environments

MDPI

Article

Evaluating Students' Literacy on Safe Pesticide Use and Sustainable Resource Management: A Case Study in Alentejo, Portugal

Cristina Coelho [1], M. Rosário Martins [2,3,4] and Henrique Vicente [5,6,7,*]

[1] IIFA—Instituto de Investigação e Formação Avançada, Universidade de Évora, Palácio do Vimioso, Largo Marquês de Marialva, Apartado 94, 7002-554 Évora, Portugal; cristina.argente@gmail.com
[2] Departamento de Ciências Médicas e da Saúde, Escola de Saúde e Desenvolvimento Humano, Universidade de Évora, Rua Romão Ramalho, 59, 7000-671 Évora, Portugal; mrm@uevora.pt
[3] Laboratório HERCULES—Herança Cultural, Estudos e Salvaguarda, Universidade de Évora, Largo Marquês de Marialva, Apartado 94, 7002-554 Évora, Portugal
[4] IN2PAST—Associate Laboratory for Research and Innovation in Heritage, Arts, Sustainability and Territory, Universidade de Évora, Largo Marquês de Marialva, Apartado 94, 7002-554 Évora, Portugal
[5] Departamento de Química e Bioquímica, Escola de Ciências e Tecnologia, Universidade de Évora, Rua Romão Ramalho, 59, 7000-671 Évora, Portugal
[6] LAQV REQUIMTE—Laboratório Associado para a Química Verde da Rede de Química e Tecnologia, Universidade de Évora, Rua Romão Ramalho, 59, 7000-671 Évora, Portugal
[7] LASI—Laboratório Associado de Sistemas Inteligentes, Centro Algoritmi, Universidade do Minho, Campus de Gualtar, Rua da Universidade, 4710-057 Braga, Portugal
* Correspondence: hvicente@uevora.pt

Abstract: The intensive use of pesticides contaminates soil and water, raising the risk of diseases like cancer and hormonal/neurological disorders. The continuous exposure to pesticides through water and food is concerning. Therefore, raising awareness about biological pest control is essential to reduce the harmful impact of pesticides on food and the environment. This study evaluates students' literacy on pesticide use and its implications, focusing on three topics, pesticide use, disease prevention, and sustainability and health promotion. Thus, a questionnaire was drawn up and distributed to students of both genders, aged between 12 and 16 years old, from Alentejo (Portugal). The students were asked to indicate their agreement grade with statements related to key themes, such as pesticide use and consumer attitudes, healthy practices and disease prevention, and sustainability and health promotion. The cohort includes 1051 students, and the results suggest that environmental education and student awareness are crucial for promoting sustainable water resources and minimizing exposure to environmental and food pesticides. This study presents an Artificial Neural Network model, with its accuracy surpassing 90%, to assess students' literacy on pesticide use and its implications. It also proposes a new approach to evaluate their potential for improvement, which is essential for developing educational strategies on health and the environmental impacts.

Keywords: environmental literacy; pesticide contamination; sustainable water resources; artificial neural networks

check for updates

Citation: Coelho, C.; Martins, M.R.; Vicente, H. Evaluating Students' Literacy on Safe Pesticide Use and Sustainable Resource Management: A Case Study in Alentejo, Portugal. *Environments* **2024**, *11*, 278. https://doi.org/10.3390/environments11120278

Received: 4 November 2024
Revised: 26 November 2024
Accepted: 2 December 2024
Published: 4 December 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The use of pesticides, including herbicides, fungicides, insecticides, and other chemical agents, has long been a central strategy in modern agriculture to increase crop yields and improve food quality. These substances effectively target and eliminate weeds, fungi, insects, and other pests that threaten plant health and productivity. As a result, pesticide use has contributed significantly to boosting food production and meeting the growing global demand for food [1,2]. However, despite these benefits, the widespread and intensive application of pesticides presents serious risks, particularly in terms of environmental contamination and public health concerns, that should be considered [2,3]. There is a growing consensus on the need to reduce reliance on chemical pesticides and shift toward

more sustainable alternatives. To support this transition, it is essential to raise awareness among young people about the benefits of biological pest control and other alternative pest management strategies [2,3]. In this context, environmental literacy plays a key role in promoting sustainable agricultural practices. Recognizing the importance of educating students about pesticide use and its implications is crucial for raising awareness of the health risks and encouraging responsible actions that promote better health outcomes. As the future generation of decision-makers, students' understanding of these issues can help shape effective, health-centered policies. Thus, this study aims to assess students' literacy on pesticide use and its implications, focusing on pesticide use, disease prevention, and sustainability and health promotion. Additionally, the research will explore how artificial neural networks can be used to model and predict students' literacy levels.

2. Literature Review

2.1. A Brief Overview of Pesticide Effects on Environment and Health

One of the major environmental challenges associated with pesticide use is their persistence in ecosystems. Many pesticides are designed to be chemically stable and resistant to degradation, which allows them to remain active in the environment long after their initial application. This low biodegradability, combined with factors such as leaching and runoff, results in the contamination of soils, water bodies, and aquifers. Pesticide residues can travel through the soil and seep into groundwater, affecting drinking water sources and threatening aquatic ecosystems. Additionally, the accumulation of these chemicals in the environment can lead to the disruption of biodiversity, as non-target species, such as beneficial insects, birds, and aquatic organisms, may be adversely affected [4].

The health risks associated with pesticide exposure are a growing concern. The results of a risk assessment for pesticide residues in various types of food by the relevant organizations showed that some pesticides pose a dietary intake risk [5]. Pesticides can cause several adverse effects on health, from acute intoxication to chronic diseases that include several cancers (breast, brain, prostate bladder, or colon cancers), leukemia and non-Hodgkin lymphoma, neurological conditions like Alzheimer's disease and Parkinson's disease, hormonal imbalances (endocrine disruption), diabetes, reproductive problems, birth defects, and disorders in children [6]. Considering these risks, there is an urgent need to reduce the reliance on chemical pesticides in agriculture and promote more sustainable alternatives. Biological pest control, which involves the use of natural predators, parasites, and pathogens to manage pest populations, offers a promising solution [7]. In addition to being environmentally friendly, biological pest control is often more sustainable in the long term. Unlike chemical pesticides, which can lead to pest resistance over time, biological agents tend to be self-regulating and adaptive to changes in pest populations.

Integrating biological control methods with other agricultural practices, such as crop rotation, habitat management, and organic farming, can help create resilient agricultural systems that are less dependent on chemical inputs [8–10]. To effectively reduce the negative impact of pesticides on food and the environment, it is crucial to raise awareness among farmers, policymakers, and consumers about the benefits of biological pest control [11]. Education and outreach efforts should focus on providing farmers with the knowledge and tools they need to implement these practices successfully [12,13]. Governments and agricultural organizations also play a key role by offering incentives, subsidies, and technical support for farmers transitioning to more sustainable pest management strategies [7,13–15].

Additionally, consumers can support this shift by choosing organically grown products, advocating for stricter pesticide regulations, and encouraging investment in the research and development of alternative pest control technologies [16–18]. Indeed, consumer awareness of pesticide residues in food is increasingly important as individuals become more informed about the potential health risks associated with these chemicals. This awareness differs significantly between conventional and organic consumers. Conventional consumers often underestimate the presence of pesticide residues and hold

misconceptions about their safety, believing that washing fruits and vegetables thoroughly can eliminate harmful residues. In contrast, organic consumers generally have a stronger aversion to pesticide use, perceiving organic products as healthier and safer alternatives due to their belief that organic farming practices minimize health risks [16–18].

2.2. A Brief Overview of Environmental Literacy

Historically, the term literacy referred to basic reading and writing skills. Though initially conceived as a broad concept, literacy has progressively been applied to specific fields like science and technology, politics, healthcare, environmental issues, and information technology. Over the years, environmental literacy has undergone changes in definition and has been discussed by various specialists. Roth [19] suggests that this idea includes elements such as a heightened environmental awareness, a deep insight into resolving ecological problems, values that favor sustainability, a strong drive to defend the environment, the relevant skills to ensure environmental safety, and a willingness to participate in eco-friendly initiatives. The concept of environmental literacy, as evidenced by Hollweg et al. [20], blends environmental knowledge, attitudes, motivations, cognitive skills, abilities, and confidence such that it enables individuals to make well-informed decisions in environmental contexts. Those who exhibit a high level of environmental literacy are prepared to take actions that enhance the well-being of individuals, communities, and ecosystems, while actively engaging in civic life. The successful development of this literacy is largely dependent on the quality of environmental education programs [21,22].

Studies conducted across different regions of the world have examined environmental literacy using various population samples, including middle school students [23–25], university students [26,27], and the general population [28,29]. Nevertheless, these studies focused on environmental literacy as a whole rather than on specific themes. Additionally, they emphasized assessing public attitudes and behaviors, particularly the link between environmental literacy, healthy ways of life, and overall well-being.

2.3. A Brief Overview of Artificial Neural Networks and Their Applications

Drawing from the brain's learning methods, artificial neural networks (ANNs) use a system of interlinked neurons to replicate cognitive functions. A significant strength of ANNs lies in their proficiency at addressing complicated challenges through example-based learning, rather than requiring a comprehensive understanding of the underlying function or mechanism involved [30,31]. The simplest variant of an ANN is the multilayer perceptron, composed of a single input layer and one output layer, which can include one or more hidden layers, operating without feedback pathways. This ANN variant processes information in a forward direction through interconnected nodes, with each layer receiving input from its predecessor. The sigmoid function is widely recognized as the primary activation function, adjusting the input features nonlinearly to yield outputs [30,31].

Backpropagation is the leading training algorithm for a multilayer perceptron [30,31] and consists of two phases, forward propagation and backward propagation. In the forward phase, the data flow through the interconnected hidden layers with random weights to produce the final output. In the backward phase, the computed error, which arises from the difference between the actual and desired output values, is transmitted back through the network to make the necessary weight adjustments [32]. In the backpropagation algorithm, two parameters, the momentum coefficient and the learning rate, govern its operation, with each parameter limited to a range between 0 and 1. The momentum coefficient influences the direction of weight changes, promoting stability, while the learning rate controls the extent of these changes in each iteration [32].

Acting as flexible modeling tools, ANNs are capable of learning and representing complex patterns in data across different fields. They efficiently handle diverse data types like images, text, and numbers and can be adapted to solve a variety of challenges, including classification, prediction, or pattern recognition through modifications to their architecture and training methods [30,31]. To use ANNs effectively across different contexts, the data and problem

must belong to the same domain or exhibit the relevant underlying patterns. An ANN that has been trained on a specific problem cannot be applied directly in a completely different context, since an ANN captures patterns based on the training data. Indeed, training with domain-specific data is essential to accurately capture the patterns and relationships, leading to reliable and useful predictions. Their flexibility allows for use in various scientific and practical domains, including finance [33,34], healthcare and medicine [35–37], manufacturing and production [38,39], and environmental analysis [40–43], among others. The robustness of ANNs allows them to effectively process data that are ambiguous, incomplete, or uncertain [31]. Advanced ANN frameworks, such as deep learning, seen as a refined version of classic ANNs, paired with hybrid models that incorporate multiple computational intelligence methods, demonstrate notable resilience to such datasets, with a minimal impact on performance [44,45].

3. Materials and Methods

In this section, the research structure is reviewed, including the study design, methods of data collection, sample attributes, and analytical techniques. The ethical considerations taken during this study are also discussed.

3.1. Study Design

Although the topic of pesticides and toxicity is not directly covered in class, it is addressed indirectly in some subjects throughout the study program and potentially in the learning experiences within non-formal contexts. The object of this study is to evaluate students' literacy regarding the use of pesticides and their implications for disease prevention, and sustainability/health promotion. The research questions addressed are as follows:

- What are the students' attitudes regarding the use of pesticides in agricultural practices?
- What is the students' literacy concerning safe pesticide use and sustainable resource management?

The questionnaire involved three sections (pesticide use and consumer attitudes; healthy practices and disease prevention; and sustainability and health promotion) to apply the procedures indicated by Fernandes et al. [46] for transforming qualitative responses into quantitative data. Additional details are presented in the next subsections.

3.2. Data Collection

To achieve the outlined goals, we relied on an efficient and multifaceted tool for data collection, ensuring usability across different geographic locations and timely execution. After a detailed analysis of the available methods, the questionnaire survey emerged as the preferred choice due to its user-friendly nature and flexibility [47,48]. Although this strategy may sacrifice nuanced understanding, it prioritizes speed, uniformity, and confidentiality. Conversely, approaches like personal interviews, collaborative sessions, observational studies, controlled trials, or detailed case reviews can offer a deeper understanding but are generally costly, susceptible to partiality, and have a limited applicability across larger populations [49,50]. Additionally, its organized structure facilitates the seamless conversion of qualitative data into quantitative outcomes.

To tackle the research questions and objectives outlined earlier, a customized questionnaire was developed. It is organized into two main segments. The first segment collects socio-demographic data, including gender, age, grade, and municipality, facilitating the analysis of the differences among the students. The second segment features a series of statements (Table 1) that focus on the study's key themes, such as pesticide use and consumer attitudes, healthy practices and disease prevention, and sustainability and health promotion. Additionally, the data from the second segment will be utilized to construct a predictive model using ANNs, designed to identify the factors impacting students' literacy on safe pesticide use and sustainable resource management and to provide a framework for further improvements. In contrast to the descriptive responses utilized in the former segment, the second one uses a five-point Likert scale (strongly agree, agree, disagree, strongly disagree, and I don't know).

Table 1. Key themes and statements presented in the second segment of the questionnaire.

Key Themes	Statements	
Pesticide Use and Consumer Attitudes	S1	Pesticides used in agriculture can leave residual amounts on food and water consumed.
	S2	The use of pesticides in agriculture is not necessary to ensure efficient food production.
	S3	Before buying food, I read the labels or tags on the packaging to determine if the food is organic.
	S4	Organic food (without pesticide use) is healthier than other food.
	S5	I am willing to pay a higher price for organic food.
	S6	Current regulations on pesticide use are enough to ensure the safety of food and drinking water.
	S7	Biological pest control in agriculture can reduce the impact of pesticides on food.
	S8	I am willing to change eating habits to reduce exposure to food with pesticide residues.
Healthy Practices and Disease Prevention	S9	I am aware of the potential health problems associated with exposure to pesticides in water and food.
	S10	Regular exposure to pesticides increases the risk of diseases such as cancer, hormonal or neurological disorders.
	S11	I strive to minimize pesticide exposure in my daily life.
	S12	Preventive measures, such as thoroughly washing food before consumption, can help reduce pesticide exposure.
	S13	Health authorities provide adequate information about the risks of pesticides to public health.
	S14	I discuss the health consequences of pesticide use in food production with my family or friends.
	S15	It is important to invest in research to develop healthier alternatives to conventional pesticides.
Sustainability and Health Promotion	S16	Excessive use of pesticides harms the environment.
	S17	Reducing pesticide use is important for promoting agricultural sustainability.
	S18	Excessive pesticide use can negatively affect soil quality and biodiversity.
	S19	Sustainable agriculture practices that reduce pesticide use can contribute to preserving natural resources.
	S20	Reducing pesticide use in agricultural practices contribute to preserve human health, the environment, and improve food quality.
	S21	Environmental education and public awareness are important for promoting more sustainable agricultural practices.
	S22	Promoting sustainable agricultural practices is the responsibility of both producers and consumers.
	S23	Organic agriculture is a viable and sustainable alternative to conventional agriculture.

Based on the suggestions provided by Bell [51], a group of experts carried out a thorough review of the questionnaire and proposed modifications that were incorporated into a revised edition. This panel comprised five professionals chosen for their expertise in environmental impact assessments, environmental sustainability, healthcare, public health, and questionnaire development and validation. An independent group of students, separate from the cohort, assessed the clarity and validity of the updated questionnaire. A hard copy of the updated questionnaire was individually handed out to each student. Data collection took place from September 2023 to April 2024, resulting in the return of all 1100 questionnaires, achieving a complete return rate of 100%.

3.3. Target Population

This study included an opportunity cohort and was conducted in secondary schools located in the municipalities of Beja, Elvas, Estremoz, Évora, and Sousel, in Alentejo, in southern Portugal. It enrolled students from 7th, 8th, and 9th grade, aged between 12 and 16 years old. From a total of 1100 questionnaires, 49 (4.4%) were discarded for missing data in the first section. Thus, the cohort included 1051 students with a mean age of 13.7 ± 0.9 years. Table 2 outlines the distribution of students by gender, age, grade, and municipality.

3.4. Qualitative Response Conversion

In the second segment of the questionnaire, qualitative data were assembled and evaluated with a five-point Likert scale. According to the method by Fernandes et al. [46], these data were converted to numerical form by plotting responses within a unit circle with a radius of $\pi^{-1/2}$. The circle is segmented into Q portions, corresponding to the number of

statements presented in the theme under analysis. The responses are plotted along the axes following the procedures presented in Section 4.3.

Table 2. Demographic distribution of students by gender, age, grade, and municipality.

Demographic Characteristics	Class	Frequency	
		N	%
Gender	Female	546	52.0
	Male	505	48.0
Age (years old)	12	111	10.6
	13	243	23.1
	14	540	51.4
	15	139	13.2
	16	18	1.7
Grade	7th	354	33.7
	8th	461	43.9
	9th	236	22.4
Municipality	Beja	213	20.2
	Elvas	48	4.6
	Estremoz	335	31.9
	Évora	408	38.8
	Sousel	47	4.5

3.5. Artificial Neural Networks

Using WEKA 3-8-6 software with default configurations [52,53], ANN models were created. The backpropagation algorithm and logistic activation function [30–32] were employed during the learning process. Each experiment was performed thirty times to obtain statistically significant results. The dataset was split into 67% for training and 33% for testing, where the training set built the model, and the test set assessed its generalization.

3.6. Ethical Aspects

The students voluntarily participated in this study without any pressure or coercion and were assured that their grades would not be affected. Written informed consent for participation was obtained from the parents or guardians of all the participants. The principals' offices of the involved schools authorized the study's conduct. The participants were fully informed of the study's aims and voluntarily participated by completing the questionnaire.

4. Results and Discussion

This section presents and discusses the results of this study, assessing literacy on safe pesticide use and sustainable resource management within a cohort of 1051 Portuguese students in the 7th, 8th, and 9th grades.

4.1. Frequency of Responses Analysis

Figure 1 illustrates the frequencies of the responses related to pesticide use and consumer attitudes. The analysis of this figure shows that agree was the most frequent response for almost all the statements, ranging from 33.0% (S6) to 51.5% (S3), except for S4 (related to organic food) where strongly agree was most frequent at 53.8%, followed by agree at 36.9%. The disagree option was selected by 1.7% to 29.7% of students, with the lowest percentage for S4 (organic food) and highest for S5 (willingness to pay more for organic food) and S6 (regulations on pesticide use). The percentage of students without an opinion on pesticide use and consumer attitudes ranged from 5.9% (S3) to 16.4% (S6). Indeed, over 10% of students lacked a defined opinion on legislation regarding pesticide use (S6) and biological pest control in agriculture (S7). Additionally, more than 10% of the students did not indicate whether

they were willing to pay a higher price for organic food (S5) or to change their eating habits to reduce exposure to pesticide residues (S8). Conversely, the students revealed levels of agreement (i.e., strongly agree and agree) over 80% for the issues relating to the importance of reading food packaging to know if the food is organic (S3), and the benefits of organic food to health (S4). Finally, it is worth noting that the level of disagreement (i.e., strongly disagree and disagree) regarding statement S3 was very low, at just 3.3%.

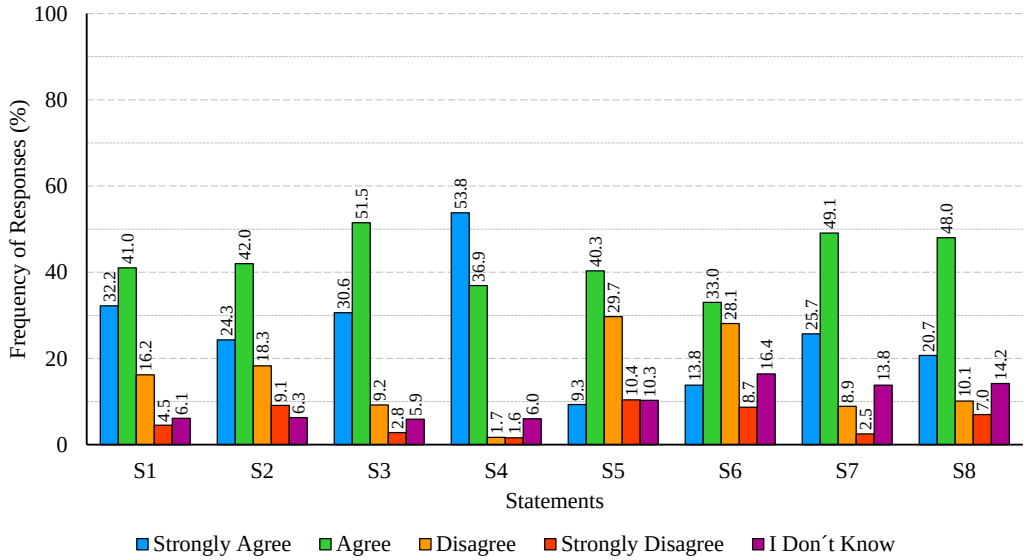


Figure 1. Percentage distribution of responses on the theme pesticide use and consumer attitudes, statements S1 to S8.

These outcomes match those found by other authors who have examined similar issues. For example, Akçay et al. [24] assessed environmental literacy among middle school students in Turkey and found that their overall level of environmental literacy was deemed acceptable. Sasa et al. [27] carried out a study to examine the environmental literacy among students at the Applied Science Private University in Jordan. The study found that the students showed a high degree of knowledge regarding energy, pollution, and recycling, but their familiarity with issues like water scarcity, global warming, and ozone layer depletion was only moderate.

Figure 2 illustrates the frequency of responses related to healthy practices and disease prevention. The analysis of this figure shows that agree was the most frequent response for all the statements, ranging from 35.5% (S14) to 54.9% (S10). For S9, S10, S11, S12, and S15, the second most common response was strongly agree, whereas for S13 and S14, the second most frequent response was disagree. In fact, the disagree option was selected by 3.0% to 25.7% of students, with the lowest percentage for S10 (concerning the increased risk of diseases due to regular exposure to pesticides) and the highest for S14 (regarding dialogue on the use of pesticides and the health consequences). The percentage of students without an opinion about healthy practices and disease prevention ranged from 5.4% (S14) to 16.3% (S13), with over 10% lacking a defined opinion on the increased risk of diseases from regular pesticide exposure (S10) and the adequacy of the information provided by health authorities (S13). Conversely, the students showed agreement levels above 80% on issues related to the increased risk of diseases from regular pesticide exposure (S10), the effectiveness of preventive measures in reducing exposure (S12), and the importance of investing in research to develop healthier alternatives to conventional pesticides (S15). Finally, it is noteworthy that the level of disagreement (47.7%) regarding statement S14 exceeds the level of agreement (46.9%). This difference may indicate that the health consequences of pesticide use in food production is not a topic frequently addressed, either within families or among friends.

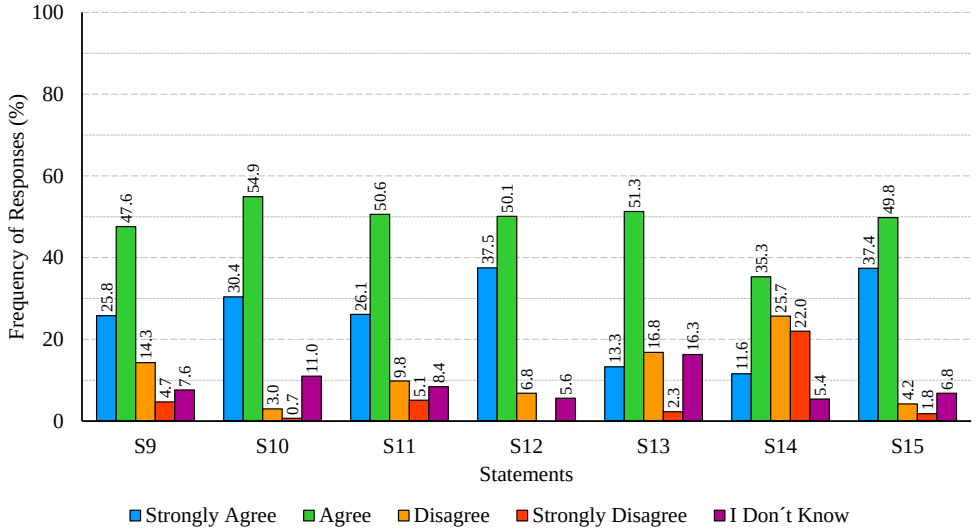


Figure 2. Percentage distribution of responses on the theme healthy practices and disease prevention, statements S9 to S15.

Figure 3 displays the frequency of the responses related to sustainability and health promotion. The analysis of this figure shows that agree was the most common response for all the statements except S16 and S20, with frequencies ranging from 40.5% (S23) to 52.5% (S21). In all the other statements, the second most frequent response was strongly agree, with percentages ranging from 22.2% (S22) to 39.9% (S18). The disagree option was selected by 3.8% to 14.2% of the students, with the lowest percentage for S16 and the highest for S22, while strongly disagree was chosen by fewer than 5% of the students across all the statements. The percentage of students without an opinion on sustainability and health promotion ranged from 4.7% (S16) to 12.9% (S22), with over 10% lacking a defined opinion on the role of pesticide reduction in promoting sustainable agriculture (S17), on sustainable agriculture's role in preserving natural resources (S19), on the role of education in promoting sustainable agriculture (S21), on the roles of producers and consumers in supporting sustainable agriculture (S22), and on the viability of organic agriculture (S23). Contrariwise, the students showed agreement levels above 80% on the issues related to the environmental impact of excessive pesticide use (S16), the effects on soil and biodiversity (S18), and the importance of reducing pesticides in order to preserve human health, the environment, and food quality (S20).

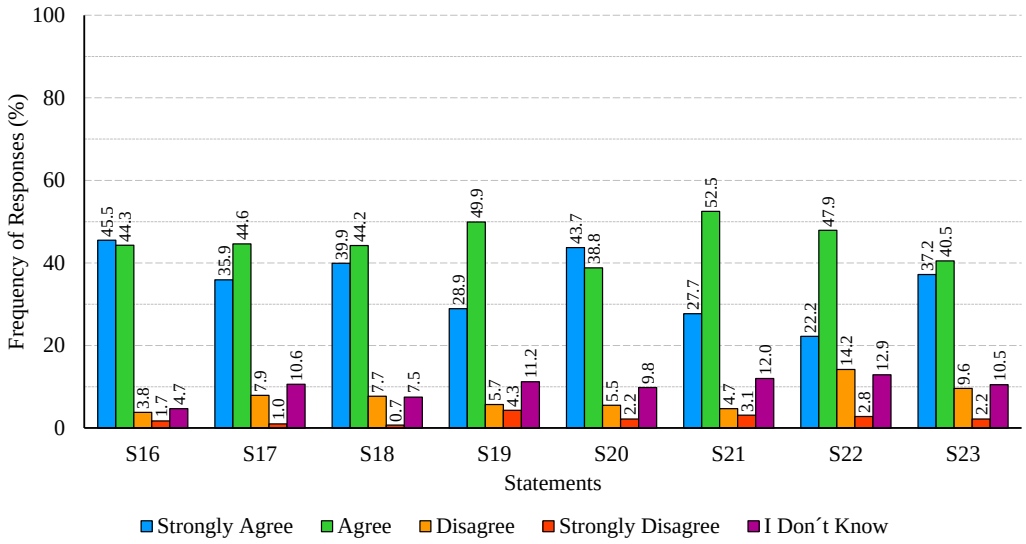


Figure 3. Percentage distribution of responses on the theme sustainability and health promotion, statements S16 to S23.

4.2. Influence of Socio-Demographic Characteristics

To understand how socio-demographic factors influence students' literacy on safe pesticide use and sustainable resource management, the results from the second segment of the questionnaire were analyzed separately by gender (Appendix A, Table A1), grade (Appendix A, Table A2), age (Appendix A, Table A3), and municipality (Appendix A, Table A4).

In examining how gender influences students' literacy on safe pesticide use and sustainable resource management, Table A1 (Appendix A) reveals that the response differences between males and females are generally below 5.0% for most of the statements in the second segment of the questionnaire. Both genders exhibit consistent patterns, showing similar levels of agreement (strongly agree and agree), disagreement (disagree and strongly disagree), and uncertainty (I don't know). However, the females tend to display slightly higher levels of agreement and lower levels of strong disagreement compared to the males, indicating a more positive perspective. These results align with the findings from Akçay et al. [24], who observed that female students tend to exhibit higher levels of environmental literacy than their male counterparts, as well as with Harris and Jenkins [54], who noted that women generally show a lower inclination toward risk-related attitudes and behaviors in health contexts. Additionally, the results are consistent with Sasa et al. [27], which suggest that gender differences do not have a major influence on literacy levels.

According to Table A2 (Appendix A), the influence of grade level on safe pesticide use, and sustainable resource management shows that the differences in uncertainty, disagreement, and agreement levels generally remained below 8.0%. Students in the 7th grade tend to show high levels of agreement and low levels of uncertainty, while those in the 8th and 9th grades exhibit more varied responses, with higher levels of disagreement, especially among the 8th graders. This evidence is consistent with the observations of Akçay et al. [24], who investigated the environmental literacy of Turkish middle school students and reported slight disparities in literacy between different grade levels.

Apart from the 16-year-old students, who represent less than 2% of the cohort, the analysis of Table A3 (Appendix A) for ages 12 to 14 suggests that age has a limited influence on uncertainty, disagreement, and agreement levels regarding students' literacy on safe pesticide use and sustainable resource management, with differences remaining below 8.0%. For these ages, the frequency of the I don't know responses is generally below 15%, fluctuating across the items but tending to decrease slightly with age. Conversely, for the 15-year-old students, the frequency of the I don't know responses is somewhat more variable across the items and tends to increase slightly. The disagreement levels are generally higher among the younger participants and tend to decrease with age, while the agreement levels tend to increase with age. These results are consistent with those obtained in the previous analysis, which examined the influence of educational level, given that the majority of the students aged 12 and 13 are enrolled in the 7th grade, the students aged 14 are predominantly in the 8th grade, and those aged 15 and 16 are predominantly attending the 9th grade.

Aside from the municipalities of Elvas and Sousel, which together comprise less than 10% of the cohort, the analysis of Table A4 (Appendix A) shows that the differences in the response frequencies for the second questionnaire segment remained below 7.5%, regardless of the municipality. These findings suggest that area of residence may not affect students' literacy on safe pesticide use and sustainable resource management. Several studies concluded that living in urban and rural settings impacts environmental literacy [24,29]. However, comparing those findings to the present research is challenging, as this study examines specific Portuguese municipalities that include both urban and rural areas.

4.3. Quantification of Qualitative Data

The selections made by student one in the second segment of the questionnaire are depicted in Appendix A, Figure A1, which also outlines the quantification of the qualitative data using the framework proposed by Fernandes et al. [46]. As per this method, a unit-area

circle (radius $\pi^{-1/2}$) was split into segments matching the number of questions for each theme. The response options were placed on marked points along the axis, as indicated in Appendix A, Figure A1, and the corresponding areas (A) were computed using Equation (1):

$$A = \frac{1}{Q}\pi\left(\frac{n}{N}\pi^{-1/2}\right)^2 \quad (1)$$

where Q corresponds to the number of statements per theme, N denotes the cardinality of the set of possible responses excluding the option I don't know, and n stands for the mark assigned to the selected option. In this instance, $Q = 8$ for the pesticide use and consumer attitudes theme and the sustainability and health promotion theme, while for healthy practices and disease prevention $Q = 7$, because there are only seven statements in this theme. $N = 4$ because the cardinality of the set of possible responses excluding the option I don´t know is four, and $n = 1,\ 2,\ 3$, and 4. for the responses strongly disagree, disagree, agree, and strongly agree, respectively. When the student selects the I don't know option, n becomes 0 since no point is assigned on the axis. Therefore, for the pesticide use and consumer attitudes theme and the sustainability and health promotion theme, one may have the following:

$$A_{I\ dont\ know} = \frac{1}{8}\pi\left(\frac{0}{4}\pi^{-1/2}\right)^2 = 0.000 \quad (2)$$

$$A_{strongly\ disagree} = \frac{1}{8}\pi\left(\frac{1}{4}\pi^{-1/2}\right)^2 = 0.008 \quad (3)$$

$$A_{disagree} = \frac{1}{8}\pi\left(\frac{2}{4}\pi^{-1/2}\right)^2 = 0.031 \quad (4)$$

$$A_{agree} = \frac{1}{8}\pi\left(\frac{3}{4}\pi^{-1/2}\right)^2 = 0.070 \quad (5)$$

$$A_{strongly\ agree} = \frac{1}{8}\pi\left(\frac{4}{4}\pi^{-1/2}\right)^2 = 0.125 \quad (6)$$

whereas for the healthy practices and disease prevention theme, the correspondent areas are as follows:

$$A_{I\ dont\ know} = \frac{1}{7}\pi\left(\frac{0}{4}\pi^{-1/2}\right)^2 = 0.000 \quad (7)$$

$$A_{strongly\ disagree} = \frac{1}{7}\pi\left(\frac{1}{4}\pi^{-1/2}\right)^2 = 0.009 \quad (8)$$

$$A_{disagree} = \frac{1}{7}\pi\left(\frac{2}{4}\pi^{-1/2}\right)^2 = 0.036 \quad (9)$$

$$A_{agree} = \frac{1}{7}\pi\left(\frac{3}{4}\pi^{-1/2}\right)^2 = 0.080 \quad (10)$$

$$A_{strongly\ agree} = \frac{1}{7}\pi\left(\frac{4}{4}\pi^{-1/2}\right)^2 = 0.143 \quad (11)$$

To demonstrate the process of converting the qualitative responses into quantitative data, the options marked by student 1 regarding the theme pesticide use and consumer attitudes (S1 to S8) were analyzed (Appendix A, Figure A1). For statements S1, S6, and S7, the student selected the option agree, yielding an area of 0.070 for each (Equation (5)). In statement S2 and S8, the option ticked was disagree, resulting in an area of 0.031 for each (Equation (4)). In statements S3 and S5, the strongly disagree option was marked, corresponding to an area of 0.008 for each (Equation (3)). Finally, in statement S4, the option ticked was strongly agree, yielding an area of 0.125 (Equation (6)). The combined

area, taking into account the responses of student 1 for this theme, was 0.600, calculated by summing up the individual values (Equation (12)).

$$A^{participant\ 1}_{statements\ S1\ to\ S8} = 0.070 + 0.031 + 0.008 + 0.125 + 0.008 + 0.070 + 0.070 + 0.031 = 0.413 \quad (12)$$

Regarding the theme of healthy practices and disease prevention (S9 to S15), student 1 selected disagree, agree, strongly disagree, strongly agree, agree, strongly disagree, and I don't know, respectively (Appendix A, Figure A1). The corresponding areas for each response can be calculated using Equations (7)–(11), with the total area determined by Equation (13). Finally, for the theme of sustainability and health promotion (S16 to S23), student 1 selected agree for S16, S19, S20, S21, and S23, and strongly agree for the others (Appendix A, Figure A1). The corresponding areas for each response can be calculated using Equations (5) and (6), with the total area given by Equation (14).

$$A^{participant\ 1}_{statements\ S9\ to\ S15} = 0.036 + 0.080 + 0.009 + 0.143 + 0.080 + 0.009 + 0.000 = 0.357 \quad (13)$$

$$A^{participant\ 1}_{statements\ S16\ to\ S23} = 0.070 + 0.125 + 0.125 + 0.070 + 0.070 + 0.070 + 0.125 + 0.070 = 0.725 \quad (14)$$

The same procedure was applied to the remaining students, with the results summarized in Table 3.

Table 3. A piece of the dataset used to model students' literacy on safe pesticide use and sustainable resource management. The "..." represents a continuous sequence of participants.

Student	Pesticide Use and Consumer Attitudes	Healthy Practices and Disease Prevention	Sustainability and Health Promotion
1	0.413	0.357	0.725
2	0.467	0.606	0.412
3	0.305	0.345	0.383
...	...	...	...
1051	0.945	0.787	1.000

4.4. Modelling Students' Literacy

The information presented in Table 3 was used to train ANNs in assessing the students' literacy on safe pesticide use and sustainable resource management. Along with the information provided in Table 3, socio-demographic characteristics (i.e., gender, age, grade, and municipality) were used as input variables. The output categorized the students' literacy into three levels (high, medium, or low) according to their responses in the second segment of the questionnaire. Various configurations of ANNs were designed and tested to find the optimal model for assessing the students' literacy on safe pesticide use and sustainable resource management. Confusion matrices were used for performance comparisons [30,31]. From the structures analyzed, the 5-3-1-1 topology (depicted in Figure 4) was identified as the most effective choice. This choice is supported by its confusion matrix (Table 4), which presents the average results from 30 experimental runs. The model's accuracy can be assessed using the information in Table 4, showing 93.8% for the training set (indicating 660 correct identifications out of 704) and 92.5% for the test set (indicating 321 correct identifications out of 347). Therefore, the 6-5-3-1 ANN model demonstrates high effectiveness in assessing the students' literacy on safe pesticide use and sustainable resource management, with accuracy rates surpassing 90%.

Examining the columns in Table 4 enables the computation of the confidence levels associated with the model's predictions, illustrating its ability to categorize the students' literacy as low, medium, or high. A total of 119 students were categorized by the model as having low literacy in safe pesticide use and sustainable resource management, representing 11.3% of the cohort. From this group, 99 (67 + 32) were accurately classified, while 20 (13 + 7) were misclassified as medium. Of the 700 students identified by the model as

having medium literacy on safe pesticide use and sustainable resource management (66.6% of the cohort), 680 (457 + 223) were accurately classified. However, 20 were misclassified, with 8 (5 + 3) rated as having low literacy and 12 (7 + 5) rated as having high literacy. Finally, the model identified 232 students as having high literacy in safe pesticide use and sustainable resource management, representing 22.1% of the cohort. Of this group, 202 (136 + 66) were correctly classified, while 30 (19 + 11) were misclassified as medium. This analysis of the columns in Table 4 allows for the quantification of confidence in the model's predictions. Thus, the confidence levels for the training and test sets are 83.8% and 80.1% for low literacy, 97.4% and 96.5% for medium literacy, and 87.7% and 85.7% for high literacy, respectively.

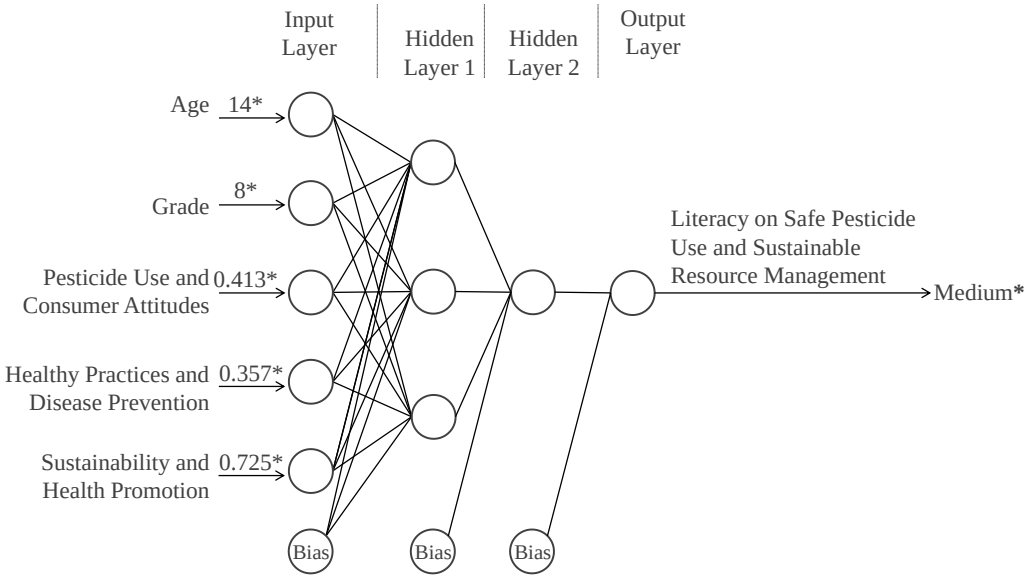


Figure 4. A conceptual illustration of the ANN architecture used to evaluate students' literacy on safe pesticide use and sustainable resource management. (* The shown values are purely illustrative and refer to student 1).

Table 4. Confusion matrix of the 5-3-1-1 ANN model to evaluate students' literacy on safe pesticide use and sustainable resource management.

Predict / Target	Training			Test		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**
Low	67	5	0	32	3	0
Medium	13	457	19	7	223	11
High	0	7	136	0	5	66

Examining the rows in Table 4 enables the calculation of the percentages of low, medium, and high responses accurately classified by the model. Thus, of the 107 students with low literacy in safe pesticide use and sustainable resource management (10.2% of the cohort), the model accurately classified 99 (67 + 32) of them, whereas 8 (5+3) were misclassified as medium. Of the 730 students with medium literacy in safe pesticide use and sustainable resource management (69.4% of the cohort), 680 (457 + 223) were accurately classified by the model. However, 50 were misclassified, including 20 (13 + 7) who were rated as having low literacy and 30 (19 + 11) who were rated as having high literacy. Finally, of the 214 students with high literacy in safe pesticide use and sustainable resource management (20.4% of the cohort), the model accurately classified 202 (136 + 66) of them, while 12 (7 + 5) were misclassified as medium. Thus, the percentages of the students having low, medium, and high literacy correctly identified by the model for the training and test

sets are 93.1% and 91.4% for low, 93.4% and 92.5% for medium, and 95.1% and 93.0% for high, respectively.

4.5. In-Depth Examination of Students' Literacy

As demonstrated in Appendix A, Figure A1 and displayed in Table 3, the approach outlined by Fernandes et al. [46] made it possible to convert the qualitative input from the students into measurable data. To conduct an in-depth examination of the students' literacy concerning safe pesticide use and sustainable resource management, the data from Table 3 were represented in a circular chart with three slices, each corresponding to a theme presented in the second segment of the questionnaire. Since the values in Table 3 originate from a unitary area circular chart, they were adjusted by dividing them by three, corresponding to the number of slices in the new chart. Figure 5 provides an overview of this methodology for student one. The overall literacy concerning safe pesticide use and sustainable resource management among students can now be evaluated numerically. The overall literacy score for student 1 is 0.499, calculated by adding the highlighted regions in Figure 5. In addition, the students' potential for improvement can be evaluated. This is determined by subtracting the overall literacy score from one and is represented by the shaded region. For student 1, the improvement potential is 0.501 (i.e., 1–0.499). Figure 5 also highlights the themes where students face the most difficulty regarding safe pesticide use and sustainable resource management. Thus, student 1 demonstrates low literacy regarding pesticide use and consumer attitudes, along with healthy practices and disease prevention. The same approach is used for the other students, with Figure 6 presenting the results for those listed in Table 3. A review of Figure 6 reveals that student 1051 possesses high literacy in safe pesticide use and sustainable resource management, regardless of the themes investigated. In contrast, student 3 exhibits low literacy across all the themes investigated. Finally, student 2 shows low literacy regarding pesticide use and consumer attitudes, along with sustainability and health promotion.

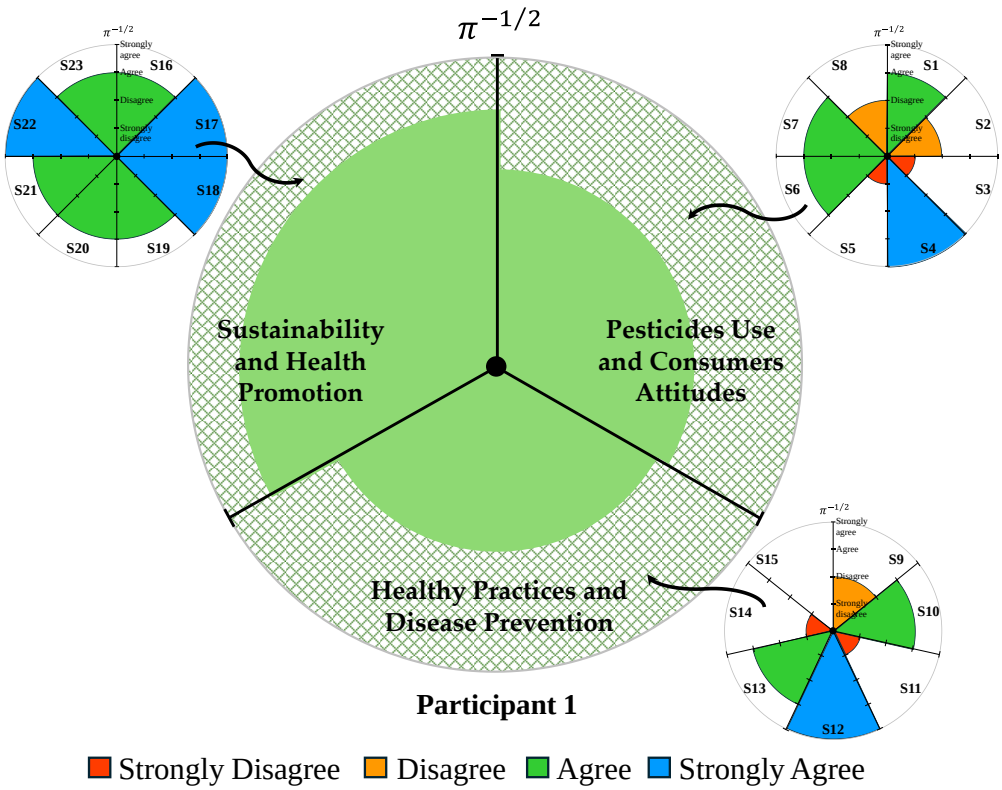


Figure 5. An illustrative summary of the process for analyzing student 1's overall literacy concerning safe pesticide use and sustainable resource management.

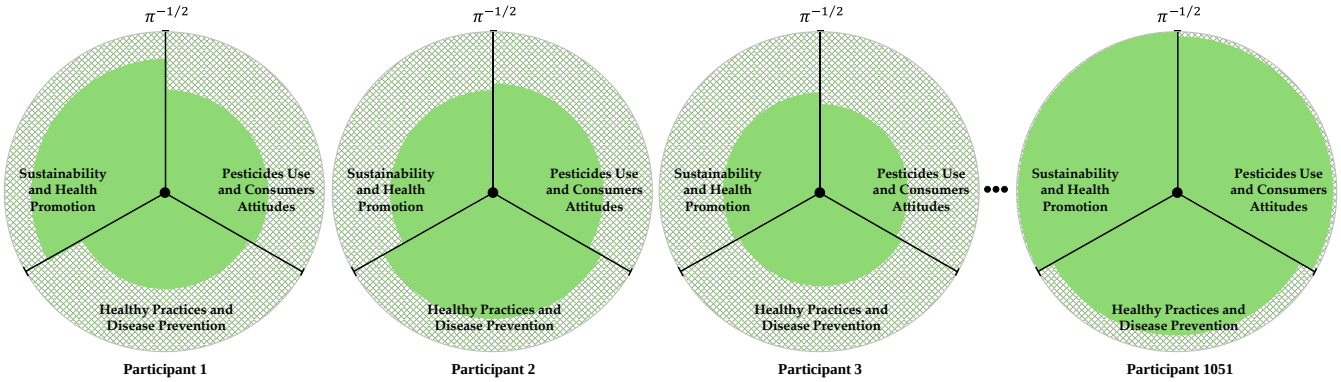


Figure 6. An illustrative summary of the process for analyzing the overall literacy concerning safe pesticide use and sustainable resource management for the students mentioned in Table 3.

The value advantage of this assessment stems from the development of a database (Table 5) to study a specific population, which enables the evaluation of the students' improvement potential and their literacy in safe pesticide use and sustainable resource management. Through this database, insights from the students' responses can be gathered, along with essential information, including the following:

- The mean value of literacy on safe pesticide use and sustainable resource management;
- The mean value of the improvement potential for the respondents of a specific age;
- The respondent with the lowest/highest value of improvement potential;
- All the respondents whose literacy in safe pesticide use and sustainable resource management exceeds or falls below a certain threshold;
- All the respondents whose improvement potential exceeds or falls below a certain threshold;
- All the respondents whose literacy on the theme healthy practices and disease prevention exceeds or falls below a certain threshold and whose literacy in safe pesticide use and sustainable resource management exceeds or falls below another threshold;
- All the respondents from the 9th grade whose literacy on safe pesticide use and sustainable resource management exceeds or falls below a certain threshold.

These insights allow for the classification of the respondents with common characteristics, supporting the development of targeted interventions to improve literacy on safe pesticide use and sustainable resource management.

Table 5. A piece of the database focused on improving students' literacy on safe pesticide use and sustainable resource management. The scores for Pesticide Use and Consumer Attitudes, Sustainability and Health Promotion, Overall Literacy Score, and Improvement Potential are expressed on a [0, 1] scale. The "..." represents a continuous sequence of participants.

Student	Gender	Age	Grade	Municipality	Pesticide Use and Consumer Attitudes	Healthy Practices and Disease Prevention	Sustainability and Health Promotion	Overall Literacy Score	Improvement Potential
1	Female	14	8	Estremoz	0.138	0.119	0.242	0.499	0.501
2	Male	16	9	Estremoz	0.156	0.202	0.137	0.495	0.505
3	Male	13	8	Estremoz	0.102	0.115	0.128	0.345	0.655
...	...	...	...	...	...	...	...	...	...
1051	Female	12	7	Estremoz	0.315	0.262	0.333	0.910	0.090

5. Conclusions

Promoting safe pesticide use and sustainable resource management is essential for achieving long-term environmental and public health goals. This endeavor, however, relies heavily on educating individuals and fostering responsible practices. Raising awareness among students about the impacts of pesticide use and resource conservation is critical, as informed individuals are more likely to adopt sustainable behaviors. In fact, students' engagement in safe pesticide practices and resource management is greatly enhanced when they have a solid understanding of the associated risks and benefits, empowering them to make responsible choices that contribute to a healthier environment and a sustainable future. This study assessed students' literacy on safe pesticide use and sustainable resource management, allowing for the formulation of some key conclusions. The comparative analysis of the students' literacy on safe pesticide use and sustainable resource management by theme reveals higher literacy levels in sustainability and health promotion, while lower levels are observed in healthy practices and disease prevention, as well as pesticide use and consumer attitudes. In particular, over 75% of the students expressed agreement or strong agreement on all the topics related to sustainability and health promotion, except for the issue concerning the roles of producers and consumers in supporting sustainable agriculture. In the theme of healthy practices and disease prevention, the students showed high literacy on some issues, including the increased risk of diseases from regular pesticide exposure, the effectiveness of preventive measures in reducing exposure, and the importance of research into healthier pesticide alternatives. For safe pesticide use and sustainable resource management, the students demonstrated high literacy only on issues related to reading food packaging to identify organic products and on the health benefits of organic foods. Socio-demographic factors such as gender, grade, age, and municipality have only a limited influence on the students' literacy concerning safe pesticide use and sustainable resource management. The gender differences are minor, with females showing slightly more agreement and less disagreement than males. The age differences are minimal, with a general pattern of increasing agreement and decreasing uncertainty as age increases, except for a slight rise in uncertainty among the 15 year olds. Additionally, an artificial intelligence-driven neural network model was implemented to predict the students' literacy on safe pesticide use and sustainable resource management, with an accuracy close to 90%, facilitating preventive educational strategies across various contexts. The core contribution of this study is identifying the topics where knowledge gaps are the widest. Addressing these gaps requires bolstering the environmental content in educational programs, especially at the basic and secondary levels. Moreover, this study presents a methodology for quantifying students' overall literacy and improvement potential. These metrics are crucial for forming groups with similar characteristics, enabling the development of targeted educational strategies. Additionally, this study presents an innovative approach, grounded in the ANN paradigm, for managing students' literacy on safe pesticide use and sustainable resource management. The ANN-based model serves as a robust tool to assess current literacy levels and identify areas for improvement, offering a proactive framework to address diverse conditions and scenarios.

This study highlights the importance of integrating comprehensive and targeted educational strategies into school curricula to improve students' literacy on safe pesticide use and sustainable resource management. Thus, school curricula should integrate modules on sustainability, health promotion, pesticide use, and resource management to address the knowledge gaps. To complement the curriculum, schools can organize non-formal activities, such as workshops, debates, and hands-on experiences, tailored to the characteristics and knowledge gaps of the identified groups, focusing on pesticide risks, preventive measures, and healthier alternatives to enhance students' literacy on safe pesticide use and sustainable resource management while addressing misunderstandings and misinformation. Further research should focus on enhancing the questionnaire by incorporating additional themes to widen the study's focus and should involve a larger and more diverse cohort, including students from other educational levels.

Author Contributions: Conceptualization, C.C., M.R.M. and H.V.; methodology, C.C., M.R.M. and H.V.; software, H.V.; validation, M.R.M. and H.V.; formal analysis, M.R.M. and H.V.; investigation, C.C., M.R.M. and H.V.; writing—original draft preparation, C.C., M.R.M. and H.V.; writing—review and editing, C.C., M.R.M. and H.V.; visualization, M.R.M. and H.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by PT national funds (FCT/MCTES, Fundação para a Ciência e Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior) through the projects UIDB/50006/2020 and UIDP/50006/2020.

Informed Consent Statement: Informed consent was obtained from all the subjects involved in this study.

Data Availability Statement: The original contributions presented in this study are included in this article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Percentage distribution of responses to statements from the second segment of the questionnaire, analyzed by theme and gender.

Response Options	Gender	Statements																						
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion							
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
I don't know	Female	6.8	7.3	5.7	6.2	10.6	18.3	14.3	12.1	7.5	9.5	9.5	5.7	16.5	6.4	7.3	3.7	9.2	8.1	10.4	10.4	10.6	12.3	10.1
	Male	5.3	5.1	6.1	5.7	9.9	14.3	13.3	16.4	7.7	12.7	7.1	5.5	16.0	4.4	6.3	5.7	12.1	6.9	12.1	9.1	13.5	13.7	10.9
Strongly disagree	Female	4.2	8.6	2.6	1.6	12.1	9.7	2.0	5.9	4.2	0.9	4.9	0.0	1.6	20.1	1.5	1.8	1.1	0.5	4.0	1.5	3.5	2.0	0.9
	Male	4.8	9.7	3.0	1.6	8.5	7.7	3.0	8.3	5.3	0.4	5.3	0.0	3.0	24.0	2.2	1.6	1.0	0.8	4.6	3.0	2.8	3.6	3.6
Disagree	Female	16.7	18.3	9.3	1.8	27.5	25.3	8.1	10.6	14.7	3.3	11.4	5.5	17.6	26.9	4.4	3.1	9.3	7.9	5.9	5.3	5.1	13.0	10.6
	Male	15.6	18.4	9.1	1.6	32.1	31.1	9.9	9.5	13.9	2.6	8.1	8.1	16.0	24.4	4.0	4.6	6.3	7.5	5.5	5.7	4.2	15.4	8.5
Agree	Female	41.2	43.8	52.2	36.1	40.3	35.0	50.7	51.8	47.4	58.4	52.0	50.0	50.2	35.9	48.9	46.5	41.6	44.5	49.8	39.2	52.7	49.3	40.5
	Male	40.8	40.0	50.7	37.8	40.4	30.9	47.3	43.8	47.7	51.1	49.1	50.3	52.5	34.7	50.7	42.0	47.9	44.0	49.9	38.4	52.3	46.5	40.6
Strongly agree	Female	31.1	22.0	30.2	54.2	9.5	11.7	24.9	19.6	26.2	27.8	22.2	38.8	14.1	10.6	37.9	44.9	38.8	39.0	29.9	43.6	28.0	23.4	37.9
	Male	33.5	26.7	31.1	53.3	9.1	16.0	26.5	22.0	25.3	33.3	30.3	36.0	12.5	12.7	36.8	46.1	32.7	40.8	27.9	43.8	27.3	20.8	36.4

Table A2. Percentage distribution of responses to statements from the second segment of the questionnaire, analyzed by theme and gender.

Response Options	Grade	Statements																						
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion							
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
I don't know	7th	7.3	7.9	4.5	4.8	10.2	16.7	14.4	14.1	8.5	8.5	8.8	5.4	16.9	5.6	6.8	4.5	9.9	7.1	9.0	9.9	10.5	12.1	8.5
	8th	5.0	5.2	7.6	4.3	12.1	13.7	14.3	12.4	7.8	12.6	8.7	3.9	13.7	5.2	6.5	5.2	10.0	8.7	12.6	9.8	10.4	13.2	12.1
	9th	6.4	5.9	4.7	11.0	6.8	21.2	11.9	17.8	5.9	11.9	7.2	9.3	20.3	5.5	7.6	3.8	12.7	5.9	11.9	9.7	17.4	13.6	10.2
Strongly disagree	7th	2.8	10.7	2.3	2.3	8.8	7.9	2.3	7.1	3.7	1.7	4.0	0.0	2.5	18.6	1.7	0.6	0.3	0.8	3.7	1.7	2.8	3.1	2.3
	8th	6.1	6.9	3.3	1.5	13.0	8.5	1.5	6.7	6.3	0.2	5.4	0.0	2.4	24.7	1.7	2.2	1.5	0.7	3.9	2.8	3.7	2.6	2.2
	9th	3.8	11.0	2.5	0.8	7.6	10.6	4.7	7.6	3.4	0.0	6.4	0.0	1.7	21.6	2.1	2.5	1.3	0.4	5.9	1.7	2.5	2.5	2.1
Disagree	7th	16.7	15.5	8.2	3.4	26.0	27.7	7.9	7.9	14.4	2.0	8.8	7.1	16.4	24.6	6.8	4.8	8.5	8.5	5.4	6.8	4.2	15.0	8.5
	8th	17.4	21.3	10.4	1.3	31.0	27.3	8.2	12.4	15.8	3.3	10.8	7.2	18.7	26.0	3.7	3.3	7.6	6.3	5.9	4.1	4.8	11.9	10.2
	9th	13.1	16.9	8.5	0.0	32.6	30.1	11.9	8.9	11.0	3.8	9.3	5.5	14.0	26.7	1.3	3.4	7.6	9.3	5.9	6.4	5.1	17.4	10.2

Table A2. *Cont.*

Response Options	Grade	Statements																						
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion							
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Agree	7th	39.5	39.8	54.5	35.9	42.9	33.6	50.6	49.2	47.2	57.9	49.2	51.1	52.0	35.3	46.3	44.1	45.8	42.9	53.4	36.2	59.3	50.6	38.7
	8th	41.6	41.0	49.5	39.3	36.2	35.4	49.2	48.2	44.9	51.0	50.3	52.5	50.1	34.5	49.7	46.4	44.7	44.5	47.1	39.3	49.5	49.0	43.6
	9th	41.9	47.0	50.8	33.9	44.5	27.5	46.6	45.8	53.4	58.1	53.4	44.1	52.5	36.9	55.1	40.7	42.8	45.8	50.0	41.9	48.3	41.9	37.3
Strongly agree	7th	33.6	26.0	30.5	53.7	12.1	14.1	24.9	21.8	26.3	29.9	29.4	36.4	12.1	15.8	38.4	46.0	35.6	40.7	28.5	45.5	23.2	19.2	42.1
	8th	29.9	25.6	29.3	53.6	7.6	15.2	26.7	20.4	25.2	33.0	24.7	36.4	15.2	9.5	38.4	43.0	36.2	39.9	30.6	44.0	31.7	23.2	31.9
	9th	34.7	19.1	33.5	54.2	8.5	10.6	25.0	19.9	26.3	26.3	23.7	41.1	11.4	9.3	33.9	49.6	35.6	38.6	26.3	40.3	26.7	24.6	40.3

Table A3. Percentage distribution of responses to statements from the second segment of the questionnaire, analyzed by theme and age.

Response Options	Age	Statements																						
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion							
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
I don't know	12 years old	6.3	6.3	5.4	7.2	6.3	9.0	18.0	17.1	9.0	5.4	8.1	7.2	14.4	4.5	7.2	2.7	9.9	6.3	9.0	5.4	13.5	10.8	7.2
	13 years old	6.2	7.4	3.3	2.9	13.6	17.3	14.4	13.6	9.5	10.7	7.8	5.3	16.9	6.2	8.2	5.3	9.9	6.6	11.5	9.9	9.9	13.2	11.9
	14 years old	6.3	5.7	7.6	5.9	10.7	15.2	13.1	13.5	6.9	11.5	9.3	4.8	14.8	5.6	5.7	5.2	10.0	8.1	11.5	10.6	10.2	14.4	11.1
	15 years old	5.8	7.2	5.0	8.6	7.2	25.9	12.9	13.7	7.2	12.9	5.8	7.9	21.6	5.0	8.6	2.9	14.4	6.5	12.2	10.8	20.1	7.9	8.6
	16 years old	0.0	0.0	0.0	22.2	0.0	11.1	5.6	27.8	0.0	22.2	11.1	5.6	22.2	0.0	5.6	5.6	11.1	16.7	5.6	5.6	22.2	16.7	5.6
Strongly disagree	12 years old	2.7	13.5	1.8	2.7	11.7	8.1	0.0	6.3	5.4	2.7	3.6	0.0	4.5	19.8	0.0	0.9	0.9	0.0	3.6	0.0	2.7	4.5	2.7
	13 years old	4.1	10.7	1.6	2.1	10.7	11.9	2.9	7.4	4.1	0.8	4.5	0.0	2.5	19.3	1.2	0.4	0.4	1.2	4.1	2.5	3.3	2.1	2.9
	14 years old	4.8	7.0	3.3	1.5	10.4	7.0	1.9	7.0	5.2	0.2	5.4	0.0	1.7	23.7	2.6	2.4	1.3	0.6	4.3	2.4	3.1	3.1	1.9
	15 years old	5.0	10.1	3.6	0.7	8.6	10.8	5.0	7.9	4.3	0.7	7.2	0.0	2.9	20.9	1.4	2.2	0.7	0.7	5.8	2.2	3.6	0.7	2.2
	16 years old	5.6	16.7	0.0	0.0	11.1	5.6	11.1	0.0	0.0	0.0	0.0	0.0	0.0	27.8	0.0	0.0	5.6	0.0	0.0	5.6	0.0	5.6	0.0
Disagree	12 years old	18.0	19.8	8.1	3.6	30.6	33.3	6.3	8.1	17.1	2.7	12.6	9.0	13.5	26.1	6.3	2.7	10.8	9.9	2.7	7.2	5.4	15.3	5.4
	13 years old	17.3	14.8	8.6	2.5	23.9	24.3	8.2	7.0	16.9	2.9	8.2	8.2	19.8	23.5	7.8	6.2	7.8	7.4	7.0	3.7	5.8	14.8	8.2
	14 years old	16.9	20.0	10.6	1.3	31.5	28.3	10.0	11.5	12.8	3.1	10.2	5.9	18.1	25.7	3.0	3.1	6.7	6.9	5.6	6.1	3.7	13.3	10.9
	15 years old	10.8	17.3	6.5	0.7	30.2	29.5	7.9	12.9	12.9	1.4	8.6	4.3	9.4	28.8	1.4	3.6	10.8	9.4	5.0	3.6	4.3	15.8	9.4
	16 years old	11.1	16.7	5.6	0.0	44.4	27.8	11.1	0.0	16.7	11.1	11.1	16.7	16.7	27.8	0.0	0.0	5.6	11.1	16.7	16.7	16.7	11.1	16.7

Table A3. *Cont.*

Response Options	Age	Statements																				
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion					
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Agree	12 years old	30.6	28.8	53.2	34.2	36.9	36.0	52.3	45.0	45.0	53.2	49.5	46.8	54.1	33.3	51.4	37.8	38.7	44.1	50.5	43.2	50.5	45.9	41.4
	13 years old	38.7	41.6	54.3	38.3	42.0	33.7	49.4	49.4	45.3	56.4	48.1	52.3	47.7	35.8	44.9	46.9	47.3	39.9	51.0	37.9	56.4	50.2	39.5
	14 years old	43.9	43.1	50.2	36.1	38.9	33.9	48.3	47.6	47.4	53.9	51.1	51.9	51.7	35.2	51.7	44.1	46.7	47.4	49.3	37.2	53.3	48.5	40.9
	15 years old	41.7	47.5	48.9	38.8	46.8	24.5	49.6	49.6	51.1	59.0	54.0	45.3	54.7	36.0	49.6	46.8	38.8	39.6	49.6	45.3	46.0	45.3	38.1
	16 years old	44.4	50.0	61.1	44.4	33.3	44.4	44.4	44.4	72.2	44.4	50.0	27.8	44.4	38.9	50.0	38.9	27.8	44.4	50.0	22.2	38.9	33.3	55.6
Strongly agree	12 years old	42.3	31.5	31.5	52.3	14.4	13.5	23.4	23.4	23.4	36.0	26.1	36.9	13.5	16.2	35.1	55.9	39.6	39.6	34.2	44.1	27.9	23.4	43.2
	13 years old	33.7	25.5	32.1	54.3	9.9	12.8	25.1	22.6	24.3	29.2	31.3	34.2	13.2	15.2	37.9	41.2	34.6	44.9	26.3	46.1	24.7	19.8	37.4
	14 years old	28.1	24.1	28.3	55.2	8.5	15.6	26.7	20.4	27.8	31.3	24.1	37.4	13.7	9.8	37.0	45.2	35.4	37.0	29.4	43.7	29.6	20.6	35.2
	15 years old	36.7	18.0	36.0	51.1	7.2	9.4	24.5	15.8	24.5	25.9	24.5	42.4	11.5	9.4	38.8	44.6	35.3	43.9	27.3	38.1	25.9	30.2	41.7
	16 years old	38.9	16.7	33.3	33.3	11.1	11.1	27.8	27.8	11.1	22.2	27.8	50.0	16.7	5.6	44.4	55.6	50.0	27.8	27.8	50.0	22.2	33.3	22.2

Table A4. Percentage distribution of responses to statements from the second segment of the questionnaire, analyzed by theme and municipality.

Response Options	Municipality	Statements																						
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion							
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
I don't know	Beja	7.5	8.5	7.5	11.3	11.3	19.2	14.6	14.1	8.0	12.7	7.5	4.2	15.5	6.6	5.6	6.6	11.7	7.5	9.9	10.8	12.2	9.9	7.5
	Elvas	2.1	10.4	12.5	10.4	4.2	6.3	14.6	8.3	8.3	8.3	10.4	4.2	14.6	8.3	2.1	2.1	10.4	6.3	12.5	2.1	10.4	14.6	8.3
	Estremoz	5.4	6.6	4.5	3.9	9.6	14.3	14.6	14.6	6.9	12.5	8.4	5.1	16.7	6.3	8.1	4.5	9.6	8.7	10.7	7.5	11.6	13.7	12.5
	Évora	6.1	4.2	5.4	3.7	11.5	18.4	13.2	13.2	7.8	10.3	8.8	6.1	15.9	4.2	7.8	4.4	9.8	6.9	13.0	12.3	12.0	14.0	10.5
	Sousel	8.5	8.5	6.4	12.8	6.4	10.6	8.5	25.5	8.5	2.1	6.4	12.8	21.3	2.1	0.0	2.1	19.1	6.4	4.3	8.5	14.9	10.6	10.6
Strongly disagree	Beja	3.8	10.8	3.3	1.4	12.2	9.4	4.7	5.2	6.1	0.5	3.8	0.0	2.3	25.4	0.9	1.4	1.4	0.9	2.3	2.8	2.8	3.3	1.4
	Elvas	2.1	8.3	2.1	2.1	8.3	12.5	0.0	2.1	6.3	0.0	4.2	0.0	2.1	33.3	4.2	2.1	0.0	0.0	2.1	2.1	4.2	0.0	2.1
	Estremoz	6.0	10.4	2.7	1.8	9.3	8.1	2.4	8.4	3.3	0.9	6.0	0.0	1.8	20.0	2.1	1.8	0.9	0.9	5.7	1.8	3.6	3.0	2.7
	Évora	4.2	6.6	2.7	1.7	10.5	8.3	1.0	7.8	5.4	0.5	5.6	0.0	2.9	21.1	2.0	2.0	1.0	0.5	2.9	2.5	2.5	2.7	2.5
	Sousel	2.1	14.9	2.1	0.0	10.6	10.6	8.5	4.3	2.1	2.1	2.1	0.0	0.0	17.0	0.0	0.0	2.1	0.0	17.0	0.0	6.4	2.1	0.0

Table A4. *Cont.*

Response Options	Municipality	Statements																					
		Pesticide Use and Consumer Attitudes								Healthy Practices and Disease Prevention							Sustainability and Health Promotion						
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**
Disagree	Beja	18.3	17.4	9.4	2.3	31.0	25.8	7.5	10.8	13.6	2.8	8.9	5.6	16.4	24.4	4.2	3.3	7.0	8.9	5.2	5.2	3.8	11.3	11.3
	Elvas	16.7	18.8	16.7	0.0	27.1	27.1	8.3	6.3	14.6	4.2	22.9	2.1	14.6	33.3	6.3	6.3	6.3	8.3	4.2	4.2	4.2	14.6	8.3
	Estremoz	15.5	17.3	7.5	2.4	30.1	27.5	9.9	10.7	16.7	3.3	6.6	7.8	19.1	24.5	4.2	3.6	8.4	7.8	5.7	5.7	5.1	11.9	9.3
	Évora	17.2	19.6	10.0	1.2	29.7	28.4	9.3	9.3	13.0	2.7	11.5	7.4	15.4	26.2	4.4	3.7	7.8	6.9	6.1	5.1	4.7	17.4	8.6
	Sousel	2.1	19.1	6.4	0.0	23.4	40.4	6.4	12.8	10.6	2.1	8.5	4.3	17.0	27.7	0.0	6.4	10.6	8.5	6.4	10.6	6.4	14.9	14.9
Agree	Beja	41.3	42.3	52.1	36.2	36.6	33.3	45.1	46.5	47.4	54.9	52.6	52.6	52.1	31.9	50.7	49.3	44.1	44.6	52.1	38.5	50.7	50.2	41.8
	Elvas	33.3	37.5	52.1	27.1	50.0	41.7	43.8	58.3	47.9	47.9	43.8	43.8	43.8	14.6	54.2	33.3	43.8	25.0	47.9	39.6	37.5	54.2	41.7
	Estremoz	43.0	40.3	51.0	39.4	42.1	35.5	51.6	47.8	47.8	51.9	52.2	51.0	51.0	36.1	47.2	45.1	46.0	44.8	50.1	42.7	54.3	49.3	37.6
	Évora	40.9	44.9	51.7	37.0	38.7	30.9	49.0	48.3	47.3	57.1	49.3	51.2	51.5	36.8	49.8	43.9	44.6	44.9	49.8	36.3	53.7	43.9	40.7
	Sousel	34.0	31.9	48.9	31.9	48.9	23.4	55.3	42.6	48.9	63.8	48.9	29.8	55.3	53.2	59.6	31.9	38.3	53.2	40.4	34.0	53.2	57.4	53.2
Strongly agree	Beja	29.1	21.1	27.7	48.8	8.9	12.2	28.2	23.5	24.9	29.1	27.2	37.6	13.6	11.7	38.5	39.4	35.7	38.0	30.5	42.7	30.5	25.4	38.0
	Elvas	45.8	25.0	16.7	60.4	10.4	12.5	33.3	25.0	22.9	39.6	18.8	50.0	25.0	10.4	33.3	56.3	39.6	60.4	33.3	52.1	43.8	16.7	39.6
	Estremoz	30.1	25.4	34.3	52.5	9.0	14.6	21.5	18.5	25.4	31.3	26.9	36.1	11.3	13.1	38.5	45.1	35.2	37.9	27.8	42.4	25.4	22.1	37.9
	Évora	31.6	24.8	30.1	56.4	9.6	14.0	27.5	21.3	26.5	29.4	24.8	35.3	14.2	11.8	36.0	46.1	36.8	40.9	28.2	43.9	27.2	22.1	37.7
	Sousel	53.2	25.5	36.2	55.3	10.6	14.9	21.3	14.9	29.8	29.8	34.0	53.2	6.4	0.0	40.4	59.6	29.8	31.9	31.9	46.8	19.1	14.9	21.3

2nd SEGMENT

For each statement tick with × the option that best reflects your opinion.

Pesticide Use and Consumer Attitudes

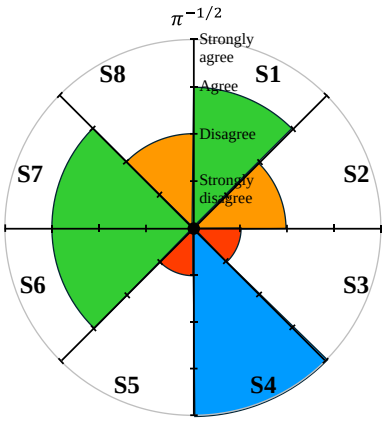
	Strongly Agree	Agree	Disagree	Strongly Disagree	I Don't Know
S1. Pesticides used in agriculture can leave residual amounts on food and water consumed.	☐	☒	☐	☐	☐
S2. The use of pesticides in agriculture is not necessary to ensure efficient food production.	☐	☐	☒	☐	☐
S3. Before buying food, I read the labels or tags on the packaging to determine if the food is organic.	☐	☐	☐	☒	☐
S4. Organic food (without pesticide use) is healthier than other food.	☒	☐	☐	☐	☐
S5. I am willing to pay a higher price for organic food.	☐	☐	☐	☒	☐
S6. Current regulations on pesticide use are enough to ensure the safety of food and drinking water.	☐	☒	☐	☐	☐
S7. Biological pest control in agriculture can reduce the impact of pesticides on food.	☐	☒	☐	☐	☐
S8. I am willing to change eating habits to reduce exposure to food with pesticide residues.	☐	☐	☒	☐	☐

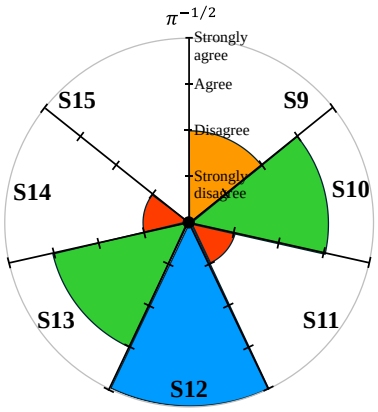
Healthy Practices and Disease Prevention

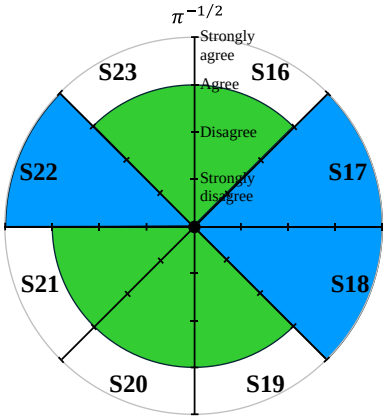
	Strongly Agree	Agree	Disagree	Strongly Disagree	I Don't Know
S9. I am aware of the potential health problems associated with exposure to pesticides in water and food.	☐	☐	☒	☐	☐
S10. Regular exposure to pesticides increases the risk of diseases such as cancer, hormonal or neurological disorders.	☐	☒	☐	☐	☐
S11. I strive to minimize pesticide exposure in my daily life.	☐	☐	☐	☒	☐
S12. Preventive measures, such as thoroughly washing food before consumption, can help reduce pesticide exposure.	☒	☐	☐	☐	☐
S13. Health authorities provide adequate information about the risks of pesticides to public health.	☐	☒	☐	☐	☐
S14. I discuss the health consequences of pesticide use in food production with my family or friends.	☐	☐	☐	☒	☐
S15. It is important to invest in research to develop healthier alternatives to conventional pesticides.	☐	☐	☐	☐	☒

Sustainability and Health Promotion

	Strongly Agree	Agree	Disagree	Strongly Disagree	I Don't Know
S16. Excessive use of pesticides harms the environment.	☐	☒	☐	☐	☐
S17. Reducing pesticide use is important for promoting agricultural sustainability.	☒	☐	☐	☐	☐
S18. Excessive pesticide use can negatively affect soil quality and biodiversity.	☒	☐	☐	☐	☐
S19. Sustainable agriculture practices that reduce pesticide use can contribute to preserving natural resources.	☐	☒	☐	☐	☐
S20. Reducing pesticide use in agricultural practices contribute to preserve human health, the environment, and improve food quality.	☐	☒	☐	☐	☐
S21. Environmental education and public awareness are important for promoting more sustainable agricultural practices.	☐	☒	☐	☐	☐
S22. Promoting sustainable agricultural practices is the responsibility of both producers and consumers.	☒	☐	☐	☐	☐
S23. Organic agriculture is a viable and sustainable alternative to conventional agriculture.	☐	☒	☐	☐	☐







Strongly Disagree Disagree Agree Strongly Agree

Figure A1. Student one's responses to statements S1 through S23, along with an illustrative summary of the method used to quantify qualitative data.

References

1. Khan, B.A.; Nadeem, M.A.; Nawaz, H.; Amin, M.M.; Abbasi, G.H.; Nadeem, M.; Ali, M.; Ameen, M.; Javaid, M.M.; Maqbool, R.; et al. Pesticides: Impacts on agriculture productivity, environment, and management strategies. In *Emerging Contaminants and Plants: Interactions, Adaptations and Remediation Technologies*; Aftab, T., Ed.; Springer: Cham, Switzerland, 2023; pp. 109–134. [CrossRef]
2. Kim, K.H.; Kabir, E.; Jahan, S.A. Exposure to pesticides and the associated human health effects. *Sci. Total Environ.* **2017**, *575*, 525–535. [CrossRef] [PubMed]
3. Rani, L.; Thapa, K.; Kanojia, N.; Sharma, N.; Singh, S.; Grewal, A.S.; Srivastav, A.L.; Kaushal, J. An extensive review on the consequences of chemical pesticides on human health and environment. *J. Clean. Prod.* **2021**, *283*, 124657. [CrossRef]
4. Mitra, S.; Saran, R.K.; Srivastava, S.; Rensing, C. Pesticides in the environment: Degradation routes, pesticide transformation products and ecotoxicological considerations. *Sci. Total Environ.* **2024**, *935*, 173026. [CrossRef] [PubMed]
5. Yang, M.; Wang, Y.; Yang, G.; Wang, Y.; Liu, F.; Chen, C. A review of cumulative risk assessment of multiple pesticide residues in food: Current status, approaches and future perspectives. *Trends Food Sci. Technol.* **2024**, *144*, 104340. [CrossRef]
6. Ahmad, M.F.; Ahmad, F.A.; Alsayegh, A.A.; Zeyaullah, M.; AlShahrani, A.M.; Muzammil, K.; Saati, A.A.; Wahab, S.; Elbendary, E.Y.; Kambal, N.; et al. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. *Heliyon* **2024**, *10*, e29128. [CrossRef]
7. Tudi, M.; Ruan, H.D.; Wang, L.; Lyu, J.; Sadler, R.; Connell, D.; Chu, C.; Phung, D.T. Agriculture Development, Pesticide Application and Its Impact on the Environment. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1112. [CrossRef]
8. FAO/WHO. *Report 2022—Pesticide Residues in Food—Joint FAP/WHO Meeting on Pesticide Residues*; Food and Agriculture Organization of the United Nations and World Health Organization Edition: Rome, Italy, 2023. [CrossRef]
9. Jankuloska, V.; Karov, I.; Pavlovska, G.; Kalevska, T.; Stamatovska, V.; Uzunoska, Z. Pesticide Residues in Food: Food Safety, Nutrition and Health. *Int. J. Food Technol. Nutr.* **2019**, *2*, 36–41.
10. Munir, S.; Azeem, A.; Zaman, M.S.; Haq, M.Z.U. From field to table: Ensuring food safety by reducing pesticide residues in food. *Sci. Total Environ.* **2024**, *922*, 171382. [CrossRef]
11. Leskovac, A.; Petrović, S. Pesticide Use and Degradation Strategies: Food Safety, Challenges and Perspectives. *Foods* **2023**, *12*, 2709. [CrossRef]
12. Aryal, S.; Aryal, L.N. Pesticide Residue and Food Safety: Retrospection and Prospects. In *Emerging Solutions. In Sustainable Food and Nutrition Security*; Ghosh, S., Panda, A.K., Jung, C., Bisht, S.S., Eds.; Springer: Cham, Switzerland, 2023; pp. 183–210. [CrossRef]
13. Gurbuz, I.B. Analysis in Terms of Environmental Awareness of Farmers' Decisions and Attitudes: Reducing Pesticide Use and Risks. *Sustainability* **2024**, *16*, 4323. [CrossRef]
14. Barbosa, M.W. Government Support Mechanisms for Sustainable Agriculture: A Systematic Literature Review and Future Research Agenda. *Sustainability* **2024**, *16*, 2185. [CrossRef]
15. Farm to Fork: New Rules to Reduce the Risk and Use of Pesticides in the EU. Available online: https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_3694 (accessed on 31 October 2024).
16. Hsu, C.-L.; Chen, M.-C. Explaining consumer attitudes and purchase intentions toward organic food: Contributions from regulatory fit and consumer characteristics. *Food Qual. Prefer.* **2014**, *35*, 6–13. [CrossRef]
17. Koch, S.; Epp, A.; Lohmann, M.; Böl, G.F. Pesticide Residues in Food: Attitudes, Beliefs, and Misconceptions among Conventional and Organic Consumers. *J. Food Prot.* **2017**, *80*, 2083–2089. [CrossRef]
18. Ssemugabo, C.; Bradman, A.; Ssempebwa, J.C.; Guwatudde, D. Consumer awareness and health risk perceptions of pesticide residues in fruits and vegetables in Kampala metropolitan area in Uganda. *Environ. Health Insights* **2023**, *17*, 1–8. [CrossRef]
19. Roth, C.E. *Environmental Literacy: Its Roots, Evolution, and Directions in the 1990s*; ERIC/CSMEE Publications: Columbus, OH, USA, 1992.
20. Hollweg, K.S.; Taylor, J.R.; Bybee, R.W.; Marcinkowski, T.J.; McBeth, W.C.; Zoido, P. *Developing a Framework for Assessing Environmental Literacy*; North American Association for Environmental Education: Washington, DC, USA, 2011.
21. McClaren, M. Revisioning environmental literacy in the context of a global information and communications ecosphere. *J. Environ. Educ.* **2019**, *50*, 416–435. [CrossRef]
22. Fang, W.T.; Hassan, A.; LePage, B.A. Environmental Literacy. In *The Living Environmental Education. Sustainable Development Goals Series*; Springer: Singapore, 2023; pp. 93–126. [CrossRef]
23. Cincera, J.; Kroufek, R.; Bogner, F.X. The perceived effect of environmental and sustainability education on environmental literacy of Czech teenagers. *Environ. Educ. Res.* **2022**, *29*, 1276–1293. [CrossRef]
24. Akçay, S.; Şengül, H. A Study on Environmental Literacy of Middle School Students. *J. Ahmet Kelesoglu Educ. Fac.* **2023**, *5*, 139–169. [CrossRef]
25. Miftahuddin, M.; Roshayanti, F.; Siswanto, J. Profile of Environmental Literacy Students of SMPN 3 Teluk Keramat. *Indones. J. Educ.* **2023**, *3*, 44–54. Available online: https://injoe.org/index.php/INJOE/article/view/47/47 (accessed on 10 October 2024).
26. Carducci, A.; Fiore, M.; Azara, A.; Bonaccorsi, G.; Bortoletto, M.; Caggiano, G.; Calamusa, A.; De Donno, A.; De Giglio, O.; Dettori, M.; et al. Pro-environmental behaviors: Determinants and obstacles among Italian university students. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3306. [CrossRef]

27. Sasa, T.; Ahmad, W.A.; Bahtiti, N.H.; Abujaber, M.; Adeyleh, A.; Miri, O. Assessment Level of Environmental Literacy among Applied Science Private University (ASU) Students. *WSEAS Trans. Environ. Dev.* **2022**, *18*, 1012–1020. [CrossRef]
28. Biswas, A. A nexus between environmental literacy, environmental attitude and healthy living. *Environ. Sci. Pollut. Res. Int.* **2020**, *27*, 5922–5931. [CrossRef] [PubMed]
29. Hou, W.-H.; Huang, Y.-C.; Lu, C.-Y.; Chen, I.-C.; Lee, P.-C.; Lin, M.-Y.; Wang, Y.-C.; Sulistyorini, L.; Li, C.-Y. A national survey of ambient air pollution health literacy among adult residents of Taiwan. *BMC Public Health* **2021**, *21*, 1604. [CrossRef]
30. Witten, I.H.; Frank, E.; Hall, M.A.; Pal, C.J. *Data Mining—Practical Machine Learning Tools and Techniques*, 4th ed.; Morgan Kaufmann: Cambridge, MA, USA, 2017.
31. Haykin, S. *Neural Networks and Learning Machines*, 3rd ed.; Prentice Hall: New York, NY, USA, 2009.
32. Rumelhart, D.; Hinton, G.; Williams, R. Learning Internal Representation by Error Propagation. In *Parallel Distributed Processing: Explorations in the Microstructure of Cognition: Foundations*; Rumelhart, D.E., McCleland, J.L., Eds.; MIT Press: Cambridge, MA, USA, 1986; pp. 318–362. [CrossRef]
33. Calabrese, G.G.; Falavigna, G.; Ippoliti, R. Financial constraints prediction to lead socio-economic development: An application of neural networks to the Italian market. *Socio-Econ. Plan. Sci.* **2024**, *95*, 101973. [CrossRef]
34. Sumi, K.V. Neural network-based liquidity risk prediction in Indian private banks. *Intell. Syst. Appl.* **2024**, *21*, 200322. [CrossRef]
35. Wang, C.; Evans, K.; Hartley, D.; Morrison, S.; Veidt, M.; Wang, G. A systematic review of artificial neural network techniques for analysis of foot plantar pressure. *Biocybern. Biomed. Eng.* **2024**, *44*, 197–208. [CrossRef]
36. Liao, Y.; Tang, Z.; Gao, K.; Trik, M. Optimization of resources in intelligent electronic health systems based on Internet of Things to predict heart diseases via artificial neural network. *Heliyon* **2024**, *10*, e32090. [CrossRef]
37. Obaido, G.; Mienye, I.D.; Egbelowo, O.F.; Emmanuel, I.D.; Ogunleye, A.; Ogbuokiri, B.; Mienye, P.; Aruleba, K. Supervised machine learning in drug discovery and development: Algorithms, applications, challenges, and prospects. *Mach. Learn. Appl.* **2024**, *17*, 100576. [CrossRef]
38. AlShannaq, H.; Aly, A.M. Review of Artificial Neural Networks for Wind Turbine Fatigue Prediction. *SDHM Struct. Durab. Health Monit.* **2024**, *18*, 707–737. [CrossRef]
39. Zhang, Y.; Guo, K.; Wang, C.; Zhang, J.; Wang, Y.; Xi, T.; Su, G.H.; Qiu, S. Artificial neural network for geometric design and optimization of three-stage segmented thermoelectric generators. *Appl. Therm. Eng.* **2024**, *256*, 124077. [CrossRef]
40. Yadav, V.; Yadav, A.K.; Singh, V.; Singh, T. Artificial neural network an innovative approach in air pollutant prediction for environmental applications: A review. *Results Eng.* **2024**, *22*, 102305. [CrossRef]
41. Kantarcioglu, O.; Kocaman, S.; Schindler, K. Artificial neural networks for assessing forest fire susceptibility in Türkiye. *Ecol. Inform.* **2023**, *75*, 102034. [CrossRef]
42. Rehman, M.A.; Abd-Rahman, N.; Ibrahim, A.N.H.; Kamal, N.A.; Ahmad, A. Estimation of soil erodibility in Peninsular Malaysia: A case study using multiple linear regression and artificial neural networks. *Heliyon* **2024**, *10*, e28854. [CrossRef] [PubMed]
43. Fernandes, A.; Chaves, H.; Lima, R.; Neves, J.; Vicente, H. Draw on artificial neural networks to assess and predict water quality. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *612*, 012028. [CrossRef]
44. Bishop, C.M.; Bishop, H. *Deep Learning—Foundations and Concepts*, 1st ed.; Springer: Cham, Switzerland, 2024.
45. Aggarwal, C. *Neural Networks and Deep Learning: A Textbook*, 2nd ed.; Springer: Cham, Switzerland, 2023.
46. Fernandes, A.; Vicente, H.; Figueiredo, M.; Neves, M.; Neves, J. An evaluative model to assess the organizational efficiency in training corporations. In *Future Data and Security Engineering*; Lecture Notes in Computer Science; Dang, T., Wagner, R., Küng, J., Thoai, N., Takizawa, M., Neuhold, E., Eds.; Springer: Cham, Switzerland, 2016; Volume 10018, pp. 415–428. [CrossRef]
47. Cohen, L.; Manion, L.; Morrison, K. *Research Methods in Education*, 8th ed.; Routledge: New York, NY, USA, 2017.
48. DeKetele, J.-M.; Roegiers, X. *Méthodologie du Recueil d'Informations: Fondements des Méthodes d'Observation, de Questionnaire, d'Interview et d'Études de Documents*, 5th ed.; DeBoeck Universite: Paris, France, 2016.
49. Patton, M.Q. *Qualitative Research and Evaluation Methods: Integrating Theory and Practice*, 4th ed.; SAGE Publications Inc: Thousand, OH, USA, 2015.
50. McMillan, J.; Schumacher, S. *Research in Education: Evidence-Based Inquiry*, 7th ed.; Prentice Hall: New York, NY, USA, 2009.
51. Bell, J. *Doing Your Research Project: A Guide for First-Time Researchers in Education, Health and Social Science*, 5th ed.; Open University Press: Maidenhead, UK, 2010.
52. Frank, E.; Hall, M.; Witten, I.H.; The WEKA Workbench. Online Appendix for "Data Mining: Practical Machine Learning Tools and Techniques" Morgan Kaufmann, Fourth Edition. 2016. Available online: https://ml.cms.waikato.ac.nz/weka/Witten_et_al_2016_appendix.pdf (accessed on 10 October 2024).
53. Hall, M.; Frank, E.; Holmes, G.; Pfahringer, B.; Reutemann, P.; Witten, I.H. The WEKA data mining software: An update. *SIGKDD Explor.* **2009**, *11*, 10–18. [CrossRef]
54. Harris, C.R.; Jenkins, M. Gender Differences in Risk Assessment: Why do Women Take Fewer Risks than Men? *Judgm. Decis. Mak.* **2006**, *1*, 48–63. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.