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# Waste Literacy Among Portuguese First-Year Tertiary Students After Compulsory Environmental Education

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## Abstract

Waste management is essential for addressing local and global environmental challenges. Failure to manage waste effectively results in several consequences, including environmental degradation, public health risks, and economic costs. Besides the need for adequate and up-to-date waste management systems, citizens' cooperation is crucial to achieving sustainable waste management in any community, which depends on their waste literacy levels, comprising the knowledge, attitudes, and behaviours required. This study assessed waste literacy among students completing compulsory education in Portugal to provide evidence regarding the outcomes of environmental education policies related to waste management. A representative sample of 1506 freshmen students was surveyed at the start of their undergraduate programmes. An online questionnaire was administered to

the sample and the data were analyzed using statistical tests for assessing the influential factors associated with students' waste knowledge, attitudes and behaviours. Results show that, on average, students demonstrated good levels of knowledge and practices on waste management, together with a predominantly ecocentric worldview. A higher performance in waste management knowledge and practices was observed among younger students, with higher grades and higher paternal educational attainment. Besides these variables, best practices were significantly more prevalent among those with a higher participation in environmental activities and holding membership in environmental organizations. The findings suggest that upon completing compulsory education in Portugal, students display generally high levels of waste literacy, while also revealing specific gaps in knowledge and practices that warrant further educational attention. The study identifies these areas for improvement, highlighting the potential value of more practical, participatory and community-based approaches to waste education.

**Keywords:** waste literacy; Ecocentrism; waste management; compulsory education; Portugal

## 1. Introduction

Global solid waste generation has more than tripled since the 1970s. Currently, at least one-third of this waste is improperly managed, with upward trends expected to persist in the coming decades [1,2]. Additionally, household and similar waste (Municipal Solid Waste) has become increasingly diverse and complex, with textiles, plastics, and waste electrical and electronic equipment becoming more present, particularly among middle- and high-income societies [3]. Several consequences arise from the high levels of waste production and its inadequate management, including environmental, public health, and economic costs [4–6]. Even in countries with up-to-date waste management systems, waste-related pollution continues to contribute to the degradation of air, water, and soil quality [7,8]. Estimates, by default, indicate that waste accounts for around 3–5% of the world's greenhouse gas emissions, particularly considering landfill disposal, meaning that this issue cannot be left out of the effort to mitigate the problem of climate change [9–11]. After decades focused on macroplastics, particularly in its consequences for marine life, recent years have revealed the colossal scale of microplastic and nanoplastic pollution. Far beyond marine fauna entanglement, microplastics and nanoplastics are absorbed/incorporated into the food chain and are now present in the main tissues of the human body, with the consequences for public health becoming increasingly evident [12–15]. Besides waste overload and inherent pollution, a lack of recycling is putting pressure on resource scarcity and demanding a circular economy [16]. Such transition requires moving beyond the traditional linear economy- based on the 'take-make-dispose' model- towards a circular system, in which materials remain in productive use for as long as possible through waste prevention, reuse, repair, remanufacturing, and recycling [17,18].

Although the characteristics and resources of the waste management systems are crucial, the cooperation among all stakeholders, including consumers, is essential to achieve adequate effectiveness [19]. However, cooperation and participation in environmental actions are highly dependent on the levels of environmental literacy [20,21]. Environmental literacy is understood as the ability to comprehend and interpret information about the environment, to be conscientious, and to integrate it into daily practices [22], including cognitive and affective dispositions influencing attitudes and behaviours. Competences for analyzing and solving environmental problems are crucial, including behaviours that benefit environmental quality [23]. As such, environmental literacy on waste management,

or waste literacy, encompasses not only the dominance of knowledge and attitudes needed for sustainable waste management, but also the adoption of appropriate practices that contribute to it. In this study, waste literacy is addressed through its knowledge, behavioural, and attitudinal dimensions, acknowledging that broader conceptualizations may also include competencies, critical thinking, and civic engagement components. In this context, knowledge refers to the understanding of waste-related concepts, processes, and appropriate management strategies, while attitudes represent individuals' perceptions, values, and evaluations regarding waste management and environmental responsibility [24]. Behaviours also refer to the observable actions adopted in daily life, such as waste prevention, separation, reuse, and recycling practices [25].

Recognizing the relevance of citizens' waste literacy for the effective functioning of waste management systems and to reduce its environmental impact, environmental education worldwide has always prioritized this topic [26–29]. In Portugal, environmental education gained prominence especially from the 1990s onwards, driven by the Basic Law of the Educational System, curricular revisions and the Law for the Environmental Associations [30]. Since then, waste management has become a central theme within school-based environmental education, benefiting from extra-curricular programmes such as Eco-Schools, which is an international environmental education programme promoted by the Foundation for Environmental Education (FEE) and implemented in Portugal by the ABAAE (Associação Bandeira Azul de Ambiente e Educação-Blue Flag Association for Environment and Education), aiming to promote sustainability education through participatory school-based actions [31]. Present in Portuguese schools since 1996, the worldwide environmental education programme Eco-Schools has waste as one of the mandatory topics, among others, such as water and energy. Currently, more than 2200 Portuguese schools (almost one-quarter of the total) participate in the Eco-Schools environmental education programme [32].

Since 2016, the National Strategy for Citizenship Education recognized environmental education as a mandatory domain for all years of the Portuguese compulsory schooling (Order Number 6173/2016, of 10 May; Decree-Law Number 55/2018, of 6 July) and, meanwhile, the Environmental Education Framework for Sustainability and the National Environmental Education Strategy were approved [33,34]. The Students' Profile by the End of Compulsory Schooling in Portugal, approved in 2016, states that students are expected to develop environmental awareness and be able to adopt behaviours that address major global environmental challenges [35].

Since 2009, in Portugal, compulsory schooling lasts 12 years (K12), with children starting at age six and ending at about eighteen years old. However, despite environmental education efforts to promote waste literacy, to our knowledge, no previous study in Portugal has addressed the extent to which this objective has been achieved immediately after upper secondary education (K-12) and before the influence of undergraduate studies. Even worldwide, only a couple of such studies have been published [36–38]. A study on waste management knowledge and practices among 332 K-12 students at a state college in the Philippines concluded that students have enough knowledge of the definition of solid waste, its effects, and, among other topics, prohibited activities [36]. The study also found good solid waste management practices in terms of reduction, reuse, segregation, recycling, and disposal. Another study in Philippines [37], with 117 K-11 students enrolled in the Science, Technology, Engineering, and Mathematics (STEM) track, found high levels of waste management knowledge and practices, the same found by Murillo and colleagues [39] for practices in a different sample of K-11 and K-12 students, but contradicted by Usman and colleagues [38] who found only moderate levels of knowledge and practices in a K-12 students' sample. In Malaysia, a study of 589 first-year university students showed only

moderate levels for knowledge, attitudes, and practices concerning waste management, revealing the need for environmental education programmes on campus [40]. In Finland, using a sample of 249 high school students, mostly aged 16–18 years, Korsunova and colleagues [41] showed that their views on the Circular Economy are mostly as recyclers and consumers, overlooking repair, maintenance, and upcycling.

Beyond the scope of compulsory school, a study at a public university in China, involving more than 1200 students, in which 66% were included in the group aged 18–20 years and 42.5% freshmen, indicated a relatively positive students' attitude towards waste separation, although without adequate knowledge and relatively ineffective in their waste separation behaviour [42]. In the Philippines, 385 students from a state university, mostly aged between 15 and 20 (68.7%) and with a mean age of 20.2 years, revealed that most had satisfactory levels for knowledge (73.4%) and attitude (71.0%) on waste management, but satisfactory practices were found only in less than half (43.1%) [43].

Evidence from Portugal remains scarce but suggests a similar pattern, with positive attitudes not always translating into effective practices. In Portugal, a study with 400 students from 16 different higher education institutions, mostly aged between 18 and 21 years old, found that, despite holding positive views for Circular Economy, their understanding of its practical applications, such as waste reduction and resource efficiency, remains limited [44]. In a Portuguese University, Spínola [45] found that students showed high levels of knowledge (81%) and attitudes (91%) towards waste management, but only a moderate level for practices (61%).

A meta-analysis developed by Hu and colleagues [25] highlighted that waste separation for recycling is most strongly associated with three individual-level psychological constructs: perceived behavioural control, intention, and attitude. At a moderate level, two external or contextual condition predictors are also relevant: infrastructure, publicity and education. Other studies corroborate these findings [46–48], reinforcing the adequacy of the Theory of Planned Behaviour (TPB) in explaining behaviour adoption [49], namely on waste management. TPB considers that an individual is likely to engage in a behaviour if he intends to do it (intention, represented by motivation), and this intention is influenced by three psychological components: attitudes (the evaluation that the individual makes on their own behaviour); subjective norms (perceived social expectations on the engagement of the behaviour); and perceived behavioural control (perceived ease of taking action) [49,50]. Moreover, additional external variables, namely in the context of household waste separation, have been introduced to allow a clearer picture of behavioural mechanisms. Socio-demographic variables and contextual influences, among others, have been used to capture a wider vision of the framework that explains behaviour change [51–53].

Despite the relevance of waste literacy for sustainable waste management, there is a significant lack of information on the levels of waste literacy with which students conclude their compulsory education or high school. The few studies that address this educational level revealed low levels of waste management practices, which evidence the importance of understanding the factors that drive best practices in waste management, particularly for defining and implementing the necessary approaches that can promote citizen cooperation.

Thus, this study aims to characterize waste literacy level among Portuguese students who have recently completed compulsory education and to identify contextual and socio-demographic variables that correlate with better waste management performance. The results of this case study in Portugal will contribute to assessing gaps and challenges that remain to be overcome in waste literacy along compulsory education.

## 2. Materials and Methods

For the present study, a convenience sample (n = 1506) of Portuguese freshmen undergraduate students was selected to characterize waste literacy after compulsory schooling. Only students of Portuguese nationality who entered higher education in September 2023 and had completed compulsory education between 2021 and 2023 were included. This sample may approximate a best-case scenario for waste literacy, since more than half of the students (58.8%) who concluded the 12 years of mandatory schooling in Portugal in 2023 followed studies in higher education in the same year [54].

Data for the present study were collected using an anonymous survey questionnaire (available as Supplementary Material) applied during the first months after students entered higher education (October–December 2023). In addition to sociodemographic variables, the questionnaire included an eight-item scale adapted from Kaiser [55] and Spínola [45,56], using a 5-point Likert-type scale (ranging from "never" to "always"), to characterize the prevalence of waste management behaviours, namely littering, reducing, recycling, and advocacy. A redundant item was included to assess response consistency. To characterize waste management knowledge, a scale of 19 questions, using a multiple-choice format, was adapted from prior surveys, covering concepts, consequences, and how to reduce and recycle [45,56,57]. To align with waste management knowledge and practices, participants' ecocentric worldview level was addressed through an eight-item scale extracted from Dunlap and colleagues [58]. New Ecological Paradigm scale (NEP), according to Spínola [59,60]. For these scales, items adapted from previous studies were translated and back-translated by different translators, and the harmonized version was reviewed by experts. After expert analysis and the needed revision, the new version of the scales was pretested with a group of undergraduate students.

With the agreement of the seven higher education institutions where the study took place, and after approval from the Data Protection Officer and the Ethics Committee (71/CEUMA/2023, 13 July 2023), the survey questionnaire was pre-tested to ensure reliability and validity. The research was conducted in accordance with the ethical principles of the Declaration of Helsinki and the European and Portuguese data protection regulations. The questionnaire included the necessary information for informed consent and ensured anonymity of participants. Each participant provided informed consent online when filling out the survey. The survey was conducted in seven public Higher Education Institutions (HEIs), covering different geographical regions (north, centre, south, coastal, inland, and islands) and various types of higher education (university and polytechnic, as well as distance and face-to-face learning). Together, these institutions accounted for 20% of students who entered Portuguese higher education in 2023.

Data analysis was conducted using IBM SPSS Statistics (version 30) software. Descriptive statistics were calculated, and correlations were computed between waste literacy outcomes and the sociodemographic variables. Waste management knowledge was determined as the percentage of correct answers, waste management behaviours as the average prevalence score on a five-point scale, and the ecocentric worldview as a concordance score also on a five-point scale. Since the Kolmogorov–Smirnov and Shapiro–Wilk tests rejected a normal distribution of data, non-parametric tests, specifically the Kruskal–Wallis Test, were employed to identify significant differences in waste literacy measures between groups of participants (gender, age, scientific areas, etc.). Pairwise significant differences were identified through Post Hoc analysis with the Dunn test with Bonferroni correction. Correlation Coefficients were calculated through Spearman's test (rs), evaluated with the criteria proposed by Funder and Ozer [61] proposing that $r \leq 0.1$ indicates a small effect, $0.1 < r \leq 0.2$ a medium effect, and $0.2 < r \leq 0.3$ a large effect, revising Cohen's [62] criteria.

Cronbach's alpha (α) was calculated [63], revealing a satisfactory level of internal consistency for waste knowledge (α = 0.71) and the ecocentric worldview scale (α = 0.74), and low internal consistency of the waste management behaviours scale (α = 0.502). A factor analysis showed that the waste management behaviours scale is multidimensional, a situation that likely stems from the fact that the various waste management practices tend to have independent assumptions for their adoption [64,65]. Although the behavioural scale exhibited limited internal consistency, an overall score was retained for exploratory purposes and to facilitate comparisons across participant groups, while individual behavioural items were also examined to identify specific strengths and weaknesses. Despite the low Cronbach's alpha value, the Spearman correlation (ρ = 0.525, $p < 0.001$) between the two redundant items included in the scale shows response consistency.

## 3. Results

The sample selected for this study (n = 1506) comprises 58.6% females and has a mean age of 18.5 (SD ± 0.7) years, mostly regular (full-time dedicated) students (97.2%) (Table 1). Those aged 18 years (62.9%) ended the 12th and last grade of Portuguese compulsory education in 2023, and the remaining students at least in 2021. Considering the number of students starting higher education in Portugal in 2023 at the same age, a confidence level of 99% with a margin of error of 3% was reached.

**Table 1.** Sample characterization.

| Category | Variables | Percentage |
|---|---|---|
| Gender | Female | 60% |
| | Male | 40% |
| Age | 18 years old | 63.7% |
| | 19 years old | 26.4% |
| | 20 years old | 9.9% |
| Student's category | Regular students | 8% |
| | Working students | 2% |
| Course scientific area | Engineering & Technologies | 17.1% |
| | Social Sciences | 40.3% |
| | Natural Sciences | 17.7% |
| | Health Sciences | 16.8% |
| | Humanities & Arts | 6% |
| | Exact Sciences | 1.5% |
| | Agrarian Sciences | 0.6% |
| Student's grades in higher school | ≤12 values | 1.6% |
| | 13–14 values | 27% |
| | 15–16 values | 43.1% |
| | 17–18 values | 25.4% |
| | 19–20 values | 2.9% |
| Place where student lived as a teenager | Rural | 25.9% |
| | Semi-Urban | 25% |
| | Urban | 49.1% |

**Table 1.** *Cont.*

| Category | Variables | Percentage |
|---|---|---|
| Place where student lived in childhood | Rural | 28.5% |
| | Semi-Urban | 24.7% |
| | Urban | 46.8% |
| Father's school qualifications | Until 12th school year | 76.5% |
| | With higher education | 23.5% |
| Father's professional situation | Unemployed | 2.2% |
| | Employee | 72.5% |
| | Entrepreneur/freelancer | 21.9% |
| | Retired | 3.3% |
| Mother's school qualifications | Until 12th school year | 63.1% |
| | With higher education | 36.9% |
| Mother's professional situation | Unemployed | 7.5% |
| | Employee | 78.3% |
| | Entrepreneur/freelancer | 12.9% |
| | Retired | 1.4% |
| Number of brothers/sisters | 0 | 20.3% |
| | 1 | 54.9% |
| | 2 | 18.6% |
| | 3 | 4.2% |
| | 4 | 1.1% |
| | >4 | 0.9% |
| Scholarship | With | 39.2% |
| | Without | 60.8% |
| Participation in environmental activities along compulsory education | Never | 30.2% |
| | Rarely | 0% |
| | Sometimes | 44.3% |
| | Many times | 18% |
| | Always | 7.6% |
| Membership of environmental organizations | Yes | 4.7% |
| | No | 95.3% |

### *3.1. Waste Management Knowledge*

An average of 72% correct answers, with a standard deviation (SD) of 15%, were achieved for waste management knowledge (Table 2). Waste management knowledge with a higher performance (above 80%) includes: (a) knowing the implications of throwing litter on the ground and into the environment or flushing it down the toilet, (b) understanding what food waste is, and (c) how to sort newspapers, cans, plastic bags and glass bottles for recycling. Also, the majority (53.1%) realize that waste production increased a lot in Portugal and worldwide over the past 60 years, while 31% consider that it has only increased. In the opposite direction, most of the students did not know how to dispose of a broken mug (34.9%) or a broken glass cup (10.9%), wrongly thinking that they should be

sorted for recycling together with glass packaging, respectively. It is also worth mentioning that around 61% know what biowaste is and that composting is its most appropriate destination. Similar percentages of correct answers were found for who to sort juice or milk cartons for recycling (60%) and the definition of circular economy (63.5%). Knowledge of waste prevention approaches was found to be moderate to high, namely regarding how to contribute to a circular economy (69.6%), how to reduce food waste (74%) and how to reduce waste production (64.2%). The majority of those who do not know how to contribute to a circular economy admit to lacking this knowledge (25.2%). In addition to the students who report not knowing (2.8%), about 22% of those unfamiliar with how to reduce food waste mentioned using leftovers to feed animals or for composting. Furthermore, 26% of students confused reducing waste production with recycling and waste biodegradability.

**Table 2.** Percentage of correct answers for Waste Management Knowledge.

| **Waste Management Knowledge** | **Correct Answers (%)** |
|---|---|
| What is the most appropriate destination for newspapers or magazines? | 97.8% |
| What is the most appropriate destination for a glass bottle? | 97.7% |
| What are the implications of throwing litter on the ground and into the environment? | 95.4% |
| What are the consequences of flushing waste down the toilet? | 95.4% |
| What is the most appropriate destination for plastic bags? | 93.6% |
| What is the most appropriate destination for soft drink can? | 86.8% |
| What is Food Waste? | 80.9% |
| What is the most appropriate destination for a banana peel? | 80.9% |
| What is the most appropriate destination for an empty packet of crisps? | 80.5% |
| How can we contribute to a Circular Economy? | 69.6% |
| How can we contribute to reducing food waste? | 74% |
| How can we REDUCE waste production? | 64.2% |
| What is a circular economy? | 63.5% |
| What is the most appropriate destination for biowaste (or organic waste)? | 61.6% |
| What are biowaste (or organic waste)? | 60.6% |
| What is the most appropriate destination for juice or milk cartons (tetrapack)? | 60.2% |
| Over the last 60 years, how evolved waste production in Portugal and around the world? | 53.1% |
| What is the most appropriate destination for a broken mug? | 34.9% |
| What is the most appropriate destination for a broken glass cup? | 10.9% |
| **Average (SD)** | **72% (± 15%)** |

Note. SD-Standard Deviation.

### *3.2. Waste Management Behaviours*

Adequate waste management behaviours have an average score of 4.1, a value meaning a 'many times' behaviour (Table 3). Considerable variability was observed across distinct behaviours, suggesting that some waste-related practices are more deeply embedded in students' routines than others. Not littering or flushing waste, alongside saving leftover food and drinking water from reusable bottles, are highly prevalent practices. Scoring above the scale's midpoint were waste sorting for recycling (3.95) and advocacy against littering or failing to recycle (3.89). Conversely, the lowest scores were found for sorting bio-waste for composting or other forms of recovery (2.61).

**Table 3.** Average scores of waste management behaviours.

| Waste Management Behaviours | Average Score [a] (SD) |
|---|---|
| I do not flush wet wipes, food, sanitary pads, condoms, dental floss, or small packages down the toilet. | 4.81 (0.68) |
| When I have leftover food, I save it for the next meal. | 4.75 (0.78) |
| I do not throw litter on the ground. | 4.74 (0.54) |
| I use a reusable bottle/flask for drinking water. | 4.10 (1.5) |
| I sort paper, glass, and plastic packaging for recycling, placing them in different containers at the recycling point. | 3.95 (1.5) |
| I call out other people when they litter or fail to recycle. | 3.89 (1.79) |
| I do not put recyclable materials (glass/plastic/paper) in the general waste bin. | 3.82 (1.4) |
| I separate bio-waste (organic waste) for composting, animal feed, or other forms of recovery. | 2.61 (1.75) |
| **Average** | **4.1 (0.61)** |

Note. [a] scale: 1 = never to 5 = always; SD = Standard Deviation.

### *3.3. Ecocentric Worldview*

On average, students align with an ecocentric worldview (4.1) (Table 4). Regarding each scale item, the highest levels of concordance were found for: "Humans are severely abusing the environment" (4.40) and "Plants and animals have as much right as humans to exist" (4.36). Only two items showed a score of concordance below 4: "The Earth is like a spaceship with very limited room and resources" and "We are approaching the limit of the number of people the Earth can support" (Table 4).

**Table 4.** Overall and by item NEP Ecocentric Worldview scores.

| NEP Ecocentric Worldview Scale | Score [a] (SD) |
|---|---|
| Humans are severely abusing the environment. | 4.40 (0.73) |
| Plants and animals have as much right as humans to exist. | 4.36 (0.91) |
| If things continue on their present course, we will soon experience a major ecological catastrophe. | 4.29 (0.78) |
| Despite our special abilities, humans are still subject to the laws of nature. | 4.26 (0.71) |
| When humans interfere with nature, it often produces disastrous consequences. | 4.07 (0.82) |
| The balance of nature is very delicate and easily upset. | 4.03 (0.835) |
| We are approaching the limit of the number of people the Earth can support. | 3.89 (0.96) |
| The Earth is like a spaceship with very limited room and resources. | 3.55 (1.02) |
| **Average** | **4.10 (0.50)** |

Note. [a] scale: 1 = strongly disagree to 5 = strongly agree; SD = Standard Deviation.

### *3.4. The Influence of Variables*

Younger students, whose parents have higher education, being an only child or having just one brother/sister, are socio-demographic characteristics that distinguish students with higher waste management knowledge. Also, being enrolled in natural or health sciences and having better grades exhibited statistically significantly better performance in waste management knowledge (Table 5).

Regarding waste management practices, significantly higher prevalence rates were observed among the groups of students characterized by being female, younger, having highly educated fathers, achieving better grades, participating more frequently in environmental activities during compulsory schooling, and holding membership in environmental organizations (Table 6).

**Table 5.** Influencing factors of waste management knowledge.

| | | | Waste Management Knowledge | |
|---|---|---|---|---|
| | | | **Average % Correct Answers (SD)** | **Sig.** |
| Socio-demographic variables | | | | |
| Gender | Female | | 72.1% (13.5%) | $p \geq 0.198$ |
| | Male | | 71.8% (16.9%) | |
| Age | 18 years | | 73% [a,b] (15%) | [a] $p = 0.001$ * [b] $p = 0.003$ * |
| | 19 years | | 70.5% [a] (13.7%) | |
| | 20 years | | 69% [b] (17%) | |
| Place where the student lived | in childhood | Rural | 72.2% (14.3%) | $p \geq 0.707$ |
| | | Semi-Urban | 72.9% (16.2%) | |
| | | Urban | 71.3% (14.9%) | |
| | as a teenager | Rural | 72.4% (14.1%) | $p \geq 0.198$ |
| | | Semi-Urban | 73.1% (16.5%) | |
| | | Urban | 71.2% (14.7%) | |
| Parents' school degree | Father | Until 12º school year | 71.6% (14.4%) | $p = 0.002$ * |
| | | With higher education | 74.2% (15.6%) | |
| | Mother | Until 12º school year | 71.4% (13.9%) | $p = 0.007$ * |
| | | With higher education | 73.4% (16%) | |
| Parents' professional situation | Father | Unemployed | 66.5% (17.8%) | $p = 1$ |
| | | Employee | 72.1% (14.5%) | |
| | | Entrepreneur/freelancer | 72.6% (15.2%) | |
| | | Retired | 72.8% (17.2%) | |
| | Mother | Unemployed | 73.4% (18.4%) | $p \geq 0.613$ |
| | | Employee | 72.2% (14.4%) | |
| | | Entrepreneur/freelancer | 70.5% (15.7%) | |
| | | Retired | 74.3% (13.1%) | |
| Number of brothers/sisters | 0 | | 70.4% [a] (13.5%) | [a] $p = 0.023$ * |
| | 1 | | 73% [a] (14.8%) | |
| | 2 | | 71.1% (16%) | |
| | 3 | | 73.5% (16.4%) | |
| | 4 | | 63.5% (14%) | |
| | >4 | | 66.4% (19.2%) | |
| Student-related variables | | | | |
| Student's category | Regular students | | 72.02% (14.9%) | $p = 1$ |
| | Working students | | 69.2% (18.6%) | |
| Course scientific area | Engineering & Technologies | | 71.5% (18.4%) | [a] $p = 0.000$ * [b] $p = 0.001$ * |
| | Social Sciences | | 69.6% [a,b] (14.5%) | |
| | Natural Sciences | | 75.1% [a] (14.4%) | |
| | Health Sciences | | 74.6% [b] (12.1%) | |
| | Humanities & Arts | | 72.1% (14%) | |
| | Exact Sciences | | 69.2% (13.1%) | |
| | Agronomic Sciences | | 73.03% (12.1%) | |

**Table 5.** *Cont.*

| | | Waste Management Knowledge | |
|---|---|---|---|
| | | **Average % Correct Answers (SD)** | **Sig.** |
| Students' grades in high school | ≤12 values | 63.6% [a,b] (17.9%) | [a,f] $p = 0.003$ * [b] $p = 0.001$ * [c,d,e] $p = 0.00$ * |
| | 13–14 values | 69.8% [c,d] (14.3%) | |
| | 15–16 values | 70.9% [a,e,f] (15.2%) | |
| | 17–18 values | 76.6% [a,c,e] (12.9%) | |
| | 19–20 values | 79.4% [b,d,f] (11.9%) | |
| Scholarship | With | 72.2% (15%) | $p = 1$ |
| | Without | 72.2% (14.7%) | |
| Participation in environmental activities along compulsory education | Never | 69.8% (15.9%) | $p \geq 0.690$ |
| | Rarely | - | |
| | Sometimes | 72.5% (14.2%) | |
| | Many times | 73.4% (15%) | |
| | Always | 73.7% (14.6%) | |
| Others variables | | | |
| Membership of environmental organizations | Yes | 76.0% (11.3%) | $p = 0.101$ |
| | No | 71.8% (15.1%) | |

Note. SD-Standard Deviation. * Significant for $p < 0.05$, with Bonferroni correction. [a–f] Pairs of values with statistically significant differences.

**Table 6.** Influencing factors of waste management behaviours.

| | | | Waste Management Behaviours | |
|---|---|---|---|---|
| | | | **Average Scores (SD)** | **Sig.** |
| Socio-demographic variables | | | | |
| Gender | | Female | 4.2 (0.57) | $p < 0.001$ * |
| | | Male | 3.9 (0.65) | |
| Age | | 18 years | 4.12 [a] (0.60) | [b] $p = 0.037$ * |
| | | 19 years | 4.04 [a] (0.63) | |
| | | 20 years | 4.02 (0.66) | |
| Place where the student lived | in childhood | Rural | 4.12 (0.63) | $p \geq 0.185$ |
| | | Semi-Urban | 4.13 (0.63) | |
| | | Urban | 4.05 (0.60) | |
| | as a teenager | Rural | 4.11 (0.65) | $p \geq 0.568$ |
| | | Semi-Urban | 4.13 (0.63) | |
| | | Urban | 4.06 (0.59) | |
| Parents' school degree | Father | Until 12º school year | 4.07 (0.63) | $p = 0.004$ * |
| | | With higher education | 4.21(0.57) | |
| | Mother | Until 12º school year | 4.05 (0.63) | $p = 0.000$ * |
| | | With higher education | 4.2 (0.58) | |

**Table 6.** *Cont.*

| | | | Waste Management Behaviours | |
|---|---|---|---|---|
| | | | **Average Scores (SD)** | **Sig.** |
| Parents' professional situation | Father | Unemployed | 4.06 (0.63) | $p = 1$ |
| | | Employee | 4.10 (0.62) | |
| | | Entrepreneur/freelancer | 4.07 (0.59) | |
| | | Retired | 4.13 (0.58) | |
| | Mother | Unemployed | 4.03 (0.71) | $p = 1$ |
| | | Employee | 4.10 (0.60) | |
| | | Entrepreneur/freelancer | 4.17 (0.57) | |
| | | Retired | 4.16 (0.70) | |
| Number of brothers/sisters | | 0 | 4.06 (0.64) | $p = 1$ |
| | | 1 | 4.1 (0.59) | |
| | | 2 | 4.1 (0.65) | |
| | | 3 | 4.04 (0.70) | |
| | | 4 | 4.0 (0.58) | |
| | | >4 | 4.3 (0.67) | |
| Student-related variables | | | | |
| Student's category | | Regular students | 4.1 (0.61) | $p = 1$ |
| | | Working students | 3.9 (0.74) | |
| Course scientific area | | Engineering & Technologies | 4.02(0.63) | $p \geq 0.190$ |
| | | Social Sciences | 4.08 (0.64) | |
| | | Natural Sciences | 4.18 (0.57) | |
| | | Health Sciences | 4.07 (0.58) | |
| | | Humanities & Arts | 4.16 (0.6) | |
| | | Exact Sciences | 4.1 (0.67) | |
| | | Agronomic Sciences | 4.09 (0.62) | |
| Students' grades in high school | | ≤12 values | 3.84 (0.61) | [a] $p = 0.038$ * [b] $p = 0.049$ * |
| | | 13–14 values | 4.05 [a] (0.63) | |
| | | 15–16 values | 4.07 [b] (0.62) | |
| | | 17–18 values | 4.19 [a,b] (0.59) | |
| | | 19–20 values | 4.16 (0.61) | |
| Scholarship | | With | 4.08 (0.62) | $p = 1$ |
| | | Without | 4.09 (0.61) | |
| Participation in environmental activities along compulsory education | | Never | 3.93 [a,b,c] (0.63) | [a–c] $p = 0.00$ * [d] $p = 0.019$ * |
| | | Rarely | - | |
| | | Sometimes | 4.12 [a,d] (0.58) | |
| | | Many times | 4.18 [b,] (0.64) | |
| | | Always | 4.30 [c,d] (0.56) | |
| Others variables | | | | |
| Membership of environmental organizations | | Yes | 4.25 (0.58) | $p = 0.032$ * |
| | | No | 4.08 (0.62) | |

Note. SD-Standard Deviation. * Significant for $p < 0.05$, with Bonferroni correction. [a–d] Pairs of values with statistically significant differences.

A significantly higher ecocentric attitude was found among female students, those enrolled in the social, natural, or health sciences, and students with better grades or a higher economic status (i.e., not receiving a scholarship). Furthermore, higher endorsement was associated with more frequent participation in environmental activities during compulsory schooling and membership in environmental organizations (Table 7).

**Table 7.** Influencing factors of ecocentric worldview (NEP) scores.

| | | | Ecocentric Worldview | |
|---|---|---|---|---|
| | | | **Average Scores (SD)** | **Sig.** |
| Socio-demographic variables | | | | |
| Gender | | Female | 4.2 (0.42) | $p < 0.001$ * |
| | | Male | 4.0 (0.54) | |
| Age | | 18 years | 4.12 (0.47) | $p = 1$ |
| | | 19 years | 4.10 (0.53) | |
| | | 20 years | 4.09 (0.56) | |
| Place where the student lived | in childhood | Rural | 4.11 (0.47) | $p = 1$ |
| | | Semi-Urban | 4.09 (0.53) | |
| | | Urban | 4.12 (0.50) | |
| | as a teenager | Rural | 4.12 (0.47) | $p = 1$ |
| | | Semi-Urban | 4.09 (0.53) | |
| | | Urban | 4.11 (0.49) | |
| Parents' school degree | Father | Until 12º school year | 4.12 (0.47) | $p = 1$ |
| | | With higher education | 4.08 (0.56) | |
| | Mother | Until 12º school year | 4.13 (0.45) | $p = 1$ |
| | | With higher education | 4.08 (0.54) | |
| Parents' professional situation | Father | Unemployed | 4.04 (0.53) | $p = 1$ |
| | | Employee | 4.13 (0.46) | |
| | | Entrepreneur/freelancer | 4.07 (0.56) | |
| | | Retired | 4.13 (0.46) | |
| | Mother | Unemployed | 4.16 (0.47) | $p = 1$ |
| | | Employee | 4.12 (0.48) | |
| | | Entrepreneur/freelancer | 4.07 (0.58) | |
| | | Retired | 4.18 (0.57) | |
| Number of brothers/sisters | | 0 | 4.12 (0.42) | $p = 1$ |
| | | 1 | 4.12 (0.49) | |
| | | 2 | 4.10 (0.56) | |
| | | 3 | 4.02 (0.53) | |
| | | 4 | 4.09 (0.58) | |
| | | >4 | 4.00 (0.40) | |
| Student-related variables | | | | |
| Student's category | | Regular students | 4.11 (0.49) | $p = 0.794$ |
| | | Working students | 4.01 (0.6) | |

**Table 7.** *Cont.*

| | | Ecocentric Worldview | |
|---|---|---|---|
| | | **Average Scores (SD)** | **Sig.** |
| Course scientific area | Engineering & Technologies | 3.97 [a,b,c] (0.55) | [a] $p = 0.002$ * [b] $p = 0.006$ * [c] $p = 0.001$ * |
| | Social Sciences | 4.13 [a] (0.47) | |
| | Natural Sciences | 4.13 [b] (0.56) | |
| | Health Sciences | 4.18 [c] (0.40) | |
| | Humanities & Arts | 4.14 (0.47) | |
| | Exact Sciences | 3.95 (0.41) | |
| | Agronomic Sciences | 3.91 (0.55) | |
| Students' grades in high school | ≤12 values | 3.99 (0.37) | [a] $p = 0.026$ * |
| | 13–14 values | 4.05 [a] (0.48) | |
| | 15–16 values | 4.12 (0.53) | |
| | 17–18 values | 4.16 (0.44)) | |
| | 19–20 values | 4.30 [a] (0.33) | |
| Scholarship | With | 4.08 (0.52) | $p = 0.044$ * |
| | Without | 4.16 (0.46) | |
| Participation in environmental activities along compulsory education | Never | 4.04 [a,b] (0.5) | [a] $p = 0.001$ * [b] $p = 0.043$ * |
| | Rarely | - | |
| | Sometimes | 4.12 (0.51) | |
| | Many times | 4.18 [a] (0.44) | |
| | Always | 4.18 [b] (0.50) | |
| Others variables | | | |
| Membership of environmental organizations | Yes | 4.30 (0.44) | $p = 0.000$ * |
| | No | 4.10 (0.49) | |

Note. SD-Standard Deviation. * Significant for $p < 0.05$, with Bonferroni correction. [a–c] Pairs of values with statistically significant differences.

The correlation between socio-demographic variables and waste management practices and knowledge had a significant medium effect size ($\rho < 0.3$; $p < 0.05$). Also, ecocentric attitude correlates significantly with average scores for waste knowledge ($\rho = 0.164$, $p < 0.001$) and with waste practices ($\rho = 0.186$, $p < 0.001$), with a medium effect. Similarly, waste knowledge correlates with a medium effect with waste practices ($\rho = 0.184$, $p < 0.001$).

## 4. Discussion

The present study extends previous research by simultaneously examining waste-related knowledge, self-reported behaviours, and environmental worldview in a large and nationally representative sample of Portuguese first-year university students. This comprehensive approach provides evidence that may support the development of targeted environmental education policies and interventions.

After compulsory schooling, students in Portugal showed, on average, good levels of knowledge and practices on waste management, and a sound concordance with an ecocen-

tric worldview. Knowledge shortcomings on waste management were clearly identified, demanding a reinforcement of the clarification on how to sort specific items for recycling, such as glass, biowastes, and milk cartons, as well as understanding of the Circular Economy concept and the fact that waste production has grown over time. The difficulties identified regarding items such as broken glassware and mugs suggest that students may associate material appearance with recycling categories rather than understanding the technical criteria underlying waste-sorting systems. This distinction is relevant because effective recycling depends not only on general awareness but also on accurate knowledge of local waste management procedures [25]. Despite a large majority being well oriented in knowledge of waste prevention approaches, its relevance for responsible decision-making competence development demands an effort to improve the results found. As such, enlightening students' doubts on how to contribute to a circular economy and demystifying the confusion between reducing and recycling is a priority.

As school grades are positively associated with better knowledge of waste management, the data suggest that, as found by others [66,67], school performance is relevant in establishing students' waste management knowledge. Supporting this finding is also the better performance among younger students, who completed mandatory schooling on the regular timeline and have stronger academic records. A curricular track in natural and health sciences showing higher levels of waste management knowledge could be related to the fact that these students had followed Science and Technology secondary school programmes, in which the mandatory subjects that address environmental topics are included [68]. Despite the absence of association between waste literacy and the students' socioeconomic status (considering whether they are, or not, scholarship recipients), the result that evidences the positive relation between better waste management knowledge and fathers' higher level of education could be related to the socioeconomic factors that have long been proven to influence students' performance [69]. Thus, social, economic, and environmental dimensions must be interconnected, highlighting the importance of sustainable development [27].

Although participants demonstrated reasonable factual knowledge about waste management, their responses to questions related to waste prevention, circular economy practices, and food waste reduction suggest more limited action-oriented knowledge. This distinction is important because environmental literacy requires not only understanding environmental concepts but also being able to translate that knowledge into informed and effective behavioural choices.

Results on waste management practices suggest that the biggest margin for improvement is related to sorting waste for recycling, particularly biowaste, and advocating against littering and not sorting. The correlation between waste knowledge and practices did not reveal a large effect size, suggesting the influence of the above-mentioned knowledge gaps, which may contribute to limiting the proper adoption of waste management behaviours [70]. Nevertheless, results indicate that waste management practices are boosted mostly by being involved in practical activities and committed to environmental organizations, along with socioeconomic and cultural factors, such as gender, school performance (grades) and parents' education. Therefore, mandatory schooling in Portugal should put a special effort into promoting students' mobilization to achieve more demanding goals on waste recycling practices. Collaborative and inclusive learning environments that promote participation from students with diverse genders, backgrounds and perspectives may help strengthen engagement in waste management practices.

The results of the present study strengthened the findings from the previously published studies with the same students' profile [36,37,39]. And contrast with the Desa and colleagues [40] study results with Malaysia' students, by evidencing students' higher waste

knowledge. Also, the present students' sample exhibited much better results for waste management knowledge and practices than a higher education students' sample from China, in a study with a high proportion of participants aged 18 to 20 years (66%) and freshmen (42.5%) [42]. Conversely, a previous study with students from a single Portuguese university showed higher levels of waste knowledge than the present study, but lower levels for practices [45]. In addition to addressing the reported worldwide scarcity of studies on waste literacy after compulsory education, the present study goes beyond merely characterizing knowledge and practices in waste management. It significantly expands the diversity of sociodemographic variables evaluated, thereby identifying the path toward more effective environmental education.

Despite students' high levels of knowledge and practices on waste management found in this study, results should be interpreted as the best scenario after the end of compulsory schooling in Portugal. The present study only sampled students who continued their studies in higher education, which tend to be the ones with a better school performance, therefore with significantly higher levels of waste literacy. Additionally, waste management practices were assessed through self-reported measures, which may be affected by social desirability bias and may therefore overestimate the prevalence of environmentally responsible behaviours. Furthermore, the cross-sectional design of the study did not allow causal inferences regarding the relationships observed between knowledge, attitudes and waste management practices.

The variability between behavioural domains highlights that waste literacy does not translate uniformly across all practices. Similar to findings from other contexts, recycling-related behaviours appear more consolidated than behaviours involving waste prevention or organic waste recovery [40,43].

The Theory of Planned Behaviour (TPB) posits that an individual is likely to engage in a behaviour if they are motivated to do so. This motivation is highly influenced by attitudes, subjective norms, perceived behavioural control, and several external variables (such as contextual, socioeconomic, and cultural factors) [49–53]. Despite present study was not designed to evaluate it, results are aligned with TPB, considering: (i) that pro-environmental attitude is supportive to engage in waste management behaviours; and (ii) the positive correlation found with waste management practices, envisioning waste management knowledge as a prerequisite to perceive behavioural control. However, although an ecocentric worldview showed a positive and significant correlation with waste management knowledge and practices, attitudes towards waste management could provide better insights to explain the adoption of waste management practices according to the TPB [49]. Thus, future studies may benefit from incorporating waste-specific attitudinal measures to better understand the drivers of waste-related behaviour. The positive association found with several contextual and sociodemographic variables is also acknowledged by the TPB, giving a wider vision on the waste management behaviour change [51–53].

Overall, the findings indicate that improving waste literacy requires more than increasing factual knowledge. Educational strategies should also foster critical thinking, decision-making skills, and opportunities for students to apply sustainable practices in authentic contexts. Such approaches may contribute to narrowing the gap between environmental awareness and environmentally responsible behaviour. Another frequently found gap, the green gender gap [71], which was also confirmed in the present study, should be considered in future approaches to promoting waste literacy. Despite the lack of a clear theoretical explanation [71], the systematically better performance of females should be used as leverage to enhance waste literacy, namely through gender-balanced, collaborative, and inclusive learning environments.

It should be noted that the present study did not assess the causal direction between environmental knowledge and attitudes, nor did it examine students' prior environmental interests or value orientations as determinants of their choice of academic field. Therefore, although students from Natural Sciences programmes exhibited higher levels of environmental knowledge, these findings should not be interpreted as evidence that the curriculum alone explains these differences. Future studies should further explore relationships between environmental literacy outcomes and other variables, such as pre-existing environmental interests or ecocentric value orientations and students' educational choices, using appropriate research designs.

In conclusion, despite not being proven to be a total or partial result of compulsory education and neither addressing its possible negative influences, students starting higher education in Portugal demonstrate generally favourable levels of waste-related knowledge and practices. The main flaws in knowledge and behaviours towards waste management are identified, enabling environmental education to be directed more specifically towards those aspects that need to evolve. The most prominent gaps identified concern biowaste sorting, the disposal of non-packaging glass items, understanding of circular economy principles, awareness of long-term increases in waste generation, and proactive intervention against improper waste-disposal behaviours. Additionally, the study confirms that environmental education towards waste literacy needs to adopt more practical and collective approaches, empowering students and communities through gender-balanced social groups in solving the real waste management limitations. Furthermore, adopting an integrative collaborative approach regarding the socio-economic characteristics of the students reinforces that waste literacy is embedded in societal development- one that encompasses environmental, social, and economic dimensions. Particularly to promote knowledge, waste topics also need to be made more attractive to those focused on the humanities or social sciences, which can be done by including them through history, the literature, and arts programmes [72,73]. In summary, to improve waste literacy, our study supports the conclusion that mandatory schooling needs to adopt a more dialogic and transformative learning approach [74,75]. This transformative learning should focus on interdisciplinary, multi- and integrated approaches in which waste is seen as a resource, following a circular-thinking model [76]. Also, more proactive and less reactive approaches should be taught to the students, following a better connection, respect, and care for nature that could co-develop responsible environmental actions [77].

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/recycling11080144/s1, Waste Literacy Survey.

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