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ORIGINAL ARTICLES

Sentiment mapping of microplastic awareness in educational environments

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Abstract

Microplastic pollution poses a significant environmental and health challenge due to its persistence and pervasive distribution across ecosystems. This study investigates public perceptions of microplastics, focusing on their environmental and health impacts, through semi-structured interviews with 96 participants from diverse educational backgrounds in Rio de Janeiro, Brazil. Sentiment analysis, hierarchical clustering, and machine learning techniques were employed to analyze the data. Participants ‘ educational levels and interview locations influenced substantial variability in awareness and attitudes towards microplastics. Academic groups, particularly those specialized in environmental sciences, expressed higher concerns than less specialized or non-academic groups. Sentiment analysis indicated a predominance of neutral to mildly positive sentiments, with 36 distinct clusters identified. The study highlights the need for targeted educational interventions to bridge knowledge gaps and promote pro-environmental behaviors. The results underscore the role of academic background in shaping public perceptions, suggesting tailored communication strategies to mitigate microplastic pollution.

Keywords: *education, environmental perception, microplastics, sentiment analysis.*

Data Availability: Research data is available upon request from the corresponding author.

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1. Introduction

Plastics are instrumental in modern society, permeating nearly every culture and social class today[1-12]. From the advent of the first synthetic plastic, Bakelite, in 1907, it has been preserving its dominance till now by serving humanity for countless purposes[13]. It can be utilized in several modern-day industries, such as electronics, construction, packaging, and medicine[14-17]. They have become indispensable, improving lives in countless ways, such as enabling the production of medical devices used in critical care[18,19]. Also, the food industry relies heavily on plastic for packaging, promoting food safety and waste reduction[20-22].

However, despite these advantages, inadequate plastic waste management has escalated in the past decades, becoming a significant global problem. The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Intergovernmental Oceanographic Commission (IOC) estimated that 8-10 million metric tons of plastic waste end up in the oceans annually[23]. Marine pollution has severe consequences for the environment and economics worldwide[24], inflicting global damages on human health, biodiversity loss, and others, with an estimated cost of over $2.2 trillion annually[25]. Besides all efforts, only 9% of the plastic waste discontinued into the ocean is being recycled, while the largest portion persists in the ocean. The rest of the plastic either remains in landfills or is incinerated, releasing harmful chemicals into the atmosphere[23-25].

Once in the environment, all this plastic waste exposed to weathering degrades into smaller particles, also known as plastic debris. These fragments, which range in size to the micrometric level, dismantle in the ocean and permeate all sorts of life forms, from the smallest invertebrates to the largest species of whales[26,27]. The persistence of microplastics in the environment has sparked growing concern among environmentalists, scientists, and the general public in the twenty-first century[28].

Defined as plastic particles smaller than 5 mm, microplastics originate either from the direct release of primary microplastics, such as microbeads found in cosmetics and industrial cleaners or are the product from the degradation of larger plastic parts through natural processes including ultraviolet light, wearing or biotic activity[29-31]. Microplastics' ability to persist in marine ecosystems and be transported through the atmosphere makes them capable of being present in the planet's most far-flung regions. Recent research revealed microplastic presence even in the most remote areas of our planet, such as Antarctica and the Himalayas[32,33].

Microplastics are a growing concern due to their potential impacts. Their ability to persist in the environment and their potential to bioaccumulate in organisms pose significant risks to ecosystems and human health[34]. The literature review for this article reveals that some of the existing studies have implications of microplastics breaking food chains, accumulating in living species, and even passing the placenta barrier[31,35-37]. Consequently, the World Health Organization (WHO) has raised concerns through its unveiled report regarding the threats of health impacts of microplastic consumption via food items, air, and water. Although scientific data is insufficient to infer health effects, its known that their deposition in the alveolar regions of the lungs, where their biopersistence can have adverse effects, such as asthma and other respiratory disorders[38]. Recent scientific literature points to the need for a more in-depth investigation of the reasons for cultural differences in perceptions and behavior concerning microplastics[39].

Therefore, this research aimed to explore citizens' perceptions of microplastics' impacts on the environment and human health through qualitative methodologies, specifically semi-structured interviews. Understanding these perceptions has significant implications for shaping environmental and public health policies, as public awareness and attitudes are critical drivers of policy effectiveness. Additionally, the influence of the media in shaping public understanding of microplastics must be considered. The literature underscores the media's role in amplifying or distorting environmental issues, highlighting the need for well-crafted communication strategies that raise awareness and encourage behavioral change[40].

This research underscores the importance of targeted educational interventions to promote pro-environmental behaviors, with environmental values mediating in shaping these behaviors. By applying advanced analytical techniques such as sentiment analysis, hierarchical clustering, and machine learning, this study provides a nuanced understanding of the public's perceptions, offering valuable insights for policymakers and educators to develop more effective strategies for addressing microplastic pollution[41,42].

2. Materials and Methods

2.1 Questionnaire design

The research team designed a 12-question, open-ended questionnaire to assess the public's perception of microplastics and their associated risks. The sample group consisted of individuals in Rio de Janeiro and its metropolitan region. The questionnaire was administered orally by research team members over two days in October 2023, and 96 participants from diverse educational backgrounds participated.

The questionnaire was structured into three sections. The first section gathered demographic information, such as educational level, gender, and age. The second section explored participants' awareness of microplastics, covering such issues as the sources of microplastic pollution, particle size, and the environmental and health risks posed by microplastics. The third section focused on participants' opinions on potential actions to address microplastic pollution, including views on recycling, government regulations, and the role of industries in mitigating the issue.

Participants were categorized into five groups based on their educational backgrounds and locations:

- **Control group**: Citizens in public spaces with varying levels of academic education.
- **Academic group from Literacy Courses**: Participants from the Federal University of Rio de Janeiro (UFRJ) literacy programs.
- **The non-specialized academic group from UFRJ's Technological Center (CT)** consists of university students who do not specialize in plastics or related fields.
- **Secondary technical students from IFRJ/CDUC**: Students with a background in chemistry.
- **The postgraduate group from the Institute of Macromolecules Professor Eloisa Mano (IMA/UFRJ)**: Professors, Master's, and Ph.D. students specializing in macromolecular sciences.

This comprehensive grouping allowed for a nuanced analysis of perceptions based on educational background, providing insight into how knowledge and academic exposure influence awareness and attitudes toward microplastic pollution.

2.2 Data collection and management

After the interviews, the audio recordings were transcribed using Take a Blip - Viratexto (blib.ai), integrated with the WhatsApp platform. This tool allows for easy transcription by sending the audio file via chat after accepting the terms of use. The transcriptions were reviewed manually to correct spelling errors or misinterpretations, ensuring accuracy in capturing the participants' responses. Once the necessary corrections were made, the transcripts were saved as plain text files (*.txt) for further analysis. These text files were then processed using a sentiment analysis system to categorize and evaluate the emotional tone of the responses. The study employed hierarchical clustering and connection mapping techniques to identify groups and individuals with varying interest levels or concerns regarding microplastics.

Applying Artificial Intelligence (AI) in the data analysis allowed for a deeper, more structured interpretation of the participants' sentiments. By leveraging advanced AI tools, the research achieved a higher level of precision in identifying patterns, thus contributing to the robustness and scientific rigor of the study.

2.3 Sentiment analysis

Sentiment analysis was performed using a systematic and structured approach with Python, a machine learning and data mining tool, to analyze the corpus of texts obtained from interviews with students and teachers. The methodological process consisted of several sequential steps designed to prepare and analyze the data effectively.

Data Import and Preparation: Textual documents were initially imported from a folder labeled "TXTs", with the software configured to process the Portuguese language. This phase involved applying lemmatization, part-of-speech tagging (POS), and named entity recognition (NER) to normalize and enrich the linguistic data.

Corpus Construction: The data was consolidated into a corpus, and each document was assigned a unique identifier based on the 'name' variable. The primary focus of the analysis was on the textual content, ensuring a structured approach to managing the information.

Text Pre-processing: The texts were cleaned and structured, including converting all characters to lowercase and removing accents, URLs, and unnecessary common words (stopwords) in Portuguese. Tokenization was performed using regular expressions to identify words and separate them from punctuation, further refining the text for analysis.

Bag of Words (BoW) Modeling: A Bag of Words model was employed to transform the textual data into a quantitative representation. This involved counting term frequency and applying the smoothed Inverse Document Frequency (IDF) to weigh the importance of each term in the corpus. L2 regularization was used to prevent overfitting and ensure a balanced distribution of term weights across the dataset.

Distance Calculation: The similarity between the documents was quantified by calculating the distances between feature vectors. While the specific metric was not explicitly defined, the software offered a range of distance measures such as Euclidean, Manhattan, and Mahalanobis, allowing for flexibility in measuring document proximity.

Sentiment Analysis: Sentiment classification was conducted using a multilingual algorithm compatible with Portuguese. This algorithm categorized the sentiments expressed in the text as positive, negative, or neutral. This approach efficiently interpreted the emotional valence of the content without requiring customized sentiment dictionaries.

The combination of natural language processing (NLP) and machine learning (ML) techniques enabled a detailed and nuanced analysis of the sentiments expressed by the participants. The methodology provided qualitative and quantitative insights, comprehensively understanding public attitudes toward microplastics.

3. Results and Discussions

This study analyzed interviews with participants in the academic community, school environments, and the general public (control group) to assess awareness and attitudes toward microplastic pollution. The primary goal was to understand how these perceptions influence sustainable behaviors and identify directions for effective educational and policy interventions. Machine learning methodologies were employed to reveal patterns within the collected data.

The hierarchical clustering process identified an intricate structure in the responses, with the average-link configuration displaying groupings based on the similarity of textual responses. The analysis revealed 36 distinct clusters where proximity patterns suggested content and emotional response affinities. Demographic factors, such as educational background and prior knowledge, were significant in shaping these groupings, emphasizing the role of education in determining awareness and attitudes toward microplastics. After processing through sentiment analysis, lemmatization, and Bag of Words modeling, the data allowed for more unambiguous identification of perception patterns. Distance metrics further facilitated the understanding of how different participant groups related to the issue based on their educational levels and other demographic factors. The sentiment analysis revealed varying degrees of concern, with academic groups, especially those specialized in environmental fields, expressing higher concerns than the control group. The MDS process provided a spatial representation of the data, with a Kruskal stress metric of 0.389, indicating good preservation of the original distances after reducing the data to two dimensions. This spatial representation allowed for a clear visualization of the semantic relationships between participants' responses without imposing a fixed number of clusters, offering a fluid observation of group dynamics and interactions.

Figure 1 illustrates the sentiment analysis results using a color gradient ranging from -4 (most negative) to 5 (most optimistic). Blue represents the most negative sentiments, yellow is the most positive, and green is neutral. The sentiment gradient indicates that most responses fell within the neutral to mildly positive range, with a higher occurrence of positive attitudes towards potential solutions for microplastic pollution.

Figure 1 also differentiates respondents by gender and educational level. Circles represent female respondents from secondary-technical education at IFRJ/CDUC, while triangles represent male respondents from superior education at IFRJ/CDUC. The X denotes female respondents from UFRJ literature courses, while crosses and lozenges indicate male and female respondents from superior education backgrounds in public spaces like the Shopping Center. The stars represent participants with diverse educational backgrounds.

The sentiment analysis revealed that respondents from academic environments, particularly those with a background in chemistry or environmental sciences, displayed more positive attitudes (green to yellow) compared to the general public, whose sentiments leaned more neutral. This suggests that educational context and proximity to scientific knowledge are crucial in shaping attitudes toward microplastic pollution.

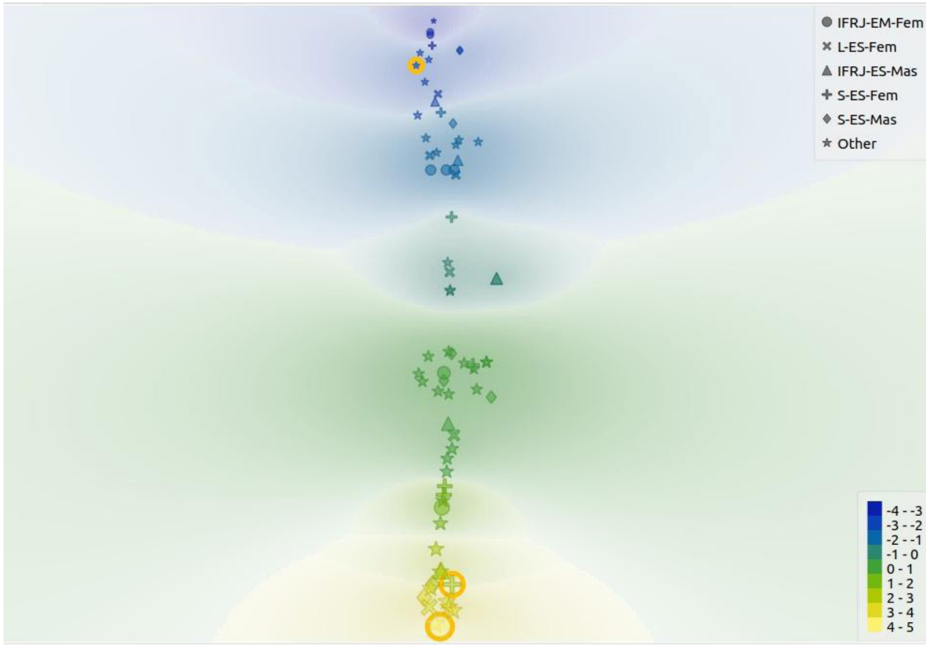

Figure 1. Color Gradient of Sentiment Analysis.

3.1 Local prospecting

Figure 2 illustrates the sentiment distribution across different locations where interviews were conducted, including the Technological Center of UFRJ (CT), IFRJ/CDUC, the Macromolecular Institute (IMA), Literacy Courses (L), and the Shopping Center (S). This graphical representation shows a clear differentiation in sentiment across these locations.

Interviewees from the Technological Center (CT) and IFRJ/CDUC displayed a stronger awareness of the impacts of microplastics, with a more varied emotional response compared to participants from the Literacy Courses (L) and the Shopping Center (S). This indicates that the location and educational environment significantly influenced the participants' perceptions.

While CT and IFRJ/CDUC respondents demonstrated heightened concern and a broader range of emotional responses, participants from Literacy Courses, showed limited interest in the subject. Similarly, respondents from the Shopping Center displayed a nearly equal balance between positive and negative sentiments, suggesting that public spaces may host a more indifferent or less informed demographic regarding environmental issues.

Participants from the Macromolecular Institute (IMA), a specialized academic group, exhibited the least diversity in sentiment. The responses leaned slightly positive, reflecting a more optimistic outlook towards potential solutions for addressing microplastic pollution, possibly due to their advanced understanding of the subject matter and prospects in microplastic mitigation.

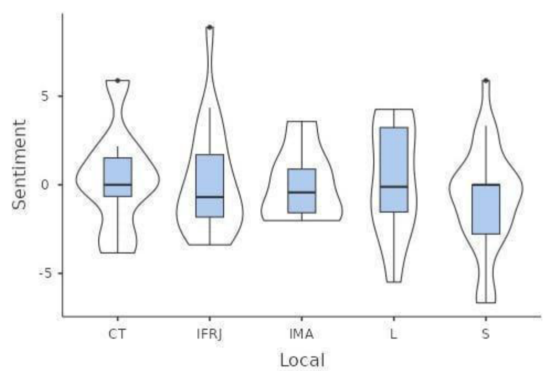

Figure 2. Sentiment Analysis by Local.

3.2 Education prospecting

Figure 3 illustrates the sentiment distribution based on the participants' education levels, categorized as primary education (EF), secondary education (EM), and higher education (ES). The figure highlights the variation in emotional responses towards microplastics among individuals from different educational backgrounds.

Participants with secondary (EM) and higher education (ES) exhibited a broader range of sentiments towards microplastic pollution, showing more awareness and sensitivity to the issue. Those currently enrolled in educational institutions, particularly at CT and IFRJ, demonstrated a heightened sensitivity to the topic. This indicates that formal education, especially in scientific or technological fields, is pivotal in shaping attitudes toward environmental concerns.

In contrast, participants from Literacy Courses demonstrated limited knowledge and concern regarding microplastics despite their educational engagement. The lack of strong sentiment in these groups suggests that more than mere academic involvement is required to foster awareness of environmental issues without targeted education.

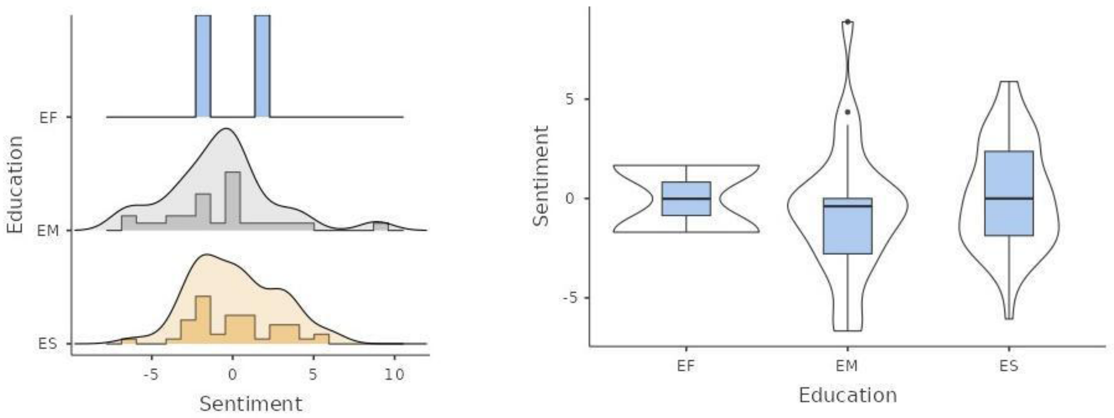

Figure 3. Sentiment Analysis by Education Level.

At the Shopping Center (S), where respondents came from diverse educational backgrounds, there was no clear or consistent stance on microplastics, indicating that public spaces may harbor a more indifferent or less engaged demographic.

The most striking result is from participants with only primary education (EF), who showed little concern or opinion about microplastics. This lack of awareness underscores the need for early-stage educational interventions to address environmental knowledge gaps and encourage pro-environmental behaviors. These findings confirm that educational background significantly influences perceptions and attitudes toward microplastics, with higher education levels correlating with increased awareness and concern.

3.3 Gender prospecting

Figure 4 illustrates the sentiment distribution across gender categories, including female (Fem), male (Mas), and non-binary/indeterminate (Ind) participants. The graphical representation shows distinct differences in how participants of different genders perceive the issue of microplastic pollution.

Both men and women demonstrated concern about the issue, with noticeable variations in the intensity and polarity of their sentiments. Male respondents exhibited a broader range of emotions, including higher positive sentiments, indicating a more vital interest in the microplastics issue than female respondents. This suggests that male participants engage more actively with the topic or potentially have greater exposure to information related to microplastic pollution.

While still concerned, female respondents displayed a more neutral to mildly positive sentiment, with fewer extreme responses than their male counterparts. This may indicate a moderate level of awareness but less pronounced emotional engagement with the issue.

Regarding non-binary/indeterminate (Ind) participants, the sentiment distribution was relatively narrow, with responses concentrated around neutral. No significant trend or behavioral pattern was observed within this group, and it was impossible to ascertain a clear position on the issue of microplastics. This could suggest a need for more awareness or a more cautious approach.

Overall, the data indicates that gender plays a role in shaping attitudes toward microplastic pollution, with men showing a slight tendency toward stronger opinions and engagement. However, the differences between male and female participants are not stark, suggesting that awareness campaigns and educational interventions can be broadly applied across genders to address the issue effectively.

3.4 Overall sentiment landscape

Figure 5 presents a general overview of the sentiment analysis, showing the density distribution of responses across the sentiment spectrum. The graph illustrates that most responses clustered around neutral sentiment, followed by moderately negative and moderately positive sentiments.

The density plot reveals that many participants expressed neutral or slightly concerned views on microplastic pollution. This suggests that, while many individuals are aware of the issue, it does not provoke strong emotional reactions. These neutral responses may reflect a limited understanding of microplastics' environmental and health impacts or a lack of exposure to comprehensive information on the subject.

Moderately negative sentiments were the next most common. These responses likely stem from participants with a greater awareness of the harmful effects of microplastics, particularly those concerned about environmental degradation and health risks. The concern is especially evident among those with higher levels of education or specialized academic backgrounds, as seen in other sections of the analysis.

Positive sentiments, while present, were less frequent. These optimistic responses reflect confidence in mitigation strategies, such as recycling programs or future technological solutions to microplastic pollution. However, the lower occurrence of positive responses indicates a general skepticism or lack of trust in current efforts to combat the problem.

The analysis underscores that most participants hold neutral or mildly concerned views, with only a minority expressing strong positive or negative opinions. This sentiment landscape highlights the need for enhanced public awareness campaigns and educational efforts to foster deeper engagement with environmental issues like microplastic pollution.

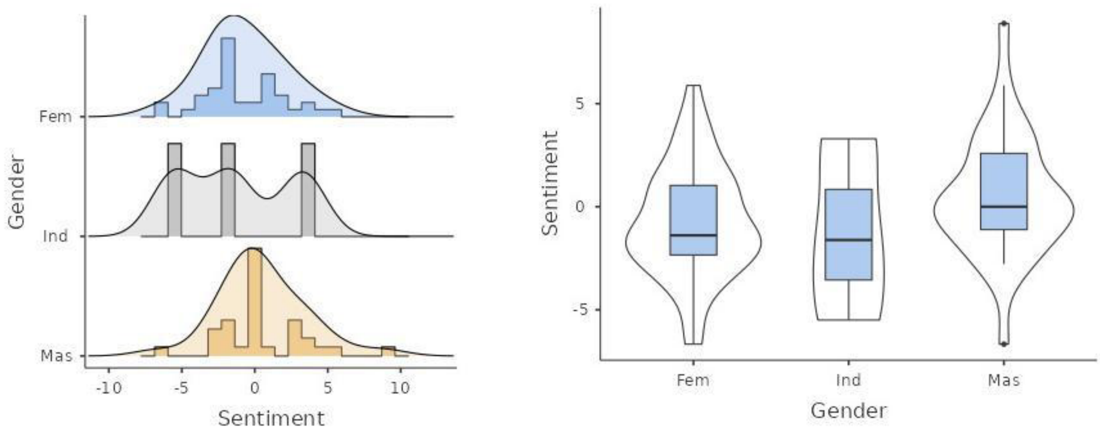

Figure 4. Sentiment Analysis by Gender.

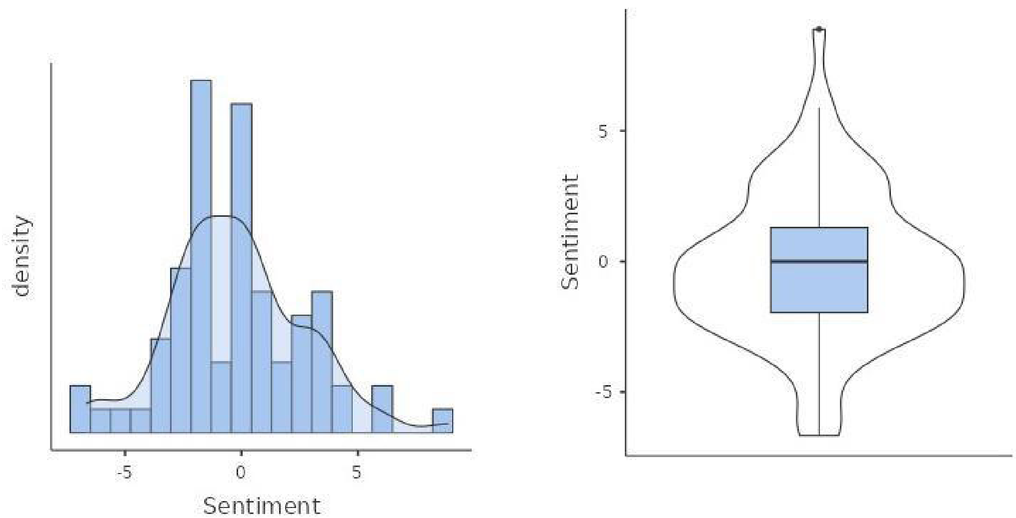

Figure 5. Density of answer in the general overview.

A significant innovation of this study lies in its application of advanced analytical techniques, such as sentiment analysis, hierarchical clustering, and machine learning. Incorporating Multidimensional Scaling (MDS) further enhanced the analysis by visually representing the semantic relationships between participant responses, uncovering subtle patterns those traditional qualitative methods might overlook.

The findings emphasize the need for targeted educational efforts to address the public's knowledge gaps, especially among individuals with lower levels of formal education or those outside specialized academic fields. Tailored educational programs that effectively communicate microplastics' environmental and health impacts can promote pro-environmental behavior across various demographic groups.

From a policy perspective, the study suggests that public sentiment should inform the design of regulations and initiatives to mitigate microplastic pollution. Incorporating diverse perceptions into policy frameworks ensures that interventions are more attuned to public attitudes, leading to more sustainable practices. Additionally, it underscores the importance of media and communication strategies in shaping public perceptions, highlighting the need for well-designed campaigns to engage broader audiences and foster informed public action.

While the study acknowledges certain limitations, these challenges reflect the broader research context in this emerging field. The sample size, though limited to 96 participants, provides valuable insights into the variability of perceptions within a diverse urban population. Although localized to Rio de Janeiro, the study offers a meaningful case study that serves as a foundation for future research in different cultural and regional contexts. The predominance of neutral sentiments underscores the complexity of public understanding of microplastics and indicates that the topic still requires greater public engagement. The absence of notable trends among non-binary participants suggests an opportunity for future studies to adopt a more inclusive approach, expanding the scope of research to underrepresented groups.

4. Conclusions

This study applied machine learning methodologies to analyze perceptions and attitudes toward microplastics among individuals in academic settings and the broader educational environment. The clustering process highlights how educational background and prior knowledge shape attitudes toward microplastics, with academics, particularly in environmental sciences, exhibiting higher concern and requiring advanced, technical discussions rather than introductory materials. In contrast, the general public (control group) showed lower concern levels, necessitating more engaging and accessible communication strategies such as interactive media, infographics, and social campaigns.

The sentiment analysis, presented via a color gradient, quantified participants' emotional responses, revealing a wide range of feelings towards microplastics. Some responses displayed positive sentiments, potentially linked to confidence in mitigation efforts or advancements in recycling technologies. Conversely, negative responses likely reflected deep concerns about environmental degradation and the health risks posed by microplastics. The spectrum of responses highlights the complexity of public engagement with the issue.

In conclusion, this study confirms a tangible level of awareness among participants regarding microplastics, though their sentiments reflect a mix of concerns, knowledge, and misconceptions. The data gathered is valuable for designing educational interventions and shaping public policies that deepen understanding and foster greater engagement with environmental strategies to combat microplastic contamination. Future efforts should address the identified knowledge gaps and promote informed, pro-environmental behavior, particularly within educational contexts.

5. Author's Contribution

- **Conceptualization** – Fernando Gomes de Souza Júnior; Viviane Silva Valladão; Sérgio Thode Filho.
- **Data curation** – Viviane Silva Valladão.
- **Formal analysis** – Viviane Silva Valladão; Letícia de Souza Ribeiro; Maria Eduarda da Silva Carneiro; Raynara Kelly da Silva dos Santos.
- **Funding acquisition** - Fernando Gomes de Souza Júnior
- **Investigation** – Viviane Silva Valladão; Letícia de Souza Ribeiro; Maria Eduarda da Silva Carneiro; Raynara Kelly da Silva dos Santos.
- **Methodology** – Fernando Gomes de Souza Júnior; Viviane Silva Valladão; Sérgio Thode Filho.
- **Project administration** – Fernando Gomes de Souza Júnior; Viviane Silva Valladão.
- **Resources** – Fernando Gomes de Souza Júnior.
- **Software** – Fernando Gomes de Souza Júnior.
- **Supervision** – Fernando Gomes de Souza Júnior.
- **Validation** – Fabíola da Silveira Maranhão; Sérgio Thode Filho.
- **Visualization** – Sérgio Thode Filho; Fabíola da Silveira Maranhão.
- **Writing – original draft** – Viviane Silva Valladão.
- **Writing – review & editing** – Fernando Gomes de Souza Júnior; Sérgio Thode Filho; Fabíola da Silveira Maranhão.

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