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An Examination of Knowledge, Thoughts, and Attitudes Toward Microplastics in the Context of Science Teacher Education

Abstract

This study analyzes the knowledge levels, perceptions, and attitudes of science teacher candidates in Turkey regarding microplastics, aiming to inform educational programs that enhance awareness of this global environmental issue. The research data were collected using a data collection instrument designed to evaluate the knowledge, risk perceptions, and waste-reduction attitudes regarding microplastics of a total of 142 science teacher candidates, aged between 19 and 22. Data were collected using a tool with three dimensions and seven open-ended questions and analyzed through content analysis. Findings revealed that while most participants defined microplastics based on size, only a small proportion provided scientifically accurate definitions. Participants exhibited varying awareness levels regarding the environmental impacts of microplastics and potential solutions, but knowledge alone did not guarantee behavior change. Factors such as living conditions, lack of awareness, and sensitivity levels posed significant challenges to altering habits. These results highlight the need for educational programs that go beyond knowledge dissemination to foster sustainable behavioral changes through practical applications. Integrating microplastic-related topics into curricula at all levels is essential to enhance awareness and encourage environmentally responsible behaviors. Addressing these gaps in education can help mitigate the impacts of microplastic pollution and contribute to global sustainability efforts in a meaningful and lasting way. The results of this study indicate that revealing teacher candidates' knowledge, thoughts, and attitudes regarding microplastics represents an important step toward the development of sustainable education programs.

Key words: Attitude, Behavior, Environment, Microplastic pollution, Teacher Candidate.

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SDG Keywords: Good Health and Well-being (SDG 3), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Life Below Water (SDG 14), Life on Land (SDG 15)

INTRODUCTION

Concepts such as environmental sensitivity, awareness of environmental issues, and sustainability have increasingly become integral to our lives. This trend is unfortunately driven by the constant emergence of new threats of varying scales, necessitating a focus on identifying these problems and seeking effective solutions as a fundamental pursuit of humanity and science. Among these challenges, microplastics stand out as a significant threat. The conveniences offered by plastics in various aspects of life have led to a rapid increase in their use and consequently to the widespread production of plastics, bringing microplastic pollution to the forefront. Microplastics, which are formed by the breakdown of larger plastic materials, infiltrate the air, soil, water, seas, and oceans. As a result, their potential for bioaccumulation in the food chain has increasingly raised concern and interest (Kowalski, 2016). Furthermore, microplastics are highlighted as significant contributors to the global rise in environmental pollution (Duis & Coors, 2016). The United Nations' Sustainable Development Goals for 2030 illustrate the severity of the microplastic pollution threat, aligning it with goals such as Goal 3 (Good Health and Well-being), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), Goal 14 (Life Below Water), and Goal 15 (Life on Land) (United Nations Development Programme [UNDP], 2024).

Although the impact of environmental pollution is evident, humanity's dependence on plastic materials has created a complex relationship with plastics (Menzel et al., 2021). Over the years, this dependence has led to a significant increase in exposure to microplastics (Usman et al., 2020).

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In addition to seafood, individuals are exposed to microplastics through contaminated drinking water, salt, sugar, fruits, vegetables, meats, dairy products, and grains (Ziani et al., 2023). Alarmingly, many people remain unaware of this danger or lack adequate knowledge about the pollution caused by microplastics and their effects. However, disseminating information about the existence and risks of plastic or microplastic-related hazards can be assumed to enhance societal awareness, leading to attitudes and behaviors capable of mitigating the issue (Dowarah et al., 2022). Education that fosters sustainability—encouraging individuals to "live today with tomorrow in mind"—can significantly contribute to addressing this challenge. According to Anderson et al. (2016), the increasing use of plastics constitutes a global sustainability issue. Similarly, Luo et al. (2022) identify plastic pollution as a pressing global concern. Vazquez and Garcia-Ael (2021) even describe microplastics as an "invisible enemy." Addressing microplastic pollution and its effects requires actions such as formulating waste management regulations, promoting reuse, reducing consumption, recycling, and education at local, regional, and global levels. Given the current scale of the problem, it is evident that prioritizing education to raise awareness is crucial. Despite the rapid growth in knowledge about microplastics, comprehensive data on public perceptions remain insufficient (Raab et al., 2021). Therefore, effectively and accurately communicating scientific findings on microplastics to the public is of critical importance.

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Therotical Framework

Small in name, big in impact

Plastic waste undergoes various transformations in the environment, often breaking down from larger plastic materials into smaller particles, such as microplastics and nanoplastics (Yee et al., 2021; Zhang et al., 2021). While microplastics are defined differently depending on their source

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and size, Hartmann et al. (2019) propose that microplastics should not only be classified by size but also by chemical composition, shape, origin, and color. For instance, they suggest defining microplastics within the size range of 1–1000 µm. However, the most widely accepted definition, as noted by Arthur et al. (2009), classifies microplastics as particles smaller than 5 mm.

The production of plastics has increased dramatically over the past 70 years, from just two million tons in 1950 to over 450 million tons annually today (Ritchie et al., 2023). Plastics have become ubiquitous in our lives due to advancements in chemical and material sciences. As plastic production increases, microplastics have become a new indicator of humanity's growing plastic footprint, posing significant risks to overall organism health and sustainable environments (Aslan, 2018). Most plastics produced today originate from fossil fuels—such as petroleum, natural gas, and coal—making them non-renewable petrochemical products. While these plastics are inexpensive and possess unique physical properties, they are highly engineered materials that degrade differently based on their chemical composition, often taking decades or centuries to decompose completely (Chamas et al., 2020). Only 18% of global plastic waste is recycled, 24% is incinerated, and the remaining 58% is discarded in landfills or natural environments where it accumulates for extended periods (Napper & Thompson, 2020).

Microplastic pollution in soil contributes to increased greenhouse gas emissions, exacerbating climate change (Chia et al., 2023). Recent studies have shown that plastics also interfere with the carbon sequestration capacity of marine environments, directly impacting climate change (Ford et al., 2022; Kakar et al., 2023). For example, Shen et al. (2023) observed that plastic pollution in marine environments hinders carbon storage while triggering greenhouse gas emissions into the atmosphere, further contributing to climate change. Thus, research highlights that microplastics pose significant threats not only to humans but also to marine ecosystems (Sharma et al., 2024).

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According to recent statistics, plastics account for 80% of total marine pollution, with approximately 8–10 million metric tons of plastic waste entering oceans annually (Fava, 2022). Over the last two decades, plastic waste in marine ecosystems has emerged as an international environmental crisis. However, regulatory efforts to address this issue have been insufficient, prompting calls for plastic waste to be classified as hazardous material (Rochman et al., 2018). Research shows that approximately 10% of produced plastics enter the oceans directly, and that microplastics account for 92% of the 5.25 trillion plastic particles found on the ocean surface (Eriksen et al., 2014; Rezania et al., 2018; Lusher, 2015; Thompson, 2015). Eriksen et al. (2014) and Van Sebille et al. (2015) reported that between 98,000 and 268,000 tons of microplastics are floating in the oceans. Since the structures and densities of microplastics vary depending on environmental conditions, all types of microplastics can be observed across different layers of the marine ecosystem (GESAMP, 2015; Xuan & Jianlong, 2019). Significant amounts of microplastics accumulated on the ocean floor (Woodall et al., 2014) have also been noted as potentially accumulating in organisms through the food chain (Seltenrich, 2015). Taken together, these findings clearly demonstrate that microplastics pollute not only oceans but also freshwater ecosystems.

Awareness of microplastics and their associated dangers serves as a fundamental starting point for developing attitudes and behaviors to address this issue. Questions such as "How can we eliminate microplastics from our lives?" or "How can we use them more sparingly and responsibly?" highlight critical avenues for solutions. However, findings in the environmental education literature regarding the influence of general attitudes on environmentally beneficial behaviors indicate that the attitude–behavior relationship is often relatively weak. This situation suggests that

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creating cognitive awareness alone is not sufficient; social norms, perceived behavioral control, and contextual conditions also need to be taken into account.

At this point, one of the ways to address the problem of microplastics lies in education and informational activities. Within the framework of Ajzen and Fishbein's (1980) Theory of Reasoned Action, individuals' intentions to perform a particular behavior are shaped by their attitudes toward that behavior and by perceived subjective norms. Acquiring knowledge is a fundamental precondition for understanding the possible consequences of behaviors and evaluating these consequences, and it plays a critical role in the formation of attitudes and intentions. From this perspective, increasing the level of knowledge regarding microplastics may be regarded as an important variable that can influence individuals' risk perceptions, attitudes, and ultimately their behaviors. At the same time, social norms and societal expectations are also decisive in shaping behaviors related to the use of microplastics and plastic consumption. The theoretical framework adopted in this study examines, on the basis of Ajzen and Fishbein's (1980) behavioral approach, the effects of knowledge, awareness, and risk perception regarding microplastics on the attitudes and intentions associated with environmentally responsible behaviors.

The role of educational activities in increasing awareness and knowledge of environmental issues is widely documented in the literature (Avelar & Farina, 2022; Gherheş et al., 2022; Liu et al., 2020; Orion & Leshem, 2016; Situmorang et al., 2022). Considering future generations, it is essential that students and educators—groups engaged heavily in science communication within schools—are the most aware of the risks posed by microplastics. In the context of environmental problems such as microplastics, knowledge construction often requires relating abstract concepts to concrete experiences, meaningfully integrating new information with students' prior

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knowledge, and guiding this process through a constructivist instructional approach on the part of teachers. Despite increased media coverage of microplastics and the pollution they cause, these topics have yet to be significantly integrated into school curricula (Janauskova et al., 2020). Incorporating comprehensive information and awareness programs about microplastics into education systems could enable future generations to act more responsibly and develop more effective solutions to environmental problems.

Adding topics such as microplastics and environmental pollution to school programs can significantly enhance knowledge and raise awareness. For instance, Hogan and Urban-Rich (2024) developed and tested a new science curriculum aimed at raising middle school students' awareness and understanding of microplastic pollution. The curriculum was implemented with 84 eighth-grade students (ages 13–15) and assessed through pre- and post-course surveys. Before the course, 90% of students defined microplastics merely as "small" or "tiny" plastic pieces, and 10% admitted having no prior knowledge. After the course, all students could provide a definition, with 23% offering a scientifically accurate definition of microplastics (<5 mm in size). Additionally, the number of definitions including elements of microplastic pollution (e.g., its sources or effects) increased. Forakis et al. (2024) designed a course-based undergraduate research experience (CURE) focusing on detecting microplastics in a local watershed. Integrated into a year-long general chemistry lab course in collaboration with an environmental conservation organization, the program involved water sampling from a local river to identify and quantify microplastics. Students analyzed the data and discussed findings, with pre- and post-course assessments revealing enhanced scientific self-concept and environmentally conscious behaviors.

Such innovative and practical educational approaches provide effective methods for fostering both scientific awareness and environmentally friendly behaviors. Interventions aimed at reducing

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waste often highlight the importance of social norms and education (Byerly et al., 2018). For example, presenting information about plastic recycling and microplastic formation through infographics has proven to be an effective educational tool in the United States (Reed & Chen, 2022). Similarly, Luo et al. (2022) found that visualizing the impacts of plastic waste on marine life can effectively encourage the reduction of plastic waste. Understanding pollution's effects serves as a critical determinant in fostering eco-friendly behaviors such as recycling, reusing, and reselling (Khan et al., 2019). Influencing consumer behavior has also become a priority for European environmental policies (Hartley et al., 2020). However, it is widely recognized that messages and interventions need to be tailored to specific target audiences and communities (Brennan & Portman, 2017; Jefferson et al., 2014). Research highlights that current educational programs often fail to adequately address microplastics and related environmental issues, or in some cases, overlook them entirely. Addressing these gaps is crucial for fostering more effective environmental awareness and behavioral changes. By focusing educational programs on the issues surrounding microplastics, society can not only improve knowledge levels but also promote the adoption of environmentally responsible behaviors. This approach is pivotal in addressing the challenges posed by microplastic pollution and ensuring a more sustainable future.

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Relevant Literature

The pervasiveness of microplastics necessitates the expansion of research on this issue across different disciplines. The presence of microplastics in various environments and products necessitates broad dissemination of knowledge and awareness. Consequently, studies on microplastics address diverse dimensions of the issue. For example, Dowarah et al. (2022) conducted a study with 220 students from various educational institutions in India, finding that 61.5% of participants had heard of microplastics, but only 40% were aware that microplastics

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could be present in everyday consumer products. They concluded that the severity of microplastic pollution was not yet deeply understood by students.

Similarly, students' levels of knowledge and perceptions regarding microplastics vary across different countries. Raab and Bogner (2021) examined 267 students at a public university in Germany, using surveys to measure conceptual understanding, risk perception, behavior, and knowledge about microplastics. Their findings revealed that 36% classified microplastics as "very dangerous," 55% as "dangerous," and only 3% as "not very dangerous."

In the Czech Republic, Janoušková et al. (2020) surveyed approximately 400 students from seven universities. They observed that more than one-third relied on mass media as their primary information source and possessed only partial knowledge of microplastics. While over 80% correctly identified microplastic sources, only 44% could explain both the sources and formation mechanisms, and only 4% identified the correct size range (5 mm to 1 μm).

One reason for the low level of awareness regarding microplastics is that knowledge about the issue is often acquired in a limited manner through the media. Henderson and Green (2020) studied public knowledge and perceptions of microplastics among six focus groups, revealing that most participants were unaware of microplastics. However, environmentally conscious individuals were familiar with the concept of "microbeads" through media coverage on regulations. Anderson et al. (2016) similarly found that environmental activists were aware of plastic microbeads in personal care products, but there was a lack of awareness among beauty trainees and university students. Chang (2015) assessed polyethylene microbeads in popular U.S. cosmetic brands, concluding that consumers were largely unaware of the microplastics in their products. Yan et al.

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(2020) explored microfiber pollution (MFP) in the sportswear industry, finding that participants were unclear about the distinction between microfibers and microplastics.

However, it has also been observed in some studies that awareness of the sources and health effects of microplastics is comparatively higher. Oleksiuk et al. (2022) investigated knowledge among 410 Polish students, finding that most could accurately define microplastics, identify sources, and recognize health risks such as accumulation in human organs. Similarly, Praveena (2024) studied 750 participants in Malaysia, reporting that while awareness of plastic waste was high, only 54.2% had heard of the term “microplastic,” and over 50% recognized associated risks.

Recent studies indicate that although the risks of microplastics are known, the awareness that translates into behavior has not developed sufficiently. Park et al. (2024) evaluated awareness of microplastics in face masks among 1,000 participants, finding high awareness of microplastic risks but limited comprehension of their implications, particularly among younger individuals. Azmi et al. (2023) assessed 105 university students' knowledge and attitudes toward microplastic pollution, highlighting moderate awareness and concluding that education is critical to reducing microplastic pollution among younger generations. Similarly, Righi et al. (2024) studied 220 university students in Italy, identifying significant knowledge gaps about the definition, sources, and pathways of human exposure to microplastics and nanoplastics.

Overall, the literature indicates that there are significant gaps between knowledge, perception, and behavior with respect to microplastics. These studies collectively demonstrate that gaps in knowledge about microplastics, their sources, and their risks persist across populations, especially among younger generations. Even when the dangers are recognized, translating this knowledge

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into actionable behavior remains a challenge, emphasizing the need for education and targeted awareness campaigns to mitigate the impact of microplastic pollution.

Purpose and Significance

The widespread use of plastic materials in daily life and the rapidly growing body of knowledge on microplastics have heightened the need to evaluate societal awareness and perceptions regarding this issue. While the adverse effects of microplastics on the environment and living organisms have been scientifically proven, effectively and accurately conveying this information to society is of utmost importance. In this context, identifying the knowledge, perceptions, and behaviors of teacher candidates, who play a critical role in science communication, represents a significant step toward developing sustainable educational programs. Teacher candidates internalize sustainable values through knowledge, pedagogical experience, and reflection, and subsequently develop action competence, moving to the stage of putting what they know into practice. As their professional identity strengthens, these values are reflected as behaviors in classroom practices and school culture. This study aims to analyze the knowledge levels, perceptions, and attitudes of science teacher candidates regarding microplastics and to contribute to the design of educational programs aimed at increasing awareness about this issue. Enhancing teacher candidates' awareness could have a foundational impact on instilling environmental consciousness in their students and, consequently, in society. Additionally, the findings could guide the development of more comprehensive educational materials addressing the environmental impacts of microplastics within teacher training programs.

Research Problem

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This study seeks to answer the following research questions:

- What is the knowledge level of science teacher candidates regarding microplastics, a global environmental issue, and their effects on the environment and living organisms?
- What are the perceptions and attitudes of teacher candidates regarding microplastics and solutions to this problem?
- What tendencies and attitudes do teacher candidates exhibit in behaviors aimed at reducing the impacts of microplastics?

The answers to these questions will provide insights into the educational adjustments needed to enhance teacher candidates' knowledge and behaviors related to microplastics and broader environmental issues.

METHOD

A case study approach was employed for this research. Case studies are well-suited for in-depth examination of specific events, conditions, or phenomena (Creswell, 2012). Two primary reasons guided the selection of this method: (i) to provide a detailed account of how and to what extent the concept of microplastics is embedded in daily life, and (ii) to identify the behaviors and risk perceptions of teacher candidates concerning microplastics. In this context, the unit of analysis (Yin, 2013) is the knowledge, behaviors, and risk perceptions of teacher candidates regarding microplastics.

Participants

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This study was carried out during the fall semester of the 2023–2024 academic year with the voluntary participation of 142 science teacher candidates from a public university in Turkey. Of the students, 55 are in their second year, 61 are in their third year, and 26 are in their fourth year of study. Purposeful sampling was used to select participants. Since the participants were enrolled in a science teacher education program, they were expected to have an interest in and sensitivity toward the globally significant issue of microplastics.

The participants' high school curricula did not directly cover microplastics, although some mention of plastic waste was made. Similarly, while university courses such as environmental chemistry, waste management, and environmental education exist, plastic pollution is not treated as a distinct topic in these curricula.

Before participation, teacher candidates were provided with comprehensive information about the study's objectives and data evaluation methods. To ensure confidentiality, their responses were anonymized using codes such as S1, S2, S3. This process was implemented to maintain ethical standards and ensure the reliability of the data collection and analysis processes.

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Data Collection Tool

The data were collected using a data collection instrument designed to assess the knowledge, risk perceptions, and waste-reduction attitudes related to microplastics of a total of 142 science teacher candidates aged between 19 and 22. The instrument consisted of three dimensions and seven open-ended questions. In preparing these questions, those used in the study by Raab and Bogner (2021) were examined, and since their questions were found to be primarily descriptive of existing conceptions, additional open-ended questions focusing on awareness, prediction, and solution generation were developed for this study. Furthermore, expert opinions were sought to best reflect

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the intended dimensions, and consensus was reached among the experts. For content validity, the questions were developed with reference to the literature. Questions addressing the definition, sources, and effects of microplastics were aligned with scientific frameworks. Coding categories were derived from students' responses and compared with the literature to ensure conceptual validity. The prepared instrument was administered during class time to students who volunteered to respond to the survey. Teacher candidates were given one class hour to complete the questions, and necessary clarifications were provided to participants who experienced any uncertainties during the process. This method offered an effective approach to enabling teacher candidates to clearly express their views and to obtain data aligned with the aims of the study. Table 1 presents the questions included in the data collection tool.

Data Analysis

The data obtained in this study were analyzed using the content analysis method. Responses provided by the teacher candidates for each question were evaluated by creating codes and categories. The coding process was conducted independently by two academic experts in physics and chemistry education. Subsequently, the codes were compared, and final coding results were determined through consensus. The coding agreement among researchers was assessed using the method proposed by Miles and Huberman (1994), with an agreement rate of 92%. For discrepancies in coding, researchers convened to re-examine and discuss student responses. Through this iterative process, consensus was achieved, ensuring 100% agreement on the coding outcomes. With the participation of two independent coders in the content analysis, reliability was ensured. This is a fundamental method for enhancing reliability in qualitative research. The analysis of teacher candidates' responses to the questions in the data collection instrument revealed three dimensions: knowledge of the microplastics concept, risk perception, and waste-reduction

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behavior. These findings were presented in tables, including categories for each question type and examples of participant responses. Additionally, the tables provided the number and percentage of participants corresponding to each category, offering a detailed view of the distribution of perceptions regarding microplastics.

This systematic approach aimed to provide a comprehensive understanding of teacher candidates' perceptions and behaviors related to microplastics and to present these findings clearly and concisely.

RESULTS AND DISCUSSION

In this section, the findings and results obtained from the questions in the data collection tool directed to teacher candidates to address the research problem are presented. A total of seven open-ended questions were asked to 142 science teacher candidates, covering the dimensions of knowledge, risk perception, and behavior.

Knowledge Status

To determine the knowledge levels of teacher candidates, the first question, *"What are microplastics?"* was posed. As shown in Table 2, the responses were categorized into four groups. When these categories are examined, it is seen that teacher candidates, as expected, largely emphasized the size characteristic (85.2%) when defining the concept of microplastics. Among those who defined microplastics based on size, 39.4% incorrectly described them as “the smallest structure of plastic,” while 20.4% provided an incomplete definition by stating that they are “microscopic plastics too small to be seen with the naked eye,” thus drawing attention only to their size. However, only 9.2% provided the scientifically accepted definition of microplastics as

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"plastics smaller than 5 mm." After size, the second most common definition related to the presence of microplastics in nature, with 13.4% describing them as "materials causing environmental pollution." Other definitions included references to non-biodegradability and water insolubility. Although these definitions contain correct information, they do not represent the accurate answer to the intended question. Moreover, it is noteworthy that a small proportion of teacher candidates (1.4%) held inaccurate knowledge by defining microplastics as “substances that do not mix with nature.” Some participants (11.2%) highlighted the harmful nature of microplastics, describing them as dangerous to human and other living organisms' health. This response is correct in terms of its impact dimension; however, it does not constitute the proper answer to the given question. Additionally, 14.0% focused on the formation process, defining microplastics as "structures formed by the degradation, fragmentation, or conversion of plastics and composed of polymers." These definitions contain valid information about the formation of microplastics; however, they do not represent the intended definition.

These findings indicate that most teacher candidates define microplastics by their size, but the proportion of those offering scientifically accurate and comprehensive definitions is notably low. The results align with Righi et al.'s (2024) study in Italy, which identified significant knowledge gaps among university students concerning microplastics. Similarly, Raab and Bogner's (2021) research in Germany found that 78% of university students defined microplastics as "small plastic particles," while 5% referred to them only as "plastic." Oleksiuk et al. (2022) reported that over 68% of educated young adults (ages 18–24) defined microplastics as "tiny pellets formed from plastics and the breakdown of plastics." Furthermore, a study by Willis and Fytianos (2022) assessing motivation to change daily habits to minimize plastic pollution found that two-thirds of

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participants had limited knowledge of microplastics, while one-third admitted knowing very little or nothing about them.

The second question posed to assess knowledge levels was *"What materials cause microplastic pollution?"* As shown in Table 3, the responses were grouped into three categories. The first category, petroleum products, accounted for 46.4% of responses. Some participants mentioned specific products like plastic bottles, shopping bags, and vehicle tires, while most provided the general answer "plastic products." These responses are consistent with the literature. The second category, industrial products, included cosmetics, petrochemical products, textiles, packaging materials, cleaning products, mining, and nuclear power plants, comprising 41.6% of responses. The third category, waste, primarily referred to litter left in nature, followed by pharmaceuticals, medical waste, industrial waste, electronic waste, and batteries. Some of the wastes mentioned in these categories, such as litter discarded into nature and batteries, can indeed contribute to microplastic pollution. In addition, products such as pharmaceuticals and hospital waste may or may not generate microplastic pollution, depending on disposal practices that vary from country to country. Students, however, assumed that these materials would cause microplastic pollution without taking such details into account. Righi et al. (2024) found that students identified "primary sources releasing microplastics directly into the environment" as the most challenging question, with only 7.7% answering correctly. Similarly, Dowarah et al. (2022) noted that while most participants in their study in India recognized plastic waste as a source of environmental problems, they primarily associated plastic pollution with marine life and were unaware of its contribution via daily consumer products. In the study conducted by Raab and Bogner (2021) with university students, it was found that students generally identified household sources such as plastic packaging and cosmetic products, while overlooking other sources such as fibers from hygiene

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products and plastics in organic waste. In the study by Oleksiuk et al. (2022), the majority of participants (49.5%) identified synthetic textiles and vehicle tires used in traffic as the main sources of microplastics, additionally citing urban air and cosmetic products among the sources.

The third question, *"What environments are affected by microplastic pollution?"*, categorized responses into ecosystems, industrial areas, and others in Table 4. Within ecosystems, water environments were most frequently mentioned, including sewage, oceans and seas, rivers, lakes, and drinking water. A total of 48.5% of participants associated microplastic pollution with water ecosystems. Land ecosystems, such as soil and glaciers, accounted for 8.4%, while atmospheric ecosystems were mentioned by 1.4%. It is observed that the responses align with the information in the literature. Industrial areas, encompassing factories, industrial sites, packaged foods, and canned goods, represented 19.6% of responses. Raab and Bogner's (2021) study similarly found that few students considered groundwater contamination as a microplastic issue. Oleksiuk et al. (2022) observed that while participants recognized water pollution by microplastics, they overlooked other environmental elements.

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To assess knowledge statuses, the fourth question, *"Where did you hear about the concept of microplastics?"*, divided responses into school, media, and other categories in Table 5. The internet was the primary source for 50.7% of participants, followed by university courses at 30.3%. Notably, 4.9% reported never having heard of microplastics. Similar findings were reported by Righi et al. (2024), where students cited schools (45%), television (40%), and family discussions (15%) as sources of information. Raab and Bogner's (2021) study identified media (52%) and educational institutions (21%) as key sources. Additionally, Janoušková et al. (2020) highlighted media as the primary information source for students' understanding of microplastic origins and

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formation. Cammalleri et al. (2020), study of university students in Rome also found that the internet was the predominant source of knowledge about microplastics.

These results underscore the critical role of media as an information source about microplastics. However, as Righi et al. (2024), noted the correlation between exposure to ecology and science courses and awareness of microplastics remains surprisingly low. This situation reveals that microplastic-related topics are not systematically included in curricula and that students rely heavily on the media as their primary source of information. Although media-based learning can create rapid awareness, it often remains limited in terms of content accuracy and depth. These findings highlight a critical gap in science education with respect to content updates. This highlights the urgent need for integrating microplastic-related topics effectively into school curricula.

Risk Perception Status

To determine risk perceptions, teacher candidates were first asked the question, *"What are the effects of microplastics on humans and other living organisms?"* As shown in Table 6, the responses were categorized into three groups: ecological effects, impacts on human health, and impacts on animals. Commonly identified risks included ecosystem imbalance, pollution of living habitats, plants being unable to absorb sufficient nutrients from the soil, contamination of natural resources, and degradation of natural structures. Participants also highlighted that microplastics could enter the human body through ingestion, inhalation, or consumption of contaminated food, leading to developmental disorders, digestive system issues, reproductive disorders, and hormonal imbalances. Additionally, they noted the potential harm to marine life through ingestion of microplastics, which could increase the risk of extinction for certain species. Therefore, this

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finding indicates that risk perception toward microplastics generates a strong level of awareness at the dimensions of attitude and intention; however, the extent to which this intention is translated into actual behavior constitutes a critical area of evaluation within the framework of Ajzen and Fishbein's (1980) Theory of Reasoned Action. These findings align with Raab and Bogner's (2021) research, where most students indicated that microplastics could accumulate in the tissues of all living organisms, posing significant health risks. Similarly, Righi et al. (2024) observed that while students were well-informed about the environmental and wildlife impacts of microplastics, they exhibited notable knowledge gaps regarding their effects on human health.

The second question aimed at evaluating risk perceptions was, *"What could happen if the increase in microplastics continues rapidly?"* As shown in Table 7, the responses were grouped into four categories. The most frequently mentioned risks included increasing environmental pollution due to the long-term persistence of plastics in nature, alongside adverse impacts on human and animal life, with some participants even suggesting a potential reduction in human life expectancy. It is observed that the students' responses align with findings from recent scientific studies on the biological effects and risks of microplastics, indicating that they possess a certain level of awareness. According to Ajzen and Fishbein's (1980) Theory of Reasoned Action, individuals' attitudes toward a given behavior are based on their beliefs about the consequences of that behavior. The fact that the participants believe that the increase in microplastics will lead to serious ecological and health consequences indicates that negative attitudes toward microplastic pollution have strengthened. Notably, none of the participants described microplastics as harmless, in contrast to Raab and Bogner's (2021) findings, where 3% of students classified microplastics as "less dangerous." Oleksiuk et al. (2022) reported that participants were aware of microplastics' sources and their spread in the environment and food chain. They also recognized potential health

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risks, such as tumor development, gastrointestinal issues, and, to a lesser extent, reproductive system disorders.

Attitude Dimension

To explore attitude, the question, *"How can microplastics be reduced, and what should we do?"* was posed to teacher candidates. As seen in Table 8, the responses were categorized into four groups. Upon examining the responses, the most emphasis (%82) was placed on the need for a change in consumption habits. Many participants suggested reducing plastic usage, avoiding single-use plastics, and opting for eco-friendly alternatives such as glass. Additional suggestions included using public transportation instead of personal vehicles, choosing environmentally friendly clothing and cosmetics, and avoiding packaged products. Other recommendations included preventing waste pollution, promoting recycling, shifting to renewable energy sources, and preventing industrial waste from contaminating nature. The findings indicate that the behavioral suggestions expressed by the participants regarding the prevention of microplastic pollution are consistent with the attitude–subjective norm–behavioral intention relationship described in Ajzen and Fishbein's (1980) Theory of Reasoned Action. The emphasis by the majority of participants on avoiding petroleum-based products, reducing plastic consumption, abandoning single-use plastics, and preferring environmentally friendly alternatives suggests that they have developed positive and environmentally oriented attitudes toward combating microplastics. Furthermore, the expression of recommendations such as the use of public transportation, the promotion of recycling, the adoption of renewable energy sources, and the control of industrial waste indicates that the participants perceive environmentally appropriate behaviors as socially approved; therefore, subjective norms appear to support behavioral intentions. Participants also stressed the importance of increasing awareness through education

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and implementing legal regulations, emphasizing the need for targeted awareness campaigns. These findings are consistent with Righi et al.'s (2024) study, where most students recognized the need for action to mitigate microplastic pollution. However, students also admitted to continuing habits such as using synthetic clothing, packaged food, bottled water, plastic coffee capsules, and tea bags in their daily lives. Deng's (2020) survey of 437 participants found that as knowledge of plastics and microplastics increased, positive behavioral changes also improved. Similarly, Cammalleri's (2020) study at Rome Sapienza University observed that information sessions significantly enhanced participants' risk perception, leading to more effective behaviors to reduce microplastic pollution.

In another study by Vazquez et al. (2021), government policies and environmental education initiatives in Mexico led to students being more cautious about reducing microplastic usage. This study, involving 572 university students from Mexico and Spain, found that although Mexican students had lower levels of knowledge about microplastics compared to their Spanish counterparts, they were more proactive in checking product labels for microplastic beads and were more willing to reduce their microplastic consumption.

These findings reveal that while teacher candidates have ideas about how to address microplastic pollution, changing established habits is often challenging. Factors such as living standards, lack of awareness, and varying levels of sensitivity make behavior change a complex process. This inconsistency between awareness and behavior once again demonstrates that behavior-change interventions should not focus solely on increasing knowledge, but must also take into account structural barriers such as economic conditions, habits, and social norms.

CONCLUSION

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Young generations play a significant role in ensuring future environmental sustainability, making it crucial to raise their awareness and encourage them to adopt eco-friendly attitudes and behaviors. In this process, educators and community leaders play a critical role in fostering awareness and promoting behavior change.

Although the relationship between understanding the dangers of microplastics and altering behavior is complex, a connection can be identified. For instance, awareness of the harmful effects of microplastics can inspire individuals to become more conscious and lay the groundwork for attitude changes toward environmental issues. However, knowledge alone often does not guarantee behavior change. Nevertheless, increased sensitivity to the issue of microplastics may encourage individuals to reduce plastic consumption and shift toward eco-friendly alternatives. Factors such as perceived risks, psychological perceptions of individual efforts being ineffective, ease of access, and societal awareness also influence behavioral changes. For these factors to result in positive behavioral shifts, a series of supportive measures must be implemented. For example, educational programs that explain the harms of microplastics in a simple and effective manner, role models, and exemplary behaviors can serve as strong sources of motivation. Additionally, research and data demonstrating the tangible impacts of these behaviors on the environment can help individuals maintain consistency in behavior change. One of the main factors that makes behavior change difficult arises from the gap between knowledge and behavior. For example, an individual may know that microplastics are harmful to health yet still purchase water in plastic bottles. In addition, the high cost of environmentally friendly alternatives stands out as another significant barrier. Therefore, promoting environmentally friendly behaviors requires consideration of economic and structural obstacles as well. Knowing what microplastics are and the risks they pose constitutes the first step toward behavioral change. However, since knowledge alone is not sufficient, the

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transformation of knowledge into action also requires not only educational practices that enhance motivation but also psychological, social, and economic support mechanisms. Consequently, it becomes essential that educational programs at every level include practices that support behavior change in addition to providing knowledge.

It can thus be argued that both targeted interventions and broader systemic efforts need to be implemented together to support behavior change. At the micro level, awareness workshops, the use of behavioral reminders, students setting personal goals to monitor their own environmental behaviors, and teacher candidates modeling sustainable values through classroom practices can be effective. At the macro level, horizontal integration of sustainability topics into curricula, adoption of policies such as reducing plastic waste and improving energy efficiency in schools, support for community-based environmental projects, and the implementation of incentive and reward mechanisms can be recommended. Furthermore, incorporating sustainability modules as compulsory courses into teacher education programs would facilitate the integration of these values into teacher candidates' professional identities. Such multilayered initiatives can help transform individual awareness and habit changes into lasting behaviors and create a more systematic impact across educational institutions.

In conclusion, this study highlights the necessity of revising educational programs to improve science teacher candidates' knowledge and awareness of microplastics and environmental issues. It is recommended that the topic of microplastics be integrated more comprehensively into environmental education curricula, supported by both theoretical and practical lessons, and emphasized through activities that encourage individual behavior change. Furthermore, these educational efforts are expected to not only enhance individual awareness but also contribute to

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societal consciousness, thereby facilitating the implementation of effective solutions to combat microplastic pollution.

Although the study was conducted in the context of Turkey, the findings are also significant for international education systems, particularly regarding emerging environmental issues such as microplastics. However, addressing environmental education solely as an independent solution focused on increasing knowledge is not sufficient; it must be concluded that educational interventions should be integrated with psychologically based practices that influence individuals' decisions and habits, as well as with system, infrastructure, and policy changes that facilitate or guide behavior.

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Limitations

This study has several limitations. First, the research was conducted solely with 142 preservice science teachers enrolled in the science education department of a public university in Turkey. Therefore, the generalizability of the findings is limited, and studies encompassing broader and more diverse demographic groups, or data collected from different universities, departments, or countries, may yield different results.

Second, the concept of microplastics was not directly addressed in the participants' educational backgrounds. While plastic waste is partially covered in high school and university curricula, microplastics are not treated as a separate topic. This may be considered a factor influencing preservice teachers' knowledge levels and perceptions regarding the subject.

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Third, the study data are based on self-reports. Participants' accounts of their knowledge, risk perceptions, and behaviors related to microplastics relied on their own statements, which may have been influenced by social desirability bias. Consequently, discrepancies may exist between the reported behaviors and their actual practices in daily life.

Fourth, only qualitative data collection and content analysis methods were used in the study. Although this approach provides in-depth information, the absence of supporting quantitative data may limit the measurement of participants' knowledge and attitude levels.

Fifth, the data in this study were analyzed without being disaggregated according to age groups or other sub-demographic categories among the participants. This is a consequence of the design of the study, which focuses on the common tendencies of the students. However, the fact that potential differences based on age or year of study were not examined should be considered one of the limitations of the research. It is considered that, in future studies, detailed subgroup analyses conducted on the basis of these variables will make an important contribution to the literature.

Finally, environmental factors (e.g., economic conditions, accessibility of eco-friendly products, and the level of social awareness) were not directly included within the scope of the study. However, these factors are important variables that could influence preservice teachers' knowledge, attitudes, and behaviors.

References

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Prentice-Hall.

ARTICLE IN PRESS

Anderson, A. G., Grose, J., Pahl, S., Thompson, R. C., & Wyles, K. J. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. *Marine Pollution Bulletin, 113*(1–2), 454–460.

Arthur, C., Baker, J. E., & Bamford, H. A. (2009). *Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris*. University of Washington Tacoma.

Avelar, A. B. A., & Farina, M. C. (2022). The relationship between the incorporation of sustainability in higher education and the student's behavior: Self-reported sustainable behavior scale. *International Journal of Sustainability in Higher Education, 23*(7), 1749–1767.

Azmi, A., Rani, S. I. A., Shaifuddin, S. N. M., Rajan, S., Masngut, M. I., Mokhtar, M. A. M., & Rafi, S. B. M. (2023). A preliminary survey on knowledge and attitudes of university students regarding microplastic pollution and its impact on the environment. *Malaysian Journal of Medicine & Health Sciences, 19*(5).

Brennan, R. E., & Portman, M. E. (2017). Situating Arab-Israeli artisanal fishermen's perceptions of marine litter in a socio-institutional and socio-cultural context. *Marine Pollution Bulletin, 115*(1–2), 240–251.

Byerly, H., Balmford, A., Ferraro, P. J., Hammond Wagner, C., Palchak, E., Polasky, S., ... & Fisher, B. (2018). Nudging pro-environmental behavior: Evidence and opportunities. *Frontiers in Ecology and the Environment, 16*(3), 159–168.

Cammalleri, V., Marotta, D., Antonucci, A., Protano, C., & Fara, G. M. (2020). A survey on knowledge and awareness on the issue "microplastics": A pilot study on a sample of future public health professionals. *Annali di Igiene, 32*(5), 577–589. https://doi.org/10.7416/ai.2020.2377

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., ... & Suh, S. (2020). Degradation rates of plastics in the environment. *ACS Sustainable Chemistry & Engineering, 8*(9), 3494–3511.

Chang, M. (2015). Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions. *Marine Pollution Bulletin, 101*(1), 330–333.

Chia, R. W., Lee, J. Y., Lee, M., Lee, G. S., & Jeong, C. D. (2023). Role of soil microplastic pollution in climate change. *Science of the Total Environment, 887,* 164112.

ARTICLE IN PRESS

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Sage Publications.

Deng, L., Cai, L., Sun, F., Li, G., & Che, Y. (2020). Public attitudes towards microplastics: Perceptions, behaviors, and policy implications. *Resources, Conservation and Recycling, 163,* 105096. https://doi.org/10.1016/j.resconrec.2020.105096

Dowarah, K., Duarah, H., & Devipriya, S. P. (2022). A preliminary survey to assess the awareness, attitudes/behaviours, and opinions pertaining to plastic and microplastic pollution among students in India. *Marine Policy*, *144,* 105220.

Duis, K., & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: Sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe, 28*(1), 1–25.

Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borrell, J. C., Galgani, F., Ryan, P. G., & Reisser, J. (2014). Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLOS ONE, 9*(12), e111913. https://doi.org/10.1371/journal.pone.0111913

Fava, M. (2022). Ocean plastic pollution an overview: Data and statistics. *Ocean Literacy Portal*. https://oceanliteracy.unesco.org/plastic-pollution-ocean/

Forakis, J., Johnston, B., & March, J. L. (2024). A CURE for microplastics: Introducing first-year honors students to environmental chemistry through undergraduate research. *Journal of Chemical Education, 101*(2), 420–428.

Ford, H. V., Jones, N. H., Davies, A. J., Godley, B. J., Jambeck, J. R., Napper, I. E., ... & Koldewey, H. J. (2022). The fundamental links between climate change and marine plastic pollution. *Science of the Total Environment, 806,* 150392.

Garcia-Vazquez, E., & Garcia-Ael, C. (2021). The invisible enemy: Public knowledge of microplastics is needed to face the current microplastics crisis. *Sustainable Production and Consumption, 28,* 1076–1089. https://doi.org/10.1016/j.spc.2021.06.007

Gherheş, V., Fărcaşiu, M. A., & Para, I. (2022). Environmental problems: An analysis of students' perceptions towards selective waste collection. *Frontiers in Psychology*, *12,* 803211. https://doi.org/10.3389/fpsyg.2021.803211

Hartley, K., van Santen, R., & Kirchherr, J. (2020). Policies for transitioning towards a circular economy: Expectations from the European Union (EU). *Resources, Conservation and Recycling, 155,* 104634. https://doi.org/10.1016/j.resconrec.2019.104634

ARTICLE IN PRESS

Hartmann, N. B., Huffer, T., Thompson, R. C., Hassellöv, M., Verschoor, A., Daugaard, A. E., & Wagner, M. (2019). Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. *Environmental Science & Technology, 53*(3), 1039–1047. https://doi.org/10.1021/acs.est.8b05297

Henderson, L., & Green, C. (2020). Making sense of microplastics? Public understandings of plastic pollution. *Marine Pollution Bulletin, 152,* 110908. https://doi.org/10.1016/j.marpolbul.2020.110908

Hogan, S., & Urban-Rich, J. (2024). Bilim eğitimi yoluyla karma sınıf ortamındaki ABD ortaokul öğrencilerinde mikroplastik kirliliğine ilişkin bilgi ve farkındalığın artırılması. *Jeolojik Bilimler Eğitimi Dergisi.* https://doi.org/10.1080/10899995.2024.2333725

Janouskova, S., Teplý, P., Fatka, D., Teplá, M., Cajthaml, T., & Hák, T. (2020). Microplastics—How and what do university students know about the emerging environmental sustainability issue? *Sustainability, 12,* 9220. https://doi.org/10.3390/su12219220

Jefferson, R. L., Bailey, I., Richards, J. P., & Attrill, M. J. (2014). Public perceptions of the UK marine environment. *Marine Policy, 43,* 327–337.

Kakar, F. L., Okoye, F., Onyedibe, V., Hamza, R., Dhar, B. R., & Elbeshbishy, E. (2023). Climate change interaction with microplastics and nanoplastics pollution. In *Current developments in biotechnology and bioengineering* (pp. 387–403). Elsevier. https://doi.org/10.1016/B978-0-12-821984-8.00015-6

Khan, B. A., Khan, A. A., Ahmed, H., Shaikh, S. S., Peng, Z., & Cheng, L. (2019). A study on small clinics waste management practice, rules, staff knowledge, and motivating factors in a rapidly urbanizing area. *International Journal of Environmental Research and Public Health, 16*(20), 4044. https://doi.org/10.3390/ijerph16204044

Kowalski, M. (2016). Mitigating Microplastics: Development and evaluation of a middle school curriculum.

Liu, A., Osewe, M., Wang, H., & Xiong, H. (2020). Rural residents' awareness of environmental protection and waste classification behavior in Jiangsu, China: An empirical analysis. *International Journal of Environmental Research and Public Health, 17*(23), 8928. https://doi.org/10.3390/ijerph17238928

Luo, Y., Douglas, J., Pahl, S., & Zhao, J. (2022). Reducing plastic waste by visualizing marine consequences. *Environment and Behavior, 54*(4), 809–832.

ARTICLE IN PRESS

Lusher, A. (2015). Microplastics in the marine environment: Distribution, interactions and effects. In M. Bergmann, L. Gutow, & M. Klages (Eds.), Marine Anthropogenic Litter (pp. 245–307). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_10

Menzel, C., Brom, J., & Heidbreder, L. M. (2021). Explicitly and implicitly measured valence and risk attitudes towards plastic packaging, plastic waste, and microplastic in a German sample. *Sustainable Production and Consumption, 28,* 1422–1432.

Miles, M. B., & Huberman, M. A. (1994). *Qualitative data analysis: An expanded sourcebook.* Sage.

Napper, I. E., & Thompson, R. C. (2020). Plastic debris in the marine environment: History and future challenges. *Global Challenges, 4*(6), 1900081.

Oleksiuk, K., Krupa-Kotara, K., Wypych-Ślusarska, A., Głogowska-Ligus, J., Spychała, A., & Słowiński, J. (2022). Microplastic in food and water: Current knowledge and awareness of consumers. *Nutrients, 14*(22), 4857.

Park, Y., Bae, H., Park, H. N., Park, J., Hong, J., & Kim, Y. (2024). The unseen threat: Microplastic emissions from face masks and limited public awareness. *Korean Journal of Chemical Engineering, 41*(1), 237–247.

Raab, P., & Bogner, F. X. (2021). Conceptions of university students on microplastics in Germany. *PLoS ONE, 16*(9), e0257734. https://doi.org/10.1371/journal.pone.0257734

Reed, M. R., & Chen, W. T. (2022). Plastics crash course: A website for teaching plastics recycling and microplastics prevention through infographics. *Recycling, 7*(5), 65.

Rezania, S., Park, J., Din, M. F. M., Taib, S. M., Talaiekhozani, A., Yadav, K. K., & Kamyab, H. (2018). Microplastics pollution in different aquatic environments and biota: A review of recent studies. Marine Pollution Bulletin, 133, 191–208. https://doi.org/10.1016/j.marpolbul.2018.05.022

Righi, S., Bergami, E., Simonini, R., & Prevedelli, D. (2024). Level of awareness and attitudes towards plastic contamination by students of an Italian university. *Sustainability, 16*(11), 4637.

Ritchie, H., Samborska, V., & Roser, M. (2023). Plastic pollution. *Our World in Data.* https://ourworldindata.org/plastic-pollution

Rochman, C. M. (2018). Microplastics research—from sink to source. *Science, 360*(6384), 28–29. https://doi.org/10.1126/science.aar7734

ARTICLE IN PRESS

Seltenrich, N. (2015). New link in the food chain? Marine plastic pollution and seafood safety. *Environmental Health Perspectives, 123*(2), A34. https://doi.org/10.1289/ehp.123-A34

Sharma, S., Bhardwaj, A., Thakur, M., & Saini, A. (2024). Understanding microplastic pollution of marine ecosystem: A review. *Environmental Science and Pollution Research, 31*(29), 41402–41445. https://doi.org/10.1007/s11356-024-26874-1

Shen, M., Liu, S., Hu, T., Zheng, K., Wang, Y., & Long, H. (2023). Recent advances in the research on effects of micro/nanoplastics on carbon conversion and carbon cycle: A review. *Journal of Environmental Management, 334*, 117529. https://doi.org/10.1016/j.jenvman.2023.117529

Situmorang, A. G. M., Farahannisa, K. A., Rahmawati, I., & Rossyanti, L. (2022). Education webinar increases the knowledge of the mask waste management during COVID-19 pandemic. *Education, 3*(1).

Thompson, R. C. (2015). Microplastics in the marine environment: Sources, consequences and solutions. In M. Bergmann, L. Gutow, & M. Klages (Eds.), Marine Anthropogenic Litter (pp. 185–200). Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_7

United Nations Development Programme, (2024). Sustainable development goals. https://www.undp.org/sustainable-development-goals

Usman, S., Abdull Razis, A. F., Shaari, K., Amal, M. N. A., Saad, M. Z., Mat Isa, N., ... & Ibrahim, M. A. (2020). Microplastics pollution as an invisible potential threat to food safety and security, policy challenges and the way forward. *International Journal of Environmental Research and Public Health, 17*(24), 9591. https://doi.org/10.3390/ijerph17249591

van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B. D., van Franeker, J. A., Eriksen, M., Siegel, D., Galgani, F., & Law, K. L. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters, 10*(12), 124006. https://doi.org/10.1088/1748-9326/10/12/124006

Willis, B., & Fytianos, G. (2022). Towards microplastic reduction within institutions. *Water, Air, & Soil Pollution, 233*, 337. https://doi.org/10.1007/s11270-022-05790-8

Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G., Coppock, R., Sleight, V., Calafat, A., Rogers, A. D., Narayanaswamy, B. E., & Thompson, R. C. (2014). The deep sea is a major sink for microplastic debris. *Royal Society Open Science, 1*(4), 140317. https://doi.org/10.1098/rsos.140317

ARTICLE IN PRESS

Yan, S., Henninger, C. E., Jones, C., & McCormick, H. (2020). Sustainable knowledge from consumer perspective addressing microfibre pollution. *Journal of Fashion Marketing and Management, 24*(3), 437–454. https://doi.org/10.1108/JFMM-08-2019-0181

Yee, M. S. L., Hii, L. W., Looi, C. K., Lim, W. M., Wong, S. F., Kok, Y. Y., ... & Leong, C. O. (2021). Impact of microplastics and nanoplastics on human health. *Nanomaterials, 11*(2), 496. https://doi.org/10.3390/nano11020496

Yin, R. K. (2013). *Case study research: Design and methods* (3rd ed.). Sage Publications.

Zhang, K., Hamidian, A. H., Tubić, A., Zhang, Y., Fang, J. K., Wu, C., & Lam, P. K. (2021). Understanding plastic degradation and microplastic formation in the environment: A review. *Environmental Pollution, 274,* 116554. https://doi.org/10.1016/j.envpol.2020.116554

Ziani, K., Ioniță-Mîndrican, C. B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., ... & Preda, O. T. (2023). Microplastics: A real global threat for environment and food safety: A state of the art review. *Nutrients, 15*(3), 617. https://doi.org/10.3390/nu15030617

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Competing Interests

The author declares no competing interests.

Data Availability

All written responses provided by the participant students to the open-ended questions were transferred to an electronic format. The original Turkish responses, together with their English translations, have been uploaded to the depository: https://doi.org/10.7910/DVN/DKOQ9V. An inductive content analysis approach was applied to the responses of 142 students, and codes were derived directly from the data. The units of analysis, generated codes, and corresponding frequency counts obtained from the analysis have been uploaded to the system. Open coding was conducted for each meaningful statement, and concise, descriptive codes that best represented the participants' expressions were developed. Supporting evidence linking the units of analysis to the codes derived from student statements has been included in the uploaded file.

Ethical Approval Statement

The planning, implementation, data collection, and analysis stages of this study were conducted in accordance with the "Directive on Scientific Research and Publication Ethics" of higher education institutions in Turkey. Ethical approval was granted by the Ethics Committee of Bursa

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Uludağ University on 24 November 2023 (Approval number: 2023-10). The ethics approval covered the study entitled "An Examination of Knowledge, Thoughts, and Attitudes Toward Microplastics in the Context of Science Teacher Education," conducted at a public university in Turkey.

Informed Consent Statement

Prior to the data collection process, all participants were provided with an information sheet detailing the purpose, scope, and procedures of the study. The voluntary nature of participation, the anonymous handling of data, and the participants' right to withdraw from the study at any time without penalty were clearly stated. Following this information, participants completed the data collection instrument in written form. The completion and submission of the instrument were considered as evidence that informed consent had been obtained. Data were collected from individuals who voluntarily participated in the study between 16th December 2023 and 20th December 2023. The written responses provided by the participant students were transferred to an electronic format and uploaded to a secure data management system for analysis. In accordance with established ethical research practices, voluntary participation following the provision of the information sheet was accepted as implied informed consent. As the study was non-interventional, posed minimal risk, and did not involve the collection of any personally identifiable information, separate signed or audio-recorded consent was not required.

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Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, manuscript preparation, and final approval of the version to be published.

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Table 1 Questions regarding the data collection tool

Question Number	Dimension to Be Measured	Questions

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1	Knowledge	What are microplastics, in your opinion?
2	Knowledge	What materials cause microplastic pollution?
3	Knowledge	What environments are affected by microplastic pollution?
4	Knowledge	Where did you first hear about the concept of microplastics?
5	Risk Perception	What are the effects of microplastics on humans and other living beings?
6	Risk Perception	What could happen if the increase in microplastics continues rapidly?
7	Attitude	How can microplastics be reduced, and what should we do?

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Table 2 Findings Related to the Question "What are Microplastics?"

Codes	***f***	***%***	***Category***	***Sample Responses***
Plastics smaller than 5 mm	13	9.2	Size	S95: "Plastics smaller than 5 mm."
Microscopic plastics invisible to the naked eye	29	20.4		S44: "Small plastic particles ranging between 5 mm and 1 micrometer."
Small plastics found in nature	2	1.4		S5: "The smallest structure of plastic."
The smallest structure of plastic	56	39.4		S21: "Plastics so small that they cannot be seen with the naked eye."
Artificially manufactured small plastics	5	3.5		S36: "Very small particles formed as a result of the fragmentation of larger plastics."
Small fragments of polymers	12	8.5		S50: "Particles so small that they are invisible to the naked eye."
Small petroleum-derived particles	4	2.8		
Materials that do not decompose quickly in nature	5	3.5	Presence in Nature	S91: "Plastics that exist because they do not fully decompose in nature."
Materials that do not integrate into the environment	2	1.4		S44: "Another form of plastic that exists in nature."
Materials causing environmental pollution	19	13.4		S65: "Artificially manufactured plastic material."
Non-recyclable plastics	2	1.4		S87: " They are small plastic particles that do not decompose in nature and cause pollution."
Water-insoluble particles	3	2.1		S129: " They are plastics that do not disappear in nature and are not recyclable."
Artificially manufactured plastics	2	1.4		
Substances that endanger human and other living beings' health	5	3.5	Harmful Substance	S131: "Small plastic particles harmful to human health."
Substances harmful to marine life	2	1.4		S113: "Marine life may mistake microplastics for food, ingest them, and choke to death."
Substances damaging to the environment	9	6.3		S52: "Materials that cause environmental pollution."
Structures formed through the degradation of plastics	3	2.1	Source	S105: "Plastic fragments formed through the breakdown of plastics."
Structures formed through the fragmentation of plastics	7	4.9		S110: "Small plastic particles composed of carbon and hydrogen atoms.
Recyclable structures	2	1.4		S111: "Structures formed as a result of the degradation of plastic materials in nature."
Structures composed of carbon and hydrogen	5	3.5		S30: "Microfibers shed from cosmetic and clothing products."
Structures formed as a result of microfibers shed from cosmetic and textile products	3	2.1		S104: "Derived from used textile products."

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Table 3 Findings Related to the Question "What Materials Cause Microplastic Pollution?"

Codes	***f***	***%***	***Category***	Sample Responses
Plastic bottles Shopping bags Vehicle tires Plastic products	10 10 3 51	7.0 7.0 2.1 35.9	Petroleum products	S111: "In bags, vehicle tires, and plastic bottles." S57: "In environments such as water bottles, shopping bags, and vehicle tires." S64: "Everywhere plastic is used."
Textile products Cosmetic products Petrochemicals Packaging products Nuclear power plants Cleaning agents Mines	12 19 19 3 2 2 2	8.5 13.4 13.4 2.1 1.4 1.4 1.4	Industrial products	S127: "Surface cleaners, cosmetic products." S56: "Personal care products, cosmetics, etc." S60: "In environments where factory operations take place." S77: "In environments where nuclear power plants are located."
Litter dumped into nature Electronic waste Batteries Industrial waste Medicines Medical waste	19 2 2 4 6 6	13.4 1.4 1.4 2.8 4.2 4.2	Waste	S53: "When the batteries we use and electronic waste are not recycled but left in nature." S110: "Used batteries, electronic waste." S55: "Hospital waste, expired medications." S133: "Syringes, medications." S136: "Plastic hospital waste."

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Table 4 Findings Related to the Question "What Environments Are Affected by Microplastic Pollution?"

Codes	***f***	***%***	***Category***	Sample Responses
Waste in oceans and seas	32	22.5	Ecosystems	S108: "I heard that it comes from wastewater."
Sewage waters	32	22.5		S58: "It usually causes pollution by being transported to rivers through sewage."
Rivers/Lakes	18	12.7		S100: "It generally forms in wastewater treatment plants."
Drinking water	7	4.9		S76: "It is found in soil, air, and water."
Soil	10	7.0		S72: "Plastics used in agriculture create pollution."
Glaciers	2	1.4		S140: "Microplastics mixed into the soil are absorbed by plants and enter the food chain, negatively impacting many living organisms."
Air	2	1.4		
Water treatment plants	19	13.4	Industrial Areas	S79: "Found in packaged and processed foods."
Factories and industrial areas	11	7.7		S131: "In food and beverage containers, and in drinks with straws."
Food packaging and packaged foods	5	3.5		S135: "I read that they are present in tea bags."
Canned foods	3	2.1		S30: "Microfibers from clothing create pollution."
Substances derived from breast milk	3	2.1	Other	S105: "Microplastics are found in food."
Foreign substances entering the body through respiration	4	2.8		S95: "Microplastics are found in breast milk."
Foreign substances entering the body through food	2	1.4		S31: "Microplastics can be ingested while breathing because they are very small."
Foreign substances entering the body through ingestion	3	2.1		

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Table 5 Findings Related to the Question "Where Did You Hear About the Concept of Microplastics?"

Codes	***f***	***%***	***Category***	Sample Responses
University High School Middle School Chemistry lessons Various activities and projects	43 3 2 11 8	30.3 2.1 1.4 7.7 5.6	School Environment	S58: "I heard about it in an elective course I took at school." S73: "I heard about it at school, but I don't have much information." S18: "I learned about it through school activities.""
TV İnternet Newspaper and magazine	8 72 2	5.6 50.7 1.4	Media	S57: "I learned about it from the internet." S1: "I heard it on a TV program." S91: "There was a program mentioning that whales were exposed to microplastics." S140: "I read about it in online news articles." S68: "I came across it on social media."
Family Contents of cosmetic products Social environment Friend Never heard of it before	2 1 2 2 7	1.4 0.7 1.4 1.4 4.9	Other	S61: "I have never heard of it before." S113: "I learned about it from a friend." S12: "It was discussed in my social environment."

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Table 6 Findings Related to the Question "What Are the Effects of Microplastics on Humans and Other Living Beings?"

Codes	***f***	***%***	***Category***	Sample Responses
Pollution of the habitat of living organisms	10	7.0	Ecological Hazard	S90: "Pollutes the habitats of living organisms." S141: "Disrupts the balance of the ecosystem. Microplastics mix with soil and water and remain for many years." S35: "They harm the ecological structure because they do not decompose in nature." S111: "Since microplastics do not dissolve in water and soil, plastics irresponsibly discarded into the environment cause soil and water pollution." S47: "They do not decompose in nature for years." S54: "Creates persistent environmental pollution." S26: "Can remain for centuries."
Contamination of natural resources	8	5.6		
Disruption of the natural structure	12	8.4		
Insufficient nutrient absorption by plants from soil	7	4.9		
Disruption of chemical structure	5	3.5		
Impact due to inability to dissolve in water and soil	12	8.4		
Negative impact on the living pyramid	8	5.6		
Long-lasting effects in nature	2	1.4		
Adverse effects on soil organisms	15	10.5		
Biological transfer	2	1.40		
Deterioration of human health	33	23.2	Effects on Humans	S35: “It damages kidneys, harming our health." S95: "Causes hormonal effects and diseases in humans." S97: "Leads to reproductive problems, cancer, and other diseases in humans." S105: "Harms the development of infants." S95: "Damages children's health." S56: "Negatively impacts development."
Cognitive developmental disorders	5	3.5		
Adverse effects on infants' digestive systems	3	2.1		
Disruption of biological structure	2	1.4		
Causing hormonal problems	5	3.5		
Reproductive issues	5	3.5		
May lead to cancer	2	1.4		
Developmental disorders in children and infants	4	2.8		

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Adverse effects on marine life	16	11.2	Effects on Animals	S94: "Accumulates in the digestive systems and tissues of marine organisms, creating hazards." S102: "When fish consume microplastics mistaking them for plankton, both marine life and the humans who eat those fish are harmed." S106: "Negatively affects the lives of aquatic organisms as it is present in the water ecosystem."
Extinction of animal species	3	2.1		
Causes growth and reproductive disorders in living organisms	3	2.1		
Negatively impacts marine life and the food chain	11	7.75		

Table 7 Findings Related to the Question "What Could Happen If the Increase in Microplastics Continues Rapidly?"

Codes	***f***	***%***	***Category***	Sample Responses
Uncontrolled increase in environmental pollution	39	27.5	Environmental degradation	S93: "Habitats of living organisms will become increasingly polluted. Plastics will be present in every area." S98: "Our world will continue to become polluted at a rapid pace." S101: "Since plastics can remain in nature for very long periods, it will take a long time for them to decompose, leading to increased environmental pollution." S102: "Large piles of trash will accumulate."
Damages caused by environmental pollution	8	5.6		
Threat to animal existence	5	3.5	Effects on Animals	S99: "As microplastic pollution in the soil increases, it harms animals that feed on plants grown in such soil." S104: "It poses a threat to aquatic and terrestrial organisms. Their life functions may deteriorate, leading to possible extinction." S106: "It affects biodiversity." S122: "It poses a significant threat to marine life."
Risk of extinction for marine species	14	9.8		
Risk of extinction for living species	20	14		
Shortening of lifespan	50	35.2	Effects on Humans	S91: "As the proportion of microplastics increases, cancer and other diseases will rise. New diseases may emerge." S95: "More microplastics will enter our bodies through the food we eat, making us ill." S97: "There may be changes in human genetics, and the variety of diseases will increase."
Adverse effects on human health/diseases	8	5.6		
Harmful effects on living organisms' bodies	5	3.5		
Genetic problems	3	2.1		

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				S100: "Hormonal disorders, cancer, and other diseases in humans will become more prevalent."
Negative impact on natural life Water pollution Disruption of ecosystem balance Environmental degradation Air pollution Soil pollution Biological transfer Acceleration of global warming Adverse effects on the ozone layer Reduction in biodiversity Threats to food security	20 7 24 1 8 10 3 3 3 3 3	14.0 4.9 16.9 0.7 5.6 7.0 2.1 2.1 2.1 2.1 2.1	Ecological Effects	S130: "Water and soil become more polluted, which further disrupts the ecosystem. This negatively affects living organisms." S94: "Seas and lakes become more polluted, leading to the extinction of many species." S86: "Life in nature is negatively affected." S96: "The amount of chemicals in nature increases, and the natural structure is disrupted." S118: "Soil and water become more contaminated." S54: "It may damage the ozone layer, and air pollution will increase."

Table 8 Findings Related to the Question "How Can Microplastics Be Reduced, and What Should We Do?"

Codes	***f***	***%***	***Category***	Sample Responses
Reducing plastic usage Promoting recycling Using eco-friendly products Reducing the use of synthetic materials Eco-friendly clothing Using environmentally friendly materials in cosmetics Reducing the use of packaged products Using public transportation	77 4 22 3 9 5 2 2	54.2 2.8 15.5 2.1 6.3 3.5 1.4 1.4	Change in consumption habits	S131: "The use of plastic products should be reduced, and alternatives like glass materials should be promoted." S132: "We should prefer using public transportation." S133: "We should produce non-synthetic, environmentally friendly clothing." S55: "We should use environmentally friendly materials that do not harm nature." S57: "Single-use plastics should be avoided."
Prioritizing waste collection and storage Increasing recycling Preventing waste pollution	12 39 2	8.4 27.4 1.4	Waste management	S135: "Recycling bins should be increased and made more widespread." S141: "Proper recycling and waste management should be implemented as much as possible." S96: "To achieve a more sustainable lifestyle, we should use recyclable materials and encourage recycling."
Raising awareness through education Environmental awareness and advocacy campaigns	20 3	14.0 1.9	Education	S140: "Initiatives that encourage the public to recycle should be implemented, and awareness-raising educational programs should be provided."

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				S104: "Legislation should be introduced to promote recycling and incentivize the public." S105: "We need to ensure that people think not only about themselves but also about their environment and future generations." S127: "Adequate education on this issue should be provided in schools." S45: "Awareness about recycling should be increased."
Shift towards renewable energy sources Reduction of industrial waste Preventing wastewater from mixing into nature Ensuring necessary measures are taken in industry Promoting eco-friendly practices	3 2 2 2 3	1.9 1.4 1.4 1.4 1.9	Innovative environmental practices	S95: "We should shift to renewable energy sources instead of using petroleum." S70: "Alternatives to plastic should be used." S95: "We should prevent wastewater from mixing into nature." S94: "Factories and industrial facilities should be monitored, and their wastewater should be regulated."

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