et al., 2021; Mensah, 2021; Sessa et al., 2010). At the same time, the willingness of the citizens (to participate in waste management strategies, circular economy initiatives etc.) and ability (the financial ability of citizens to participate) of citizens to participate in waste management initiatives is crucial in both understanding the psychological factors affective willingness to participate and altering strategies and sustainability promotion to fit this narrative (Papamichael et al., 2023a). It is noted that higher income level equals higher willingness of citizens to pay and participate in sustainable development initiatives, while this is also altered by environmental education, social attitude and cultural background (i.e. Europeans tend to care more about environmental implications while Americans do not give credit to sustainable businesses), among others (Papamichael et al., 2023a). According to Colasante and D'Adamo (2021), pro-environmental attitudes in society and education play a fundamental role in shaping the willingness of citizens to participate. This suggests that citizens' consumption patterns, waste disposal behavior and other key every-

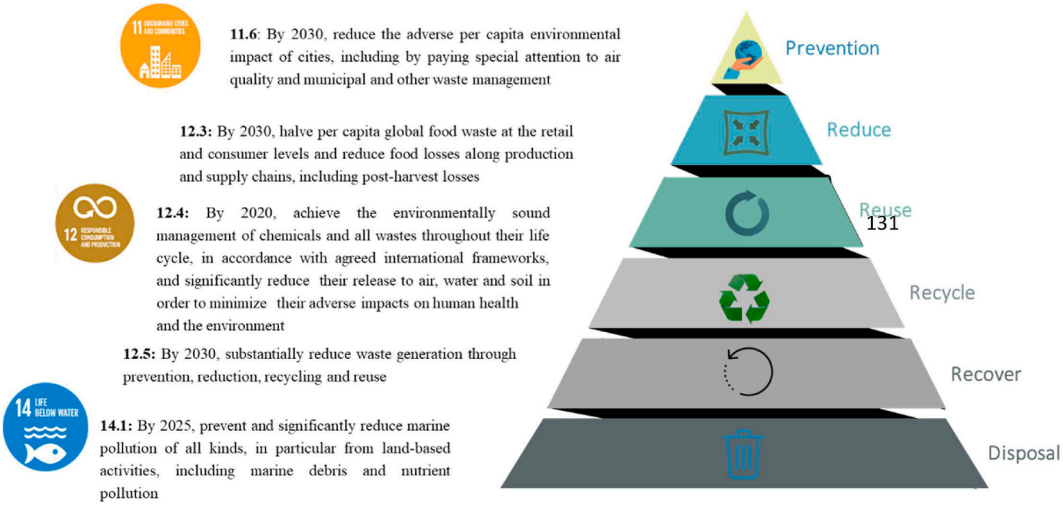

Fig. 4. Solid Waste management linked with SDGs (figure created by the authors).

day activities is not only driven by individual environmental concerns but also social influence and sustainable communal behavior (Morone et al., 2021).

Globally, environmental research community, policy makers and engineer are the professional retort to the overwhelming environmental problems (Haque and Sharif, 2021). The practice implementation of their scientific, technical, and mathematical knowledge with the use of natural laws and physical resources are crucial. The incorporation of their technology and organizational expertise is not only challenging, but also critical in today's globalized world, changing advancement and therefore the impacts in economic, social, and environmental pillars (Iqbal Khan et al., 2016). This state of mind involves different sectors from urban planning (i.e. circular waste management) (Davidescu et al., 2022), to agriculture (i.e. circular use of residues from wheat cultivation, evaluation of soil for circular economy implementation) and other key areas (Golia et al., 2021; Golia, 2023).

While sustainable development constitutes a key element of governmental agendas, entrusting strategic decision-making to otherwise lacking in sustainability expertise individuals, is a great risk. Hence, ensuring that education institutes like universities, schools etc. are the pillars of sustainable communities is of outmost importance (Biancardi et al., 2023).

At the same time, digital transformation in education refers to the process of integrating technology into various aspects of the educational landscape to enhance learning and teaching experiences (Papamichael et al., 2022b). It encompasses a wide range of technological innovations, including interactive learning platforms, virtual classrooms, digital textbooks, and personalized learning tools. By leveraging digital tools, educators can create dynamic and engaging content, tailor lessons to individual student needs, and facilitate seamless communication between teachers, students, and parents. Furthermore, digital transformation empowers learners to acquire essential 21st-century skills, such as critical thinking and problem-solving, while fostering a more inclusive and accessible educational environment. Embracing this transformative shift in education prepares students for the challenges of an increasingly digital and interconnected world, where technology plays an integral role in both education and everyday life (Papamichael et al., 2023b).

The aim of this short communication is to explore the social factors that affect the transition towards circular economy. As social influence is in many cases overlooked, observation, identification, evaluation, and monitoring of social factors that have the potential to aid or delay circular transition is of imminent importance. At the same time, in line with the digital transition of today's society, the authors explore how digitalization can help with influencing the public in terms of environmental behavior, environmental and sustainable education, social responsibility and other main areas of interest.

2. Methodology

For the recruitment of necessary references concerning environmental education and digitalization, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis- PRISMA (www.prisma-statement.org) was used (Papamichael et al., 2022a). The records were included or excluded according to specific criteria like: (i) year of publication (2000–2023) through SCOPUS platform, (ii) reports and studies providing statistical data (from 2010-current), (iii) reviews and research papers, (iv) papers published in English only. The exclusion criteria were: (i) papers in other languages than English, (ii) duplicated records, (iii) insufficient data, (iv) records not including the keyword used by the authors. The keywords used were “circular economy” AND “behavior” AND/OR “society”, “sustainable education” AND “circular economy”, “Circular economy” AND “digitalization” AND “sustainable education” AND/OR “society”. From the 3700 records identified, 71 were used in the communication, including 61 articles and 10 reports as illustrated in Fig. 5.

3. Results and discussion

The realization of the theoretical benefits of Circular Economy and sustainable development in urban and industrial sectors still encounters a significant disconnect from practical application (Jaeger and Upadhyay, 2020). Kirchherr et al. (2017) identified four main types of interconnected barriers that contribute to this delay in achieving circularity. Firstly, social barriers encompass challenges related to consumer behavior and awareness, as well as the need to instigate a shift in existing business culture to embrace circular practices. Secondly, technological barriers involve issues such as circular design complexities, challenges within the supply chain, a lack of technical expertise, and difficulties in implementing industrial symbiosis. Thirdly, regulatory barriers include legal and regulatory obstacles, as well as a lack of global collaboration on circular economy initiatives. Lastly, market barriers encompass obstacles like high investment costs, risks associated with circular economy investments, and limited funding opportunities (Araujo Galvão et al., 2018; Jaeger and Upadhyay, 2020; Loizia et al., 2021).

Concerning social barriers, according to Mensah (2021), behavior is sustaining predisposition toward a specific aspect of one's environment. In other words, it suggests that an individual's actions or conduct are influenced by a preexisting inclination or tendency they have towards a particular element within their surroundings. It is comprised of three main principles: (i) perception related to emotional impression; (ii) consciousness related to thought; (iii) and a natural tendency to act. Social behavior is influenced by the personal belief that an action will yield to a specific outcome. This depends on how the individual perceives the occurrence. In other words, people's positive views toward a phenomenon boost their willingness to take part in a particular action (Wang, 2017). Social attitudes toward waste, sustainability and circularity, their involvement in reducing waste is linked to waste disposal. When there is a negative attitude toward waste management, the disposal practices could have negative economic, social, and environmental consequences, upsetting sustainable development. Where waste disposal behavior is positive, the reverse socioeconomic and environmental impacts are enrolled, resulting positive effects on sustainability (Mensah, 2021). Similar is the theory from Fearon and Adraki (2014) who mentioned that people's desire to engage (or not engage) a behavior is the force that determines of that action. Their intentions are also influenced by their own perceptions and the subjective norm, which are viewed as two distinct factors. Behaviors, in

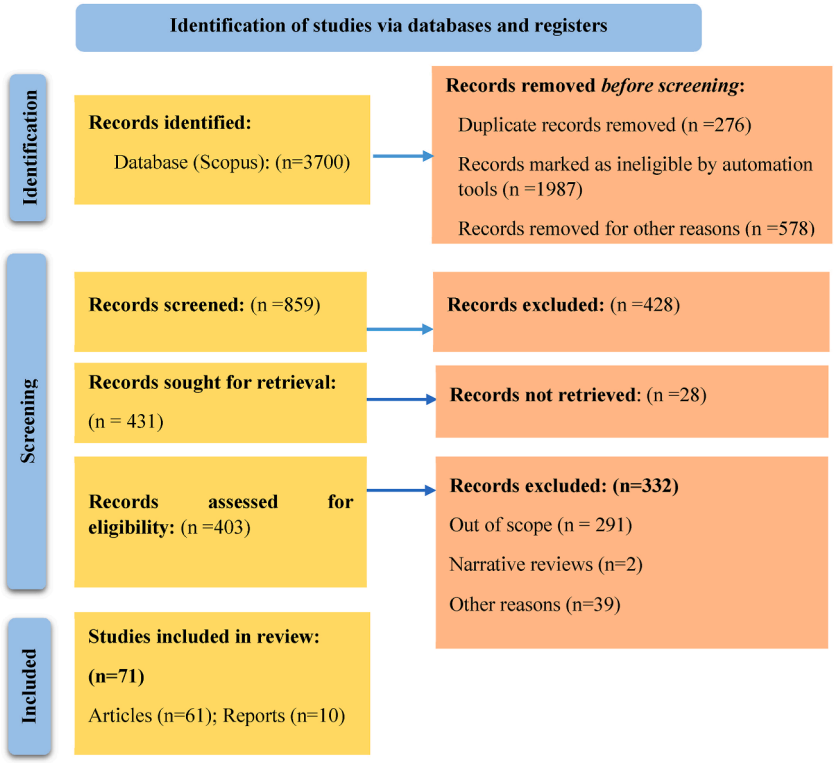

Fig. 5. PRISMA statement for the current research.

turn, are affected by beliefs about what the outcome will be and what social value and recognition this outcome will bring on the individual. In other words, the perception of the community on one's self, is a major driver of social behavior and attitude.

Without public participation, it is impossible to implement an efficient waste management strategy. Awareness raising through campaigns, educational material, pilot actions as well as the offer of incentives (such as economic funds) are some of the main actions that could be taken in order to enhance the public interaction in waste management strategy (Zorpas, 2020). Identifying the key drivers of human behavior is useful to adapt interventions and lead civil society to a stronger commitment to environmental conservation and protection. Generally, social behavior and attitude is affected by factors relating to the person, including (i) physical factors – age, gender, (ii) personal and emotional factors – personality, beliefs, expectations, emotions, (iii) life experiences – family, culture, friends, life events, (iv) educational level, (v) income level, (vi) what the person needs and wants (Meidiana et al., 2021; Xiao et al., 2023).

Omotayo et al. (2020) examined the driving factors affecting households' recycling behavior and payment for waste disposal in South Africa. They highlighted that people's waste recycling behavior and willingness to pay for waste management influenced by environmental factors, the availability of waste management infrastructures as well as several social-economic characteristics such as household's income, access to social grants or educational level. The results from their study indicated that there is a negative relationship between low income and environmental protection. In relation with the above results, there is also a direct relationship between income and social grants as the households that have access to grants have a higher chance of recycling and paying for waste management than their counterparts who do not obtain any assistance. This relation is linked to the willingness of the citizens to pay (i.e. education received, social norms, cultural background) and their ability to pay (i.e. income level) in waste management schemes (Morone et al., 2021; Papamichael et al., 2023a). These results were in line several researches (Afroz et al., 2011; Kinnaman, 2009; Omotayo et al., 2018). Similarly, according to Papamichael et al., (2023), price reduction regarding circularity development in different sectors (i.e. fashion industry, urban development etc.) must be considered as a primary element in the development of a viable circular waste management strategy. Zorpas et al. (2021) illustrated that there is a strong correlation between waste production and income level, a correlation that eludes ethical dimensions regarding accessibility to products and services (i.e. clothing), occupational hazards (i.e. close proximity of industries to residential areas) due to low income housing and other.

In terms of accumulative income changes, waste generation usually increases rapidly at lower income levels (Nguyen et al., 2020). Despite having only 16% of the world's population, high-income countries produce approximately 34% of the world's waste, or 683 million tones. Low-income countries, on the other hand, account for 9% of the global population but generate only about 5% of global waste, or 93 million tones (The World Bank, 2022). Daily per capita waste production in high-income countries is estimated to rise by 19% by 2050, while at the same time it expected to increase by more than three times by 2050 in low-income countries (Fig. 6).

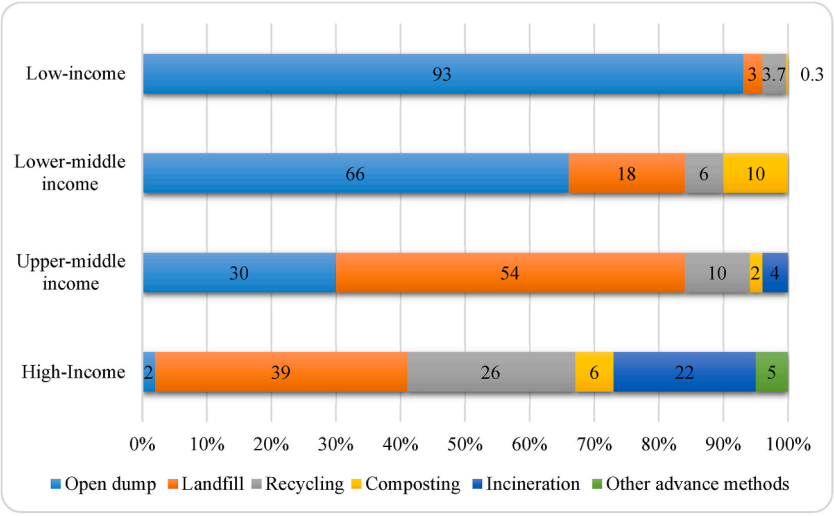

Fig. 6. Disposal methods by income (data from The World Bank, 2022).

According to Mensah (2021) when studying waste management practices related with fisherfolk, the perception and attitude of the involved citizens influenced waste disposal practices. As expected from the research, the experts had a more comprehensive knowledge of waste than the fishermen. Unlike the fishermen, who saw waste as an annoyance and useless resource, the experts had seen it as both a nuisance and a potential resource. The fishermen did not separate their solid waste in accordance with best practices. They were also dissatisfied with the payment for waste collection services, referencing poverty as the primary reason. Furthermore, while the fisherfolk identified that they had responsibility to play regarding appropriate solid waste disposal in their environment, they expected that local authority, government, and private companies to take a vital part in solid waste management in the society. This viewpoint was notified by their belief that since they had paid their taxes, a portion of the tax revenue should be used to improve solid waste management. In a similar study by Boadi and Kuitunen (2003), it is mentioned that attempts to tackle waste management difficulties in developing countries have collapsed due to people's negative perceptions of how to handle solid waste.

One of the most important pillars of boosting awareness among societal constructs are waste prevention activities which, according to the WFD (Official Journal of the European Union, 2008), waste prevention measures need to be taken before the categorization of material or discarded products (i.e., chemicals, materials, substances). Prevention activities including sharing, leasing, reusing, repairing, refurbishing, however, aim at the reduction of the quantity of waste beforehand. Therefore, their implementation should not be based on general observations, but should focus on individual waste streams which are analyzed according, but not limited, to behavior, local culture, education, waste characteristics (i.e. composition) etc. In a study held by Seng et al. (2018), result indicated that increasing income, education, and knowledge drastically enhanced solid waste awareness. The well-informed and educated participants seemed to be aware of the waste issues while Wang et al. (2018) underlined that there are three additional important factors related to social behavior and waste management. The first refers to the positive impact that residents who practice efficient waste disposal practices have on their neighbors. The second one related to the positive correlation of social behavior and the accessibility in adequate infrastructures. The third aspect is connected to legislation and policies. Punishment has historically been a crucial aspect of social behavior control. On the one hand, it is as form of justice for those who do not comply, and on the other, it serves as an exemplary punishment for everyone else (Pifferi, 2022). However, government laws that endorse the punishment philosophy are inappropriate, while to increase the popularity of waste management, authorities should develop clear, powerful policies (Fig. 7).

Still, according to many researchers (Eliades et al., 2022; Eliadis et al., 2019; Grigoriou and Efstathiadou, 2019; Mies and Gold, 2021), one of the most powerful drivers for the transition towards circular economy and adequate waste management of urban, in-

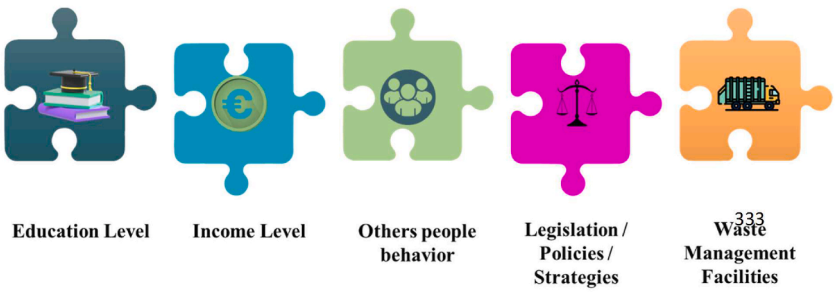

Fig. 7. Main factors affecting social behavior regarding waste management (figure created by the authors).

dustrial or otherwise compromised settings, is citizen education regarding sustainability. For several decades, climate experts, researchers and other key players of the research community have tried to raise the climate change issue on the political agenda. Climate change constitutes a globally crisis that transcends national borders, and it is an urgent problem that requires international cooperation and coordinated solutions at all levels. It's being addressed collectively through engaged agreements, strategies, and laws and regulations, through the expertise given by all the stakeholders (Kaklauskas et al., 2023). Still, political negotiations seem to be void due to high economic interests which hinder substantial growth and development (Cai and Wolff, 2023). With the 1972 Stockholm Human Environment Conference, the international community began to explore the topics of sustainable and environmental education. These events sparked a flurry of debates; for example, during the Belgrade Charter of 1975, it was stated that environmental issues may be detected, prevented, and/or remedied via education. Since 1975, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has presented the International Environmental Education Program to the worldwide community and has staged a variety of educational events aimed at laying the groundwork for a future European Union (EU) plan.

It is vital that primary to higher education needs to integrate and adopt sustainability, to create societies sensitive to sustainable development matters. The education system, as a transformative agent, has a huge impact on students' behavior and contributes to a productive community. The integration of various disciplines raises students' problem-solving abilities, prolonging their ideas to create solutions for multiple challenges (Žalėnienė and Pereira, 2021). Business-oriented transfer of knowledge should be reformed to include socioecological factors in all aspects of higher education, namely education, research, and extension (Geissdoerfer et al., 2017; Tasdemir and Gazo, 2020). Given the dynamic nature of sustainability innovation, education institutions are being forced to redesign and widen their curricula with the goal to evolve into more real-life oriented across all disciplines by developing links with industry and other institutions (Fonseca et al., 2018). This needs to be achieved not just as a catchy perpetuated phrase that was established over the years, but a strong and core social responsibility factor, armored through education and knowledge of the dynamic behind the words (Wu and Shen, 2016).

According to the U.S. partnership for Education for Sustainable Development (U.S. Partnership for Education for Sustainable Development, 2009), education in matters of sustainability is defined as a "combination of content, learning methods, and outcomes that helps students develop a knowledge base about the environment, the economy, and society, in addition to helping them learn skills, perspectives, and values that guide and motivate them to seek sustainable livelihoods, participate in a democratic society, and live in a sustainable manner". At the same time, according to the Council of the European Union, (2010), sustainable education is a lifelong learning process which is vital for achieving sustainable societies and communities. UNESCO (2012) defines sustainable education as an education which focuses on sustainable development and allows all participants to acquire the necessary skills, attitude and knowledge needed for the formulation of sustainable future communities. It includes key sustainability issues (i.e. climate change, disaster risk reduction, poverty reduction, responsible production and consumption etc.). It promotes key soft skills like critical thinking and decision making in a communal and collaborative manner.

Through the working definitions, the three main objectives of sustainable education are pinpointed as: (a) the understanding and application of basic concept of sustainability; (b) being able to recognize sustainability as an interdependent factor of environmental, social and economic systems and (c) the development of multidisciplinary approaches to learning the necessary skills and attitude for the improvement of health, well-being and knowledge development for future generations (U.S. Partnership for Education for Sustainable Development, 2009). Environmental education in higher education institutions is of primary importance in order to tackle social interaction and innovation concerning sustainability (Luna-Krauletz et al., 2021).

Main objective of sustainable education is not only to enhance eco-awareness of students and citizens but also build critical thinking and sensitivity regarding sustainability issues, on all three pillars (environment, society, economy) (Kougias et al., 2022; Zorpas et al., 2017). It aims at empowering learner for informed critical decisions and take collective actions to change societal norms bound by age, gender and other factor for cognitive progression and sustainable learning. Environmental education constitutes a lifelong process which responds to urgent challenges faced on a global scale due to collective anthropogenic activities which lead to severe environmental, social and economic consequences. The necessity of it, lies at the comprehension of the consequences of behavior when it comes to sustainability in everyday life, while at the same time, it acts as a pressure lever towards inactive governments from the citizens but also vice versa (Eliades et al., 2022; Sardianou, 2020; UNESCO, 2022).

Mobilizing the experiences and resources of academia, civil society and private sectors on matters of sustainability will enhance the development of future solutions for sustainable development in all local, national and global levels. To enhance the transition of educational systems towards sustainable learning, it is obligated to start with the Sustainable Development Goals (SDGs) of the United Nations. The knowledge concerning the SDGs should include the three dimensions of sustainability (environment, society, economy) along with the relationship between them (D'Adamo et al., 2021). A retrospective approach including the investigation of root causes for barriers towards sustainability and successful tackling of the 17 SDGs along with proposals and good practices for sustainable development beyond current trends and boundaries are vital to integrate sustainable thinking in future citizens including primary, secondary and higher education (Collazo Expósito and Granados Sánchez, 2020). At the same time, environmental education does not only require an elaborate understanding of SDGs but also facilitates it. According to Collazo Expósito and Granados Sánchez (2020), when aspects of environmental education are integrated into higher education curriculum of various areas of study, this can be used to tackle all different aspects of sustainability across different actors (i.e. engineering, architecture, social sciences, law etc.) as depicted in Fig. 8.

Addressing climate crisis as well as sustainability and legislative implications and opportunities in educational setting is vital to support robust climate action. Such initiative would enhance resilience to the adverse impacts of climate change while addressing all three sustainability pillars concerning the environment (i.e. protection of natural habitats, decrease in GHGs emissions etc.), society (i.e. safeguard public health etc.) and the economy (i.e. drive economic growth) (Gorina et al., 2023). The technological advance-

Fig. 8. Facilitating SDGs through different study areas of higher education (figure created by the authors).

ments such as digitalization, Artificial Intelligent (AI), Internet of Things (IoT), smart tools etc. of recent years have severely contributed to environmental and social issues around the globe. As access to knowledge is not hindered by physical space, platforms, applications, encyclopedias, and open-source databases support students wishing to expand their knowledge on matters of sustainability (Trevisan et al., 2023). The support of lectures and professional learning in educational systems has always been -and should always be-crucial while the development of the later around digital transformation and tailoring instructions to digital needs has been expanding in recent years. In order to facilitate professional learning in a sustainable environment, educators have the immense responsibility to enhance digitalization practices (i.e. online lectures, decrease of paper consumption through the use of digital devices etc.) in order to promote sustainable management practices first within the institution (Gorina et al., 2023).

Enabling educational community to develop digital skills around matters of environmental and sustainable education can supply future members of society with the necessary knowledge and way of thinking to promote any environmental initiatives of each given national and international setting. These skills include awareness and sensitivity, knowledge and understanding of key concepts (i.e. circular economy), cultivation of talent regarding sectors of sustainability (i.e. environmental engineering, governmental bodies, social analysts etc.) while at the same time, making this knowledge accessible through digitalization (Eliades et al., 2022). The use of digital platforms to promote both online learning for both lectures and other educational events (i.e. seminars, conferences, info days etc.) can both promote the key objectives of environmental education and be at their core sustainable by nature (i.e. less paper consumption, flight to attend in situ classes, seminars, conferences etc.). At the same time, digitalization combined with other educational methodologies has been found very effective in the area of sustainable education. Pappas et al. (2022) developed a waste management platform of a virtual city, where the user can insert real life data concerning waste management (i.e. recycling rate, waste accumulation etc.), energy consumption, strategy implementation and other, to monitor the environmental performance of an urban setting in a user friendly interactive platform. The use of gamification and gamified platforms to promote waste management can both enhance knowledge and understanding of students while making the learning process more engaging as the students treat it more like game learning and less like an obligation. Such models are vital for influencing the attitude and actions of current and future generations.

At the same time though, high educational institutions are experiencing several changes induced by this rapid technological development, calling a transformation of their structures and business models. Although many institutions are following this shift towards convergence of digital imperatives, there is still a lack of systematic academic research of rethinking management models of educational institutions centered around sustainable development using digital technologies (Pu et al., 2022; Trevisan et al., 2023). At present, adopting digitalization in the context of higher education and sustainability is strictly related to a paradigm shift where technology is presented as a complex environment which enables digital learning. Therefore, the focus is mainly on the students than technology used, deeming digitalization vital for higher education institutions for attracting more students, improving experiences, teaching materials, training and other (Abad-Segura et al., 2020).

4. Conclusion

Altering social attitude and behavior can be one of the most difficult aspects of the transition towards circular economy as well as adequate waste management strategy development. There is a misconception that in-depth learning of terms like circular economy is to be tackled at a later stage of a person's life when they are already part of a civil society. However, the integration of sustainable mindset into society, should be achieved in younger generations rather than older ones, through environmental education and digitalization, since such members of society uphold the future of sustainable cities and communities (SDG 11). Still, the transition towards circularity is not limited to educating and transfer of knowledge, but also has to do with other main social and economic factors (i.e. income level, age, culture, policies and regulations etc.). Thus, adequate tackling of circular transition in the context of social alteration is vital. Therefore, future research on social aspects affecting circular economy implementation should be monitored, not only on a global but also on a national level, to observe the transition in the context of the country's profile.

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Authors' contribution

Irene Voukkali: Conceptualization, Methodology, software, validation, formal analysis, Writing-review & editing, visualization, supervision. **Iliana Papamichael:** Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, Writing- Original draft preparation, writing-review & editing, visualization. **Florentios Economou:** Conceptualization, Validation, Formal analysis, Investigation, Data curation, Writing-Review & Editing, Visualization, Investigation. **Pantelitsa Loizia:** Conceptualization, Validation, Formal analysis, Investigation, Data curation, Writing-Review & Editing, Visualization, Investigation. **Eleftheria Klontza:** Formal analysis, Data Curation, Writing-Review & Editing, Visualization. **Demetris F. Lekkas:** Formal analysis, Data Curation, Writing-Review & Editing, Visualization. **Vincenzo Naddeo:** Formal analysis, Data Curation, Writing-Review & Editing, Visualization. **Antonis A. Zorpas:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Abad-Segura, E., González-Zamar, M.-D., Infante-Moro, J.C., Ruipérez García, G., 2020. Sustainable management of digital transformation in higher education: global research trends. Sustainability. https://doi.org/10.3390/su12052107.

Afroz, R., Tudin, R., Hanaki, K., Masud, M.M., 2011. Selected socio-economic factors affecting the willingness to minimise solid waste in Dhaka city, Bangladesh. J. Environ. Plann. Manag. 54, 711–731. https://doi.org/10.1080/09640568.2010.527472.

Araujo Galvão, G.D., de Nadae, J., Clemente, D.H., Chinen, G., de Carvalho, M.M., 2018. Circular economy: overview of barriers. Procedia CIRP 73, 79–85. https://doi.org/10.1016/j.procir.2018.04.011.

Biancardi, A., Colasante, A., D'Adamo, I., 2023. Sustainable education and youth confidence as pillars of future civil society. Sci. Rep. 13, 955. https://doi.org/10.1038/s41598-023-28143-9.

Boadi, K.O., Kuitunen, M., 2003. Municipal solid waste management in the Accra metropolitan area, Ghana. Environmentalist 23, 211–218. https://doi.org/10.1023/B:ENVR.0000017283.09117.20.

Cai, Y., Wolff, L.-A., 2023. Education and sustainable development goals. Sustainability. https://doi.org/10.3390/su15010643.

Chatziparaskeva, G., Papamichael, I., Zorpas, A.A., 2022. Microplastics in the coastal environment of Mediterranean and the impact on sustainability level. Sustain. Chem. Pharm. 29, 100768. https://doi.org/10.1016/j.scp.2022.100768.

Chioatto, E., Sospiro, P., 2023. Transition from waste management to circular economy: the European Union roadmap. Environ. Dev. Sustain. 25, 249–276. https://doi.org/10.1007/s10668-021-02050-3.

Colasante, A., D'Adamo, I., 2021. The circular economy and bioeconomy in the fashion sector: emergence of a "sustainability bias.". J. Clean. Prod. 329, 129774. https://doi.org/10.1016/j.jclepro.2021.129774.

Collazo Expósito, L.M., Granados Sánchez, J., 2020. Implementation of SDGs in university teaching: a course for professional development of teachers in education for sustainability for a transformative action. Sustainability. https://doi.org/10.3390/su12198267.

Council of the European Union, 2010. Council conclusions on education for sustainable development. https://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/educ/117855.pdf. 3.27.23.
D'Adamo, I., Gastaldi, M., Imbriani, C., Morone, P., 2021. Assessing regional performance for the sustainable development goals in Italy. Sci. Rep. 11, 24117. https://doi.org/10.1038/s41598-021-03635-8.
Davidescu, A.A., Ghinararu, C.C., Manta, E.M., 2022. In: Fotea, S.L., Fotea, I.Ş., Văduva, S. (Eds.), Mapping the Performance of Smart Cities in the European Union BT - Navigating through the Crisis: Business, Technological and Ethical Considerations. Springer International Publishing, Cham, pp. 45–69.
Di Fiore, G., Specht, K., Rover, O.J., Zanasi, C., 2022. Stakeholders' social acceptance of a new organic waste management policy in the city of Florianópolis (Brazil). J. Clean. Prod. 379, 134756. https://doi.org/10.1016/j.jclepro.2022.134756.
Domènech, F.A., 2018. La LEC práctica en fichas, second ed. J.M Bosch.
Eliades, F., Doula, M.K., Papamichael, I., Vardopoulos, I., Voukkali, I., Zorpas, A.A., 2022. Carving out a Niche in the sustainability confluence for environmental education centers in Cyprus and Greece. Sustain. Times. https://doi.org/10.3390/su14148368.
Eliadis, F., Doula, M., Zorpas, A., 2019. The Role of Environmental Education Centers in Climate Change Education and Awareness Raising of the Society. The cases of Cyprus and Greece.
European Commission, 2019. Resolution of the European committee of the regions - the green deal in partnership with local and regional authorities. In: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions the European Green Deal. p. 24. Brussels.
Fearon, J., Adraki, P.K., 2014. Perceptions and attitudes to waste disposal: an assessment of waste disposal behaviors in the Tamale metropolis. J. Environ. Earth Sci. 4, 16–22.
Fonseca, L.M., Portela, A.R., Duarte, B., Queirós, J., Paiva, L., 2018. Mapping higher education for sustainable development in Portugal. Manag. Market. 13, 1064–1075. https://doi.org/10.2478/mmcks-2018-0023.
Fuldauer, L.I., Adshead, D., Thacker, S., Gall, S., Hall, J.W., 2022. Evaluating the benefits of national adaptation to reduce climate risks and contribute to the Sustainable Development Goals. Global Environ. Change 76, 102575. https://doi.org/10.1016/j.gloenvcha.2022.102575.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – a new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048.
Golia, E., Angelaki, A., Giannoulis, K., Skoufogianni, E., Bartzialis, D., Cavalaris, C., Vleioras, S., 2021. Evaluation of soil properties, irrigation and solid waste application levels on Cu and Zn uptake by industrial hemp. Agron. Res. 19, 92–99. https://doi.org/10.15159/AR.21.016.
Golia, E.E., 2023. The impact of heavy metal contamination on soil quality and plant nutrition. Sustainable management of moderate contaminated agricultural and urban soils, using low cost materials and promoting circular economy. Sustain. Chem. Pharm. 33, 101046. https://doi.org/10.1016/j.scp.2023.101046.
Gorina, L., Gordova, M., Khristoforova, I., Sundeeva, L., Strielkowski, W., 2023. Sustainable education and digitalization through the prism of the COVID-19 pandemic. Sustainability. https://doi.org/10.3390/su15086846.
Grigoriou, M., Efstathiadou, E., 2019. Environmental education centers and experiential learning: views and opinions of an EEC director. Educ. Sci. 2019 (4), 109–125. Available at: https://ejournals.lib.uoc.gr/index.php/edusci/article/view/1218. 7.1.22.
Haque, M.S., Sharif, S., 2021. The need for an effective environmental engineering education to meet the growing environmental pollution in Bangladesh. Clean. Eng. Technol. 4, 100114. https://doi.org/10.1016/j.clet.2021.100114.
Iqbal Khan, M., Mourad, S.M., Zahid, W.M., 2016. Developing and qualifying civil engineering programs for ABET accreditation. J. King Saud Univ. - Eng. Sci. 28, 1–11. https://doi.org/10.1016/j.jksues.2014.09.001.
Jaeger, B., Upadhyay, A., 2020. Understanding barriers to circular economy: cases from the manufacturing industry. J. Enterprise Inf. Manag. 33, 729–745. https://doi.org/10.1108/JEIM-02-2019-0047.
Kaklauskas, A., Abraham, A., Kaklauskiene, L., Ubarte, I., Amaratunga, D., Lill, I., Milevicius, V., Kaklauskaite, U., 2023. Synergy of climate change with country success and city quality of life. Sci. Rep. 13, 7872. https://doi.org/10.1038/s41598-023-35133-4.
Kinnaman, T.C., 2009. The economics of municipal solid waste management. Waste Manag. 29, 2615–2617. https://doi.org/10.1016/j.wasman.2009.06.031.
Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005.
Kougias, K., Sardianou, E., Saiti, A., 2022. Attitudes and perceptions on education for sustainable development. Circ. Econ. Sustain. https://doi.org/10.1007/s43615-022-00174-w.
Kwon, H.R., Silva, E.A., 2019. Mapping the landscape of behavioral theories: systematic literature review. J. Plann. Lit. 35, 161–179. https://doi.org/10.1177/0885412219881135.
Loizia, P., Voukkali, I., Zorpas, A.A., Navarro Pedreño, J., Chatziparaskeva, G., Inglezakis, V.J., Vardopoulos, I., Doula, M., 2021. Measuring the level of environmental performance in insular areas, through key performed indicators, in the framework of waste strategy development. Sci. Total Environ. 753, 141974. https://doi.org/10.1016/j.scitotenv.2020.141974.
Luna-Krauletz, M.D., Juárez-Hernández, L.G., Clark-Tapia, R., Súcar-Súccar, S.T., Alfonso-Corrado, C., 2021. Environmental education for sustainability in higher education institutions: design of an instrument for its evaluation. Sustainability. https://doi.org/10.3390/su13137129.
Meidiana, C., Sekito, T., Sasongko, W., 2021. Determining factors of community participation in waste bank. IOP Conf. Ser. Earth Environ. Sci. 940, 12085. https://doi.org/10.1088/1755-1315/940/1/012085.
Mensah, J., 2021. Fisherfolk's perception of and attitude to solid waste disposal: implications for health, aquatic resources, and sustainable development. J. Environ. Public Health 2021, 8853669. https://doi.org/10.1155/2021/8853669.
Mies, A., Gold, S., 2021. Mapping the social dimension of the circular economy. J. Clean. Prod. 321, 128960. https://doi.org/10.1016/j.jclepro.2021.128960.
Morone, P., Caferra, R., D'Adamo, I., Falcone, P.M., Imbert, E., Morone, A., 2021. Consumer willingness to pay for bio-based products: do certifications matter? Int. J. Prod. Econ. 240, 108248. https://doi.org/10.1016/j.ijpe.2021.108248.
Nguyen, K.L.P., Chuang, Y.H., Chen, H.W., Chang, C.C., 2020. Impacts of socioeconomic changes on municipal solid waste characteristics in Taiwan. Resour. Conserv. Recycl. 161, 104931. https://doi.org/10.1016/j.resconrec.2020.104931.
Official Journal of the European Union, 2008. Directive 2008/98/EC of the European parliament and of the Council. On waste repealing certain directives. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN. 2.1.22.
Omotayo, A., Ijatuyi, E., Olorunfemi, O., Agboola, P.T., 2018. Food security situation among South African urban agricultural households: evidence from Limpopo province. Acta Acad. 14 (1), 60–74.
Omotayo, A.O., Omotoso, A.B., Daud, A.S., Ogunniyi, A.I., Olagunju, K.O., 2020. What drives households' payment for waste disposal and recycling behaviours? Empirical evidence from South Africa's general household survey. Int. J. Environ. Res. Publ. Health. https://doi.org/10.3390/ijerph17197188.
Papamichael, I., Chatziparaskeva, G., Pedreno, J.N., Voukkali, I., Almendro Candel, M.B., Zorpas, A.A., 2022a. Building a new mind set in tomorrow fashion development through circular strategy models in the framework of waste management. Curr. Opin. Green Sustainable Chem. 100638. https://doi.org/10.1016/j.cogsc.2022.100638.
Papamichael, I., Chatziparaskeva, G., Voukkali, I., Navarro Pedreno, J., Jeguirim, M., Zorpas, A.A., 2023a. The perception of circular economy in the framework of fashion industry. Waste Manag. Res. 0734242X221126435. https://doi.org/10.1177/0734242X221126435.
Papamichael, I., Pappas, G., Siegel, J.E., Zorpas, A.A., 2022b. Unified waste metrics: a gamified tool in next-generation strategic planning. Sci. Total Environ. 154835. https://doi.org/10.1016/j.scitotenv.2022.154835.
Papamichael, I., Voukkali, I., Loizia, P., Pappas, G., Zorpas, A.A., 2023b. Existing tools used in the framework of environmental performance. Sustain. Chem. Pharm. 32, 101026. https://doi.org/10.1016/j.scp.2023.101026.
Pifferi, M., 2022. Punishment and social control in historical perspective. https://doi.org/10.1093/acrefore/9780190228637.013.1784.
Pu, R., Tanamee, D., Jiang, S., 2022. Digitalization and higher education for sustainable development in the context of the Covid-19 pandemic: a content analysis approach. Probl. Perspect. Manag. 20, 27–40. https://doi.org/10.21511/ppm.20(1).2022.03.
Sardianou, E., 2020. Sustainable development integration in higher education. In: Oxford Research Encyclopedia of Education. Oxford University Press. https://

doi.org/10.1093/acrefore/9780190264093.013.767.
Seng, B., Fujiwara, T., Spoann, V., 2018. Households' knowledge, attitudes, and practices toward solid waste management in suburbs of Phnom Penh, Cambodia. Waste Manag. Res. 36, 993–1000. https://doi.org/10.1177/0734242X18790800.
Sessa, A., Di Giuseppe, G., Marinelli, P., Angelillo, I.F., 2010. Public concerns and behaviours towards solid waste management in Italy. Eur. J. Publ. Health 20, 631–633. https://doi.org/10.1093/eurpub/ckp204.
Statista, 2023. Generation of Municipal Waste Worldwide as of 2020. by select country Available at: https://www.statista.com/statistics/916749/global-generation-of-municipal-solid-waste-by-country/. 4.10.23.
Tasdemir, C., Gazo, R., 2020. Integrating sustainability into higher education curriculum through a transdisciplinary perspective. J. Clean. Prod. 265, 121759. https://doi.org/10.1016/j.jclepro.2020.121759.
The World Bank, 2022. Solid waste management. Available at: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management. 4.10.23.
The World Bank, 2018. WHAT A waste 2.0 A global snapshot of solid waste management to 2050. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/30317/211329ov.pdf?sequence=11&isAllowed=y. 11.1.22.
Trevisan, L.V., Eustachio, J.H.P.P., Dias, B.G., Filho, W.L., Pedrozo, E.Á., 2023. Digital transformation towards sustainability in higher education: state-of-the-art and future research insights. Environ. Dev. Sustain. https://doi.org/10.1007/s10668-022-02874-7.
U.S. Partnership for Education for Sustainable Development, 2009. National Education for Sustainability K-12 Student Learning Standards Version 3. Available at: https://celfeducation.org/wp-content/uploads/2020/04/US-Partnership-for-Education-for-Sustainable-Development-USPESD-K-12-Standards.pdf. 3.24.23.
UNESCO, 2022. What is education for sustainable development? Available at: https://www.unesco.org/en/education/sustainable-development/need-know. 6.26.22.
UNESCO, 2012. Education for sustainable development: building a better, fairer world for the 21st century. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000216673. 3.27.23.
United Nations, 2015. Transforming our world: the 2030 agenda for sustainable development. Available at: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. 3.30.22.
Wang, H., Schandl, H., Wang, X., Ma, F., Yue, Q., Wang, G., Wang, Y., Wei, Y., Zhang, Z., Zheng, R., 2020. Measuring progress of China's circular economy. Resour. Conserv. Recycl. 163, 105070. https://doi.org/10.1016/j.resconrec.2020.105070.
Wang, J., 2017. Perceptions of individual behavior in green event—from the theory of planned behavior perspective. Am. J. Ind. Bus. Manag. 7, 973–988. https://doi.org/10.4236/ajibm.2017.78070.
Wang, Z., Dong, X., Yin, J., 2018. Antecedents of urban residents' separate collection intentions for household solid waste and their willingness to pay: evidence from China. J. Clean. Prod. 173, 256–264. https://doi.org/10.1016/j.jclepro.2016.09.223.
Wu, Y.-C.J., Shen, J.-P., 2016. Higher education for sustainable development: a systematic review. Int. J. Sustain. High Educ. 17, 633–651. https://doi.org/10.1108/IJSHE-01-2015-0004.
Xiao, L., Fu, B., Lin, T., Meng, L., Zhang, O., Gao, L., 2023. Promoting and maintaining public participation in waste separation policies — a comparative study in Shanghai, China. Resour. Environ. Sustain. 12, 100112. https://doi.org/10.1016/j.resenv.2023.100112.
Žalėnienė, I., Pereira, P., 2021. Higher education for sustainability: a global perspective. Geogr. Sustain. 2, 99–106. https://doi.org/10.1016/j.geosus.2021.05.001.
Zorpas, A.A., 2020. Strategy development in the framework of waste management. Sci. Total Environ. 716, 137088. https://doi.org/10.1016/j.scitotenv.2020.137088.
Zorpas, A.A., Navarro-Pedreño, J., Panagiotakis, I., Dermatas, D., 2021. Steps forward to adopt a circular economy strategy by the tourism industry. Waste Manag. Res. 39, 889–891. https://doi.org/10.1177/0734242X211029087.
Zorpas, A.A., Voukkali, I., Loizia, P., 2017. Effectiveness of waste prevention program in primary students' schools. Environ. Sci. Pollut. Res. 24, 14304–14311. https://doi.org/10.1007/s11356-017-8968-7.