Longitudinal Study on Biodiversity in Ten Years of National High School Exam

Paulo Sergio Garcia [a]

Fernanda Franzolin [b]

Nelio Bizzo [c]

[a] Universidade Municipal de São Caetano do Sul, Pós-Graduação em Educação, São Paulo, SP, Brasil.
[b] Universidade Federal do ABC, Pós-Graduação em Ensino e História das Ciências e da Matemática, Santo André, SP, Brasil.
[c] Universidade Federal de São Paulo, Pós-Graduação em Ensino de Ciências e Matemática em Educação, Diadema, SP, Brasil.

ABSTRACT

Background: Biodiversity is essential for its instrumental, scientific, and political values, and its knowledge is vital to promote its preservation. Objectives: This study identified and analysed the presence of knowledge related to biodiversity in Biology and/or multidisciplinary items in the National High School Examination (ENEM) over ten years between 2009 and 2018. **Design:** Longitudinal study, based on qualitative methodology. **Setting and participants:** Education and science experts participated in the analyses. **Data collection and analysis:** Data were collected on the INEP website. Analyses performed by researchers and an expert panel. Results: We found a clear prevalence of the category "Ecology and Environmental Sciences" in the items, which is in agreement with the literature. However, we also found a disproportionate distribution of questions concerning the categories of the reference matrix of the discipline of Biology. Furthermore, there is significant variability in the theme in different years. We discussed the consequences for curriculum and conservation. **Conclusions:** There is an imbalance that reveals a dominant trend, acting as a structuring element of the questions, that silences other major areas of Biology and can influence the curriculum and practices of secondary school teachers. The high variability of the occurrence of the biodiversity theme in Biology tests suggests a non-harmonic relationship, which may be associated with the statistical demands of the IRT modelling, between the selection of questions and the reference matrix of the Biology categories, with possible consequences for the curriculum.

Keywords: Biological diversity, ENEM, School performance, Natural Sciences, Biology teaching.

Corresponding author: Paulo Sergio Garcia. Email: paulo.garcia@online.uscs.edu.br

Estudo longitudinal sobre biodiversidade em dez anos de Exame Nacional do Ensino Médio

RESUMO

Contexto: A biodiversidade é importante por seus valores instrumentais, científicos e políticos, e seu conhecimento é essencial para promover sua preservação. **Objetivos**: Este estudo identificou e analisou a presença de conhecimentos relacionados à biodiversidade em Biologia e/ou itens multidisciplinares no Exame Nacional do Ensino Médio (ENEM), ao longo de 10 anos, entre 2009 e 2018. **Design**: Estudo longitudinal, baseado em metodologia qualitativa. **Ambiente e participantes**: Especialistas em educação e ciências participaram das análises. **Coleta e análise de dados**: Os dados foram coletados no site do INEP. Análises realizadas por pesquisadores e um painel de especialistas. **Resultados**: Encontramos nítida prevalência da categoria "Ecologia e Ciências Ambientais" nos itens, o que está de acordo com a literatura. Porém, também encontramos uma desproporção na distribuição das questões em relação às categorias da matriz de referência da disciplina de Biologia. Além disso, há grande variabilidade no tema nos diferentes anos. Discutimos as consequências para o currículo e a conservação. **Conclusões**: Há um desequilíbrio que revela uma tendência dominante, atuando como elemento estruturante das questões, que silencia outras grandes áreas da Biologia e pode influenciar o currículo e as práticas dos professores do ensino médio. A alta variabilidade da ocorrência do tema biodiversidade nos testes de Biologia sugere uma relação não harmônica, que pode estar associada às demandas estatísticas da modelagem da TRI, entre a seleção das questões e a matriz de referência das categorias de Biologia, com possíveis consequências para o currículo.

Palavras-chave: Diversidade Biológica, ENEM, Desempenho Escolar, Ciências da Natureza, Ensino de Biologia.

INTRODUCTION

Biodiversity is important because of its instrumental, scientific, political, and intrinsic values (Ricklefs & Relya, 2014; Alho, 2008). Its knowledge is relevant to promote its preservation (Palmberg et al., 2015) and maintain young people's interest in nature conservation actions, which has shown an upward trend since 2007 (Franzolin, Garcia, & Bizzo, 2020). Thus, the study of possible factors that influence its teaching becomes relevant, such as the National High School Exam (ENEM), which occurs at the end of basic schooling in Brazil and strongly affects classroom work across the country.

In fact, ENEM has influenced high school curricula, a context in which teachers end up teaching what is required in the exam for young people to

obtain good results. In this way, the exam has also conditioned teachers' practices in the classroom, the development of teaching materials and guidelines for pedagogical policies. (Stadler & Hussein, 2017). There is evidence that teachers of schools with high ENEM scores use the "content of official exams and use contextualisation to enrich them" (Carvalho & Rezende, 2013, p. 555). In the same sense, it is well known that in many Brazilian schools, students are trained to take the ENEM exam since elementary school.

Several studies on ENEM have focused on understanding the questions (also called items in this article) of the natural sciences tests, in general, and of the biology curricular component, in particular.

In a study on ENEM questions between 2005 and 2014, Malimpensa and Rink (2017) analysed genetics content based on the knowledge objects proposed by the exam's reference matrix. The authors show a great imbalance between the various themes in the area, with a strong preponderance of contents related to the categories "Molecules, Cells, and Tissues" and "Heredity and Diversity of Life", on the one hand and, on the other, the category "Quality of Life in Human Populations" was very rare in the period analysed.

Brito (2015) examined the characteristics of the biology questions in the ENEM tests in 2011 and 2012, using statistical tools, among others. The author found that approximately 50% of the items that addressed issues related to the environment were in the category of "Ecology and Environmental Sciences", present in the exam's reference matrix.

More focused on understanding skills and competencies, Silva, Souza, and Carvalho (2019) carried out a survey and categorisation of biology topics addressed by ENEM between 2012 and 2016. The authors also identified that the category "Ecology and Environmental Sciences" was the most present in the analysed editions. Cestaro, Kleinke, and Alle (2020), also analysing the biology items in ENEM 2012 through 2016, and Testasicca, Araújo, Oliveira (2020), evaluating the competencies and skills determined by the matrix of reference in ENEM 2018 and 2019, reached the same results, revealing that questions related to the category "Ecology and Environmental Sciences" were more preponderant.

Garcia (2020), studying ENEM 2009, analysed the issues of the Biology curricular component, and/or multidisciplinary issues, involving contents of this module, with knowledge related to biodiversity, showing the greater presence of the category "Ecology and Environmental Sciences" and

[Digite aqui]   [Digite aqui]

the objects of knowledge associated with environmental problems, such as pollution, among others.

In this study, we identified and analysed the knowledge related to biodiversity in biology and/or multidisciplinary found in questions over ten years, between 2009 to 2018.

Biodiversity in the National High School Exam - ENEM

ENEM has a large number of participants every year, with almost nine million registered in 2014. However, in 2019, the exam had the lowest number of confirmed entries in the last five years, just over 5 million.

Table 1 summarises enrollment data from 2009 onwards.

Table 1

Number of Candidates Registered and Confirmed for ENEM – 2009/2020.
(Instituto Nacional de Estudos e Pesquisa, 2019)

Year and Number of candidates registered	2009	2010	2011	2012	2013	2014
	4,148,025	4,626,094	5,366,949	5,791,332	7,173,910	8,722,910
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
	7,792,025	8,627,371	6,731,186	5,513,000	5,095,308	5,783,357

In 2021, ENEM will complete its twenty-first edition. The assessment underwent several changes in 2009. One of them was that the examiners started using the Item Response Theory (IRT), also called Latent Trait Theory, in their methodology to prepare items and account for results, and a reference matrix of conceptual contents, called "objects of knowledge", which are grouped into large domains of the Biology curricular component, to which some authors (Brito, 2015; Malimpensa & Rink, 2017; Garcia, 2020) refer as "categories".

In the case of the IRT, it is a methodology that uses mathematical functions and models to estimate the probability of each student responding correctly to an item based on their performance on similar items (Pasquali & Primi, 2003). This modelling differs from the Classical Test Theory (CTT), which directly associates the number of correct answers to its score (Souza &

Braga, 2020). The IRT aims to measure variables that are not observable (latent trait), but that influence the responses, using the measurement of observable variables, the set of hits.

ENEM uses the three-parameter IRT logistic model, which considers the participant's proficiency (Θ), and the parameters associated with the item: item discrimination (a), difficulty (b), and chance response (c) (Andrade, Tavares, & Valle, 2000).

In the IRT, the correct answers are important; however, the methodology intends to control the coherence in the answers, correcting random correct answers. More important than the number of correct items is knowing their calibration, which is crucial for calculating the final grade. The coherence is defined by the student's performance when he/she hits the questions with a level of difficulty less than or equal to his/her level of proficiency, and misses the more difficult ones.

By requiring the calibration of the difficulty of the items, the IRT enables the comparison between questions of different editions of the assessment, as they are positioned on the same metric, with which the interpretation of the pedagogical characteristics of the item allows for a qualitative analysis of the skills that the students master or not. In this sense, the IRT accepts the premise that there is an item characteristic curve (ICC), a normal distribution curve in a given population. This curve must be established empirically, through field testing, assuming that the difficulty of the items is homogeneous in all regions of the country, i.e., there is no item bias (DIF - Differential Item Functioning), which presupposes some homogeneity in the study of young people's interests across the country.

Thus, it is assumed that the response to an item requires some psychic process that is distributed in the population as a normal curve, i.e., that most individuals have an average level of that process, and a smaller part has a low level, and another part, of similar magnitude, has a high level. As we will see below, there is concrete evidence that this assumption may not be applicable to items that refer to local contexts, such as the biodiversity of a country like Brazil.

At each edition, the National Institute of Studies and Research Anízio Teixeira (Instituto Nacional de Estudos e Pesquisas) selects a set of items, the 45 questions in each area, to assess the student's proficiency (the mastery of skills, abilities, and mastery of the objects of knowledge), and places them on

a scale of difficulty (easy, medium, and difficult items, with a preponderance of medium), estimating the minimum and maximum scores.

All ENEM questions are previously tested and classified into a school of easy, medium, and difficult items. After testing, INEP calculates the indices of difficulty, discrimination, and probability of a correct answer at random. Finally, the items become part of the National Bank of Items (Banco Nacional de Items - BNI).

The reference matrices are based on competencies and skills (Brasil, 2009). Article 32 of the National Curriculum Guidelines for High School Education (Brasil, 2018) indicates that the ENEM Matrices "must necessarily be prepared as per the National Common Curricular Base (Base Nacional Comum Curricular – BNCC) and the provisions of the References for the Preparation of Formative Itineraries (Referenciais para a Elaboração dos Itinerários Formativos". However, such an update has not yet occurred (October 2021), and the guidelines follow the previous indications.

Alongside competencies and skills, there are conceptual references of the modules, the objects of knowledge, which are grouped into broad domains, categories. In the case of Biology, the following categories are defined: Ecology and Environmental Sciences; Identity of Living Beings; Heredity and Diversity of Life; Molecules, Cells and Tissues, Origin and Evolution of Life and Quality of Life of Human Populations.

The category "Ecology and Environmental Sciences" presents as "objects of knowledge": ecosystems, biotic and abiotic factors, habitat and ecological niche, interactions between living beings, Brazilian biomes, environmental problems and climate change, which gives an idea of the amplitude of themes that belong to this category (Brasil, 2009, p. 20). Deforestation, erosion, water, soil and air pollution, biodiversity conservation, environmental legislation, forests and conservation units are also objects of knowledge in this same category, which is comprehensive and relates to the environment.

Although a broad conception of biodiversity is associated with several categories, the literal term biodiversity appears in the category "Ecology and Environmental Sciences". In a megadiverse country like Brazil, biodiversity is central in discussions and controversies, especially in recent decades, due to the significant loss of habitats resulting from total inadequate governance. In fact, the loss of biodiversity and degradation of ecosystem services have occurred intensely but differently in distinct ecosystems worldwide (Bowler et al., 2020).

However, it is a global phenomenon. In Brazil, this loss also originates from a crisis in socio-environmental governance, which is exacerbated "by the dismantling of the entire legal and institutional framework responsible for environmental governance, and the deactivation of the mechanisms that regulated the institutional relations of the State with the traditional populations of the country" (Joly & Queiroz, 2020), such as indigenous and riverine people, who are direct linked to nature.

In education, the study of biodiversity is essential to allow young people to act, among other issues, in the preservation of nature. In fact, in a meta-analysis, Zelezny (1999) showed that young people are more interested in preserving the environment than adults, especially in schooling before the age of 18. In addition, he observed that the most appropriate context for changing attitudes is the classroom in strict teaching situations. Therefore, studying biodiversity in schools during basic education is essential to improve attitudes, aiming to develop concrete actions for conservation and sustainability.

Indeed, as Swaminathan (1992) indicated, basic school education has been essential for students to develop interests, attitudes, and knowledge related to ecological awareness. For Ghisolfi (2000), the school is a space where students can master knowledge to understand biodiversity based on technical, scientific, political, and social aspects.

In this way, young people can engage in debates about the biodiversity crisis (Joly & Queiroz, 2020), causes of the local extinction of species, and loss of their habitats, putting pressure on ecosystem services that are fundamental for the survival of the populations (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019; Secretariat of the Convention on Biological Diversity, 2020).

This crisis has been intensifying in Brazil due to socio-environmental governance, as said previously. The study of local biodiversity cannot be dissociated from other social problems, focusing only on concepts addressed in a non-contextualised way (Tollefson, 2020).

In fact, Pujol (2003) and others insist that we need to find new ways of relating to nature, centred on fields that involve economic, political, social, and ecological issues. It is a systemic perspective to bring about profound changes in education, in general, and in science teaching, in particular. Such a vision moves away from an emphasis on purely informative, fragmented, and

decontextualised aspects, personified in the school environment, and seeks broader education.

The school is committed to educating citizens so that they reflect on the various environmental problems in their immediate environment and have the right to make decisions and act through their direct participation. It is the most appropriate social institution for the development of concrete educational methods and actions for the knowledge of biodiversity and conservation.

To develop such understandings, pedagogical action based on multidimensional discussions of science is necessary so that scientific knowledge can be understood from the point of view of history, nature, and its relations with society. The contents must be instruments for the critical understanding of biodiversity issues as the basis for the exercise of citizenship.

METHODOLOGY

In this study, we identified and analysed knowledge related to biodiversity in questions of biology and/or multidisciplinary ones involving contents of this subject matter in the National High School Exam, over ten years, from 2009 through 2018.

This is a qualitative study based on documentation research. In this type of study, the use of documents makes it possible to extract information to broaden the understanding of phenomena, the understanding of which requires historical and sociocultural contextualisation (Cellard, 2008).

For the author:

> the written document is an extremely precious source for every researcher in social sciences. It is, of course, irreplaceable in any reconstruction referring to a relatively distant past, as it is not uncommon for it to represent almost all the traces of human activity at certain times. (Cellard, 2008, p. 295)

Documentation research deals with materials and primary sources that have not received any analytical treatment. To facilitate the verification of the results presented below, we will always refer to the blue version of the ENEM in all ten editions analysed, as it was the colour of the test drawn to be analysed.

The analysis consisted of four stages. In the first one, the researchers identified, in the Natural Sciences tests, in a sample universe of 450 items, the questions that belonged to the Biology curricular component and/or that were

multidisciplinary involving knowledge of this subject matter. In parallel, they identified the items whose knowledge was related to biodiversity, within and any of the six thematic categories of biology in the reference matrix. This first stage indicated 78 items that approached biodiversity in the subject considered in some way.

To select the questions, we adopted the expanded concept of biodiversity, linked to the multidimensionality of the concept of biological diversity, which has been defined at three levels (Futuyma, 2002; Rawat & Agarwal, 2015). One of them, perhaps the most obvious, has been pointed out as referring to species diversity (Gaston, 2000; Futuyma, 2002). The other refers to genetic diversity, the basis on which populations can maintain themselves without accumulating considerable genetic load, to the point of accumulating lethal or deleterious recessive alleles in homozygosis by increasing the inbreeding coefficient, technically defined as a relationship between the observed frequency of heterozygotes in the deme and the expected frequency of heterozygotes under Hardy-Weinberg (Templenton, 2011, p. 57-58). The third level of biodiversity refers to the ecological level, and can be mentioned in terms of the variety of biotic communities (Rawat & Agarwal, 2015) and the diversity of functional processes that maintain complex systems (Odum & Barrett, 2008, p. 37-8).

In the second stage, a group of professionals validated the selected questions. We used here peer review methodology, the Face Validation technique (Bowling, 1997) carried out by a panel of invited experts, with the participation of a professor, master in education, specialised in the interaction of children with nature, two biologists, master's students in the field of education, and three high school Biology teachers from the city of São Caetano do Sul, state of São Paulo. These professionals analysed the items collectively and agreed with the previous selection by approximately 80%.

The third stage sought a consensus between a committee of experts and the researchers, evaluating each question selected by them. The proximity of the question statement with the theme of biological diversity was discussed in detail in each of the items. This research stage took a long time, and we reached a consensus of 78 questions in the ten editions of the exam.

In the fourth stage, the selected questions were associated by the researchers to the respective thematic categories and the objects of knowledge of the Biology curricular component of the ENEM reference matrix (Brasil, 2009). With this categorisation, it was possible to carry out comparative analyses throughout the ten editions of the exam. Identified in tables 2 and 5,

the questions are associated with the respective thematic categories of Biology for each edition of the exam.

From data collection to the analyses carried out by the researchers and the expert committee, all stages of this study occurred face-to-face before the Covid-19 pandemic outbreak.

RESULTS

Within the universe of data, the study identified 168 items (37.3%) that belonged to the Biology curricular component and/or involved knowledge of the subject matter along with others (the so-called multidisciplinary items).

Table 2

Questions About the Biology Curricular Component and/or Multidisciplinary Knowledge Involving the Subject (BLUE TEST)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2	46	47	46	50	47	46	53	91	94
3	49	48	47	53	49	47	56	92	96
4	51	49	48	55	53	54	57	94	98
7	53	51	51	56	54	56	61	96	100
8	57	53	52	59	60	59	62	98	101
9	59	57	56	60	61	61	65	100	106
10	60	59	57	62	63	66	69	109	107
11	61	61	62	63	69	67	71	111	110
13	62	64	63	70	71	69	73	116	111
16	64	65	65	73	73	72	75	117	113
21	66	68	68	78	74	74	79	123	117
23	71	69	71	80	75	80	80	125	119
24	75	71	75	84	78	81	83	128	127
25	76	76	80	88	79	83	87	135	133
28	86	79	81	-	81	84	90	-	135
33	87	80	85	-	85	87	-	-	-
34	88	82	87	-	89	89	-	-	-
41	90	85	-	-	-	-	-	-	-
42	-	87	-	-	-	-	-	-	-
-	-	88	-	-	-	-	-	-	-
-	-	89	-	-	-	-	-	-	-
-	-	90	-	-	-	-	-	-	-
19	**18**	**22**	**17**	**14**	**17**	**17**	**15**	**14**	**15**

Table 2 presents the ENEM editions from 2009 through 2018 and the number of questions identified.

The Natural Sciences tests presented an average of 16.8 (SD=2.5) questions referring to the Biology curricular component. We identified 168 items, with significant variation in the different editions, between 14 and 22 items, as in the 2011 edition.

Table 3

Number of Questions Identified and Total

ENEM	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
	8	61	47	48	53	53	47	57	98	98	
	9	64	51	51	59	54	56	61	109	101	
	10	66	64	56	60	60	59	62	111	106	
	13	75	76	57	62	61	61	71	123	107	
Number of the question in the blue test	23	76	82	62	63	63	72	73	-	111	
	28	87	87	65	70	69	80	75	-	119	
	33	-	88	68	80	71	81	79	-	133	
	42	-	-	75	84	81	83	83	-	-	
	-	-	-	81	-	-	84	90	-	-	
	-	-	-	85	-	-	89	-	-	-	
	-	-	-	87	-	-	-	-	-	-	
Total of items	8	6	7	11	8	8	10	9	4	7	78
ENEM	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**

Of these 168 items, we found 78 sociated with an expanded concept of biodiversity between 2009 and 2018. Table 3 presents the ENEM editions, with the number of questions identified.

The average of 7.8 (SD=1.98) is the result of important variation over the years, between 4 (29%) in the 2017 test, at the lower end, and 11 (69%) in the upper, in the 2012 test.

Table 4 shows the total number of Biology items and the percentage of questions with knowledge related to biodiversity in this amount.

Table 4

Biology Curriculum Component Items and the Percentage of Biodiversity Questions in this Amount

Items	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Total of Biology and/or multidisciplinary items	19	18	22	16	14	17	17	15	14	15	**168**
Items of biodiversity in Biology (%)	42.1	33.3	31.8	64.7	57.1	47.1	58.8	60	28.7	46.7	**46**

In ten years, in a total of 168 questions related to biological content, an average of 46.4% of the items were associated with an expanded conception of biodiversity. This average results from considerable variation, between 28.6% in the 2017 test and 64.7% in the 2012 test.

The distribution of questions dealing with biodiversity by the categories of the ENEM reference matrix had even more significant variation. The distribution is shown in table 5.

Table 5

Distribution of Questions by Theme

Year	Category	Blue test question
2009	Ecology and Environmental Sciences	8, 10, 13, 23, 28, 42
	Identity of Living Beings	9 and 33
	Origin and Evolution of Life	33
2010	Ecology and Environmental Sciences	61, 75, 87
	Identity of Living Beings	66
	Origin and Evolution of Life	64
	Quality of Life of Human Populations	76
2011	Ecology and Environmental Sciences	47, 51, 76, 82, 88
	Identity of Living Beings	87
	Quality of Life of Human Populations	64
2012	Ecology and Environmental Sciences	51, 56, 57, 62, 65, 68, 81, 87
	Molecules, Cells, and Tissues	48
	Heredity and Diversity of Life	75, 85
2013	Ecology and Environmental Sciences	59, 63, 80, 84
	Identity of Living Beings	53
	Origin and Evolution of Life	60
	Molecules, Cells, and Tissues	62, 70
2014	Ecology and Environmental Sciences	54, 60, 61, 63, 71, 81
	Identity of Living Beings	53
	Molecules, Cells, and Tissues	69
2015	Ecology and Environmental Sciences	47, 56, 59, 61, 80, 81, 84, 89

[Digite aqui] [Digite aqui]

	Identity of Living Beings	83
	Quality of Life of Human Populations	72
	Heredity and Diversity of Life	56
2016	Ecology and Environmental Sciences	57, 61, 62, 71, 73, 79
	Identity of Living Beings	57, 75
	Origin and Evolution of Life	70, 90
	Heredity and Diversity of Life	83, 90
2017	Ecology and Environmental Sciences	109, 111, 123
	Identity of Living Beings	98, 123
2018	Ecology and Environmental Sciences	98, 133
	Identity of Living Beings	101, 106, 111, 133
	Quality of Life of Human Populations	119
	Heredity and Diversity of Life	107

All thematic categories of the Biology curricular component in the ENEM reference matrix presented at least one question related to biodiversity in the tests surveyed. The total in the table (n=85) of questions indicates that some were related to more than one thematic category, as is the case of question 33, in the 2009 edition, of question 56, in the 2015 edition, and items 57 and 90, in 2016, among others.

Only the "Ecology and Environmental Sciences" category had issues related to the expanded concept of biodiversity in all editions of the assessment and also in higher numbers, with eight, in the 2012 and 2015 editions. Even in the year with the lowest number, in 2017, three of them belonged to this thematic category. This was the most prominent category in almost all test editions, with a single exception, in 2018, when the thematic category "Identity of Living Beings" had the highest number of questions (table 5).

Figure 1 allows us to recognise the variability of the questions in ten years of analysis and the stronger representation of the questions of the thematic category "Ecology and Environmental Sciences".

Figure 1

Biodiversity Content in ten years of ENEM - %.
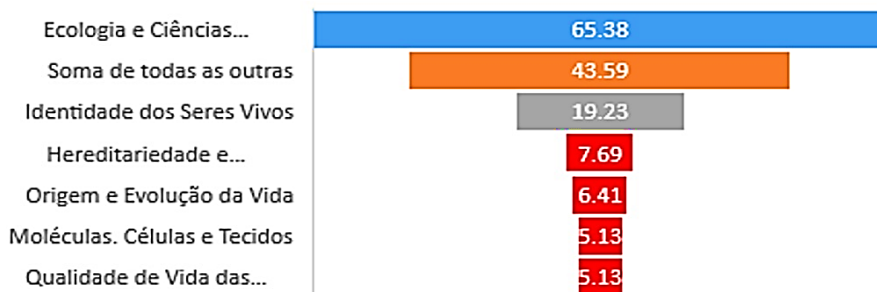
In fact, the cumulative occurrence of questions related to biodiversity included in the thematic category "Ecology and Environmental Sciences" totals more than all the others combined in ten years of analysis.

Figure 1 shows that other categories, such as "Origin and Evolution of Life", "Molecules, Cells, and Tissues", and "Quality of Life of Populations", were much less present in the ENEM tests in ten years.

The average of 14.17 occurrences per thematic category over ten years indicated in Table 5 has a large standard deviation (SD=18.52). The result indicates that more than half (n=51, or 65%) of the questions that dealt with biodiversity belonged to a single thematic category ("Ecology and Environmental Sciences"), while some categories made up less than a tenth of this value, as is the case of Quality of Life of Populations, with half an occurrence for each application of the test.

The items in the thematic category "Identity of Living Beings" that addressed the concept of biodiversity made up just under 20% of the questions related to biological knowledge. The other thematic categories contributed less than half of the second place. "Molecules, Cells, and Tissues" and "Quality of Life of Human Populations" had representations around 5%.

[Digite aqui]   [Digite aqui]

Examples of items selected in the analysis can be seen in the APPENDIX, which contains three questions from the 2009 exam. Question 6 deals with the biogeochemical cycle of carbon and explores students' knowledge of the release into the atmosphere of carbonate compounds from fossil fuels. The relationship with the topic of biological diversity is evident, given the climatic consequences resulting from the release of compounds linked to the greenhouse effect.

Soon after, question 10 of the same test brings the theme of photosynthesis, verifying if the student knows basic aspects of the origin of the energy used in the process. Those two questions address general topics that would be answered by students from any country, as it is a basic subject in Biology. In addition, the so-called "reverse induced performance" effect is perceived since reading the statement is very time-consuming and can induce the student to choose the incorrect alternative (Bizzo et al., 2013).

Question 23 is another example that features a relatively long text on the management of solid waste linked to cells and batteries and asks that the best alternative be selected to link with the topic of bioaccumulation of heavy metals in food chains. The topic had a national dimension at the time, when the change in environmental policy in the country was discussed. Once again, pollution and environmental degradation are themes closely linked to the theme of biodiversity.

DISCUSSING THE RESULTS

This study brings additional elements to the understanding of the occurrence of knowledge related to biodiversity in the questions of the ENEM tests in the Biology curricular component. This evidence allows us to delineate a broader and clearer picture of how biodiversity is presented in the exam, an element of recognised influence in the curricular development and in the pedagogical practices of basic education teachers, especially in high school.

Two findings deserve to be highlighted from the data analysed. The first is the confirmation of the hypothesis that the category "Ecology and Environmental Sciences" is the one that concentrates more questions with knowledge related to biodiversity, as suspected (Brito, 2015; Garcia, 2020). This confirms the unbalanced distribution of questions related to biodiversity (Table 5) in ENEM, in relation to the existing categories in the reference matrix of the Biology curricular component. This makes it possible to ask whether the

multidimensional nature of biodiversity is, in fact, being implemented, or whether a more restricted approach prevails.

In a previous analysis of the ENEM tests of 2011 and 2012, Brito (2015) showed that the distribution of the biology contents foreseen by the thematic categories of the subject matter was unbalanced. For the author, this finding was worrying, as it is an important assessment on the national scene, and a more balanced division of subjects was expected, without privileges for specific sets of knowledge. For Brito and Gebara (2015, p. 5), the difference between the content of the reference matrix and "the content that is effectively present in the tests reveals the presence of dominant trends, such as Ecology, which assume new concepts and act as structuring elements of the items". The authors criticised the prevalence of some themes in opposition to others in ENEM test.

Our results indicate an even more worrying scenario, as it allows us to understand in a more detailed way how this "dominant trend" of Ecology is, on the one hand, really prevalent in an extended arc of time, but, going further, on the other hand, how it manifests itself in relation to biodiversity.

The fact that biodiversity is addressed in a highly disproportionate way in the category "Ecology and Environmental Sciences", and very little in others, especially in "Identity of Living Beings" and "Quality of Life of Populations", reveals a generic approach formally related with the themes of Ecology, but without focusing on specific cases of the diversity of living beings, especially those at risk, or populations deprived of ecosystem services. It is not surprising, therefore, that the greatest disequilibrium in the distribution of all the analyses carried out was precisely centred on biodiversity in the thematic categories of items related to biology knowledge.

This finding reveals a central qualitative characteristic of this "dominant trend" pointed out in the literature, as it makes the curricula effectively practiced in basic education schools lean towards generic themes, dealing, for example, with ecological interactions in which there are generic "producers", such as "grass" and "turf/wild grass", instead of chestnut trees in the Amazon or araucarias in the South region. Likewise, the approach of "consumers" is generic, such as "crickets", "frogs", and "snakes", rather than real species, especially endemic and endangered ones. Quite the contrary:

> Biology curricula in Brazil tend to favour large charismatic specimens of exotic megafauna (e.g. polar bears, elephants, giraffes, penguins, etc.) native to other regions rather than

encouraging the study of local but less popular animals, like the insects found in the backyards of the students' own homes. (Oliveira & Cook, 2019, p. 13)

Actually, several reviews of books aimed at students revealed the poor approach of the local biota compared to exotic and generic biotas and not only in Brazil. When 251 French students were asked to name five species that should receive special attention, the answers fell on exotic and charismatic animals such as the panda bear (73.2% of the responses) and the polar bear (71.1% of the responses), whereas only 13.3% of the cited species belonged to the local biota (Ballouard, Brischoux, & Bonnet, 2011).

Brazil's poor approach to biodiversity is already well documented, especially in textbooks distributed in public schools by the National Textbook Program (PNLD). For example, Silva (2016) analysed ten textbook collections from the 2014 PNLD and found that the use of images of exotic fauna is frequent, despite the expressed recommendations of different agents. Most (70%) of the books did not bring any suggestion of practical activities about the fauna, and only one collection (10%) focused on specific cases of extinction risk.

Many teachers, not to mention the so-called "cursinhos" [courses dedicated to preparing candidates for assessments] for ENEM, can invest more time in the knowledge of the most targeted category, in the generic way usually approached, seeking the success of students in the exam. As several authors have already indicated, the ENEM influence much the curricula and teaching practices of high school teachers (Carvalho & Rezende, 2013; Stadler & Hussein, 2017, among others). Many teachers prepare students for the assessment since it is a stairway to higher education. Besides, high scores in ENEM can put schools in evidence in the media rankings.

We need deeper studies to know why the categories foreseen in the ENEM reference matrix of the curricular component of Biology are not as balanced as the alleged multidimensionality of biodiversity present in the exam. The analysis shows that between 2009 and 2018 biological diversity tends to be based on the ecological dimension of biological knowledge in a generic way and acts as a basis for structuring the items. An absolute balance between the categories or objects of knowledge on which the questions are based on each test is not expected nor desired. However, over ten years, it would be important not to have an absolute dominance of one to the detriment of all the others within the biological field.

This disproportionate distribution of questions associated with knowledge in the "Ecology and Environmental Sciences" category may raise at least two hypotheses that would need to be explored in greater detail. The first is the fact that most high school textbooks bring the knowledge of this category in their last units. This can be seen in the analyses carried out by Bezzon and Diniz (2020), Ferreira and Machado (2016), and Testasicca, Araújo, and Oliveira (2020), in which this thematic unit is in the third volume of the collection. The second, which may be associated with the previous one, is the topic. In some schools, it is studied in the third grade of high school, as seen in many plans of teachers of state high schools in the region of Grande ABC Paulista (Observatório de Educação do Grande ABC, 2020). Both circumstances may be related to allowing the young person to study the knowledge of this area, in a way closer to the completion of ENEM.

The second finding presents two new facts. The first indicates that over ten years, the biodiversity theme, in an expanded conception, has been very present in the ENEM tests. This situation, which gives prominence to the topic, may be associated with the high visibility of controversies about the environment in the media in recent decades. Actually, since 1992, when the United Nations Conference on Environment and Development, entitled Rio-92 or Eco-92 was held, including Agenda 21 and the Convention on Biodiversity, various debates and documents have sought to discuss the environment, seeking solutions to integrate society into sustainable development (Secretariat of the Convention on Biological Diversity, 2020).

The second fact, which we think disturbing, indicates that the presence of the biodiversity theme has varied much in the ENEM tests in ten years of analyses. Sometimes it was in less than 30% of the Biology items of the test (as in 2017), other times in approximately 65% of the questions (in 2012). Such oscillations clearly indicate an imbalance in the selection of the items that make up the test between the categories of the reference matrix of the Biology curricular component. The approach to biodiversity is poorly associated with "Quality of Life of Populations" and "Identity of Living Beings", indicating a generic approach to the environmental issue, possibly superficial and anodyne, i.e., silencing the seriousness of the environmental impacts of human actions on Brazilian territory.

This generality of the items and their positioning in the proficiency scale may be more related to the adequacy of the minimum and maximum score of the test, and not in a harmonic relationship of the questions with the categories of the reference matrix of the Biology curricular component. In other

[Digite aqui]   [Digite aqui]

words, possibly the architecture of the test, due to the modelling resulting from the use of IRT, ends up prevailing over the conceptual content, generating distortion in the distribution and relevance of the areas of knowledge, with inevitable repercussions, including in the curriculum itself. Questions with a generic approach to the environment to the detriment of the study focused on local biodiversity may be more necessary for the mechanics of the technique used in the accounting of hits and modelling of the results. Medium difficulty questions for students across the country would be favoured, not for their educational value, but just to satisfy the conditions of the IRT. The different categories of the exam matrix would not have the same conditions to provide items with those characteristics.

The urgency for questions of medium difficulty for students from all over the country could make the privileged category present contexts linked to general aspects of "Ecology and Environmental Sciences", to the detriment of the study of local and even tropical biodiversity in the Brazilian context.

As a result, those questions could have an inverse effect on the cause of conservation by drawing attention to generalities about the environment instead of focusing on specific issues that, as a rule, demand a deeper understanding of the tropical context. As ENEM is recognised as a way to go to higher education, this could be one factor that explains why students from the South and the Southeast have less interest in studying local biodiversity (Fernanda, Garcia, & Bizzo, 2020).

FINAL CONSIDERATIONS

Longitudinal studies on topics present in large-scale exams, such as the Exame Nacional do Ensino Médio - ENEM, are not part of the tradition of Brazilian educational research. This work differs from others, going in this direction. Through the analysis of the questions, the researchers showed the knowledge of biodiversity that was present in the ENEM, revealing which categories have been most used between 2009 and 2018.

From the empirical data found in this study, two findings contributed to expanding the understanding of items related to biodiversity present in the tests of the Biology curricular component of ENEM from 2009 to 2018.

The category "Ecology and Environmental Sciences" was the most prevalent in the questions, which was in line with the data already existing in the literature in the area. However, this finding was expanded, because the time

interval analysed was a decade, and, at the same time, more detailed, pointing out a disproportion in the distribution of questions in relation to the categories of the reference matrix of the discipline of Biology, an imbalance that reveals a dominant tendency, acting as a structuring element of the questions, which silences other major areas of this subject matter and can influence the curriculum and teaching practices of basic education teachers, in general, and high school teachers, in particular.

The high variability of the occurrence of the biodiversity theme in Biology tests suggests a non-harmonic relationship that may be associated with the statistical demands of the IRT modelling, between the selection of questions and the categories of the reference matrix of the Biology curricular component, with possible consequences for the curriculum.

ACKNOWLEDGEMENTS

AUTHORSHIP CONTRIBUTION STATEMENTS

This study is part of a Fapesp regular project linked to a thematic project. The three authors participated in the study's design in theoretical and methodological terms. They also acted in the analyses and discussions. The first author (P.S.G.) led the study and article, performing data collection and initial assessment of the work, along with the Research Group on Educational Assessment and Performance (Grupo de Pesquisas em Avaliação Educacional e Desempenho - GPAED).

DATA AVAILABILITY STATEMENT

The data supporting the results of this study will be made available by the corresponding author, P.S.G., upon reasonable request.

REFERENCES

Alho, C. J. R. (2008). The value of biodiversity. *Brazilian Journal of Biology*, *68*(4), Suppl., 1115–1118. https://doi.org/10.1590/S1519-69842008000500018

Andrade, D. F., Tavares, H. R., & Valle, R. C. (2000). *Teoria da Resposta ao Item: conceitos e aplicações*. SINAPE.

Ballouard, J. M., Brischoux, F., & Bonnet, X. (2011). Children Prioritise Virtual Exotic Biodiversity over Local Biodiversity. *PLoS ONE 6*(8), e23152. https://doi.org/10.1371/journal.pone.0023152

Bezzon, R. Z. & Diniz, R. E. S. (2020). O conceito de ecossistema em livros didáticos de Biologia do Ensino Médio: abordagem e possíveis implicações. *Educação em Revista*, *36*, e195948. https://doi.org/10.1590/0102-4698195948

Bizzo, N.; Santos-Gouw, A. M., Garcia, P. S., Monteiro, P. H. N., Tolentino-Neto, L. C. B. (2014). In-Context Items in a Nation Wide Examination: Which Knowledge and Skills are Actually Assessed?. In: *Proceedings of the ESERA 2013 Conference Science, Education Research For Evidence-based Teaching and Coherence in Learning*, Larnaca (Chipre). ESERA.

Bowling, A. (1997). *Measuring health: a review of quality of life measurement scales*. Open University Press.

Bowler, D. E. *et al.* (2020). Mapping human pressures on biodiversity across the planet uncovers anthropogenic threat complexes. *People and Nature*, *2*(2), 380-94.

Brasil. (2009). *Matriz de Referência ENEM*. https://download.inep.gov.br/download/enem/matriz_referencia.pdf

Brasil. (2018). Resolução nº 3, de 21 de novembro de 2018. Atualiza as Diretrizes Curriculares Nacionais para o Ensino Médio. *Diário Oficial da União*. Ministério da Educação/Conselho Nacional de Educação/Câmara de Educação Básica. www.in.gov.br/materia/-/asset_publisher/Kujrw0TZC2Mb/content/id/51281622

Brito, B. R. (2015). *As concepções alternativas em exames de larga escala: uma análise das questões de biologia do ENEM* (150 f.). Dissertação de mestrado, Instituto de Física Gleb Wataghin, Universidade

Estadual de Campinas, Campinas. www.repositorio.unicamp.br/handle/REPOSIP/304784

Brito, B. R. & Gebara, M. J. F. (2015). Concepções alternativas em Biologia: uma análise do Exame Nacional do Ensino Médio. In:Anais do *X Encontro Nacional de Pesquisa em Educação em Ciências ENPEC*. (pp. 1–8). www.abrapecnet.org.br/enpec/x-enpec/anais2015/listaresumos.htm

Carvalho, R. C. & Rezende, F. (2013). Políticas curriculares e qualidade do ensino de ciências no discurso de nível médio. *Ciência & Educacão*, *19*(3), 555–571. https://doi.org/10.1590/S1516-73132013000300005

Cellard, A. (2008). A análise documental. In: Poupart, J., Deslauriers, J. P., Groulx, L. H., Laperrière, A., Mayer, R., & Pires, Á. *A pesquisa qualitativa: enfoques epistemológicos e metodológicos* (pp. 295–316). Vozes.

Cestaro, D. M., Kleinke, M. U., & Alle, L. P. (2020). Uma análise do desempenho dos participantes e do conteúdo abordado em itens de genética e biologia evolutiva do exame nacional do ensino médio (ENEM): implicações curriculares. *Investigações em Ensino de Ciências*, *25*(3), 503–536. www.if.ufrgs.br/cref/ojs/index.php/ienci/article/view/2108

Ferreira, D. C., & Machado, C. J. (2016). O Conteúdo de Ecologia nos Livros Didáticos do Ensino Médio Aprovados pelo Programa Nacional do Livro Didático (PNLD) de 2012. *Ensino & Pesquisa, 14*(1), 25-35. http://periodicos.unespar.edu.br/index.php/ensinoepesquisa/article/view/504/524

Franzolin, F., Garcia, P. S. & Bizzo, N. (2020). Amazon conservation and students? interests for biodiversity: The need to boost science education in Brazil. *Science Advances*, *6*, eabb0110-10.

Futuyma, D. (2002). *Biologia Evolutiva*. FUNPEC.

Gaston, K. (2000). Global patterns in biodiversity. *Nature*, *405*, 220–227. https://doi.org/10.1038/35012228

Garcia, P. S. (2020). O que os jovens do Estado de São Paulo conhecem sobre a biodiversidade: primeiras aproximações por meio do Exame Nacional do Ensino Médio. *Contribuciones A Las Ciencias Sociales*, 10, 1-13.

[Digite aqui]   [Digite aqui]

Ghisolfi, R. M. (2000). Ensino de ciências e cidadania. In: Aragão, R. M. R. & Schnetzler, P. R. (Orgs.). *Ensino de Ciências: fundamentos e abordagens* (pp. 154–181). CAPES/UNIMEP.

Instituto Nacional de Estudos e Pesquisa. (2019). *Dados do ENEM de 2019*. Inep. https://enem.gov.br

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat. https://ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf

Joly, C. & Queiroz, H. L. (2020). Pandemia, biodiversidade, mudanças globais e bem-estar humano. *Estudos Av*ançados *34*(100), 67–82. https://doi.org/10.1590/s0103-4014.2020.34100.006

Malimpensa, G. C. & Rink, J. (2017). Conteúdos de Genética nas provas do ENEM: análise de dez anos de exame (2005-2014). In: *Anais do XI Encontro Nacional de Pesquisa em Educação em Ciências ENPEC* (pp. 1-9). www.abrapecnet.org.br/enpec/xi-enpec/anais/resumos/R1825-1.pdf

Observatório de Educação do Grande ABC. (2020). *Relatório do segundo trimestre de 2020*. Universidade Municipal de São Caetano do Sul.

Odum, E. & Barrett, G. W. (2008). *Fundamentos de Ecologia*. Cengage.

Oliveira, A. W. & Cook, K. L. (Eds.). (2019). *Evolution education and the rise of the creationist movement in Brazil*. Lexington.

Palmberg, I., Berg, I., Jeronen, E., Käkkäinen, S., Norrgard-Sillanpää, P., Persson, C., Vilkonis, R., & Yli-Panula, E. (2015). Nordic–Baltic Student Teachers' Identification of and Interest in Plant and Animal Species: The Importance of Species Identification and Biodiversity for Sustainable Development. *Journal of Science Teacher Education*, *26*(6), 549–571. https://doi.org/10.1007/s10972-015-9438-z

Pasquali, L. & Primi, R. Fundamentos da Teoria da Resposta ao Item – TRI. (2003). *Avaliação Psicológica*, *2*(2), 99–110. http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1677-04712003000200002&lng=pt

Pujol, R. M. (2003). *Didáctica de las ciencias en la educación primaria*. Sínteses.

Rawat, U. S. & Agarwal, N. K. (2015). Biodiversity: concept, threats and conservation. *Environment Conservation Journal, 16*(3), 19–28. https://doi.org/10.36953/ECJ.2015.16303

Ricklefs, R. E. & Relya, R. (2014). *Ecology: the Economy of Nature*. Freeman.

Secretariat of the Convention on Biological Diversity. (2020). *Global Biodiversity Outlook 5*. www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf

Silva, F. X da. (2016). *A diversidade faunística nos livros didáticos do programa nacional para o 7° ano do Ensino Fundamental* (66 f.). Dissertação de Mestrado, Centro de Ciências, Universidade Federal do Ceará, Fortaleza. http://www.repositorio.ufc.br/handle/riufc/22455

Silva, L. A. S., Sousa, T. T., & Carvalho, C. V. M. (2019). Categorização das temáticas de biologia no ENEM no período de 2012 a 2016. In: *Anais do XII Encontro Nacional de Pesquisa em Educação em Ciências ENPEC*. (pp. 1–9). abrapecnet.org.br/enpec/xii-enpec/anais/resumos/1/R1031-1.pdf

Sousa, L. A. & Braga, A. E. (2020). Teoria clássica dos testes e teoria de resposta ao item em avaliação educacional. *Revista de Instrumentos, Modelos e Políticas em Avaliação Educacional*, *1*(1), e020002. https://doi.org/10.51281/impa.e020002

Stadler, J. P. & Hussein, F. R. G. S. (2017). O perfil das questões de ciências naturais do novo ENEM: interdisciplinaridade ou contextualização? *Ciência & Educação*, *23*(2), 391–402. https://doi.org/10.1590/1516-731320170020007

Swaminathan, M. S. (1992). Expansão da capacidade humana de conservar a biodiversidade. In: World Resources Institute - WRI, União Internacional para Conservação da Natureza - UICN, & Programa das Nações Unidas para o Meio Ambiente - PNUMA. *Estratégia global da diversidade* (pp. 147-167). Fundação o Boticário de Proteção à Natureza.

Templenton, A. (2011). *Genética de populações e teoria microevolutiva*. Sociedade Brasilera de Genética.

Testasicca, M. C. de S., Araújo, T. M., & Oliveira, A. R. de. (2020). Approach to the theme "pollution" in ENEM questions and in textbooks: a comparative study around competences and skills. *Research, Society and Development*, *9*(11), e81691110432. https://doi.org/10.33448/rsd-v9i11.10432.

Tollefson, J. (2020). Why deforestation and extinctions make pandemics more likely. *Nature*, *584*, 175–176. https://media.nature.com/original/magazine-assets/d41586-020-02341-1/d41586-020-02341-1.pdf

Zelezny, L. C. (1999). Educational Interventions That Improve Environment Behaviors: a meta-analysis. *The Journal of Environmental Education*, *31*(1), 5–14. https://doi.org/10.1080/00958969909598627

APPENDIX

Examples of questions related to biodiversity selected in the 2009 test (BLUE Version)

Question 6

The biogeochemical cycle of carbon comprises several compartments, including the Earth, the atmosphere, and the oceans, and several processes that allow the transfer of compounds between these reservoirs. Carbon stocks stored in the form of non-renewable resources, for example, oil, are limited, and it is of great importance to realise the importance of replacing fossil fuels with fuels from renewable sources.

The use of fossil fuels interferes with the carbon cycle, as it causes

a- Increase in the percentage of carbon contained in the Earth.

b- Reduction in the rate of photosynthesis of higher plants.

c- increased production of plant-derived carbohydrates.

d- increased amount of carbon present in the atmosphere.

e- reduced global amount of carbon stored in the oceans.

Question 10

Photosynthesis is essential for life on Earth. In chloroplasts from photosynthetic organisms, the solar energy is converted into chemical energy that, together with water and carbon dioxide (CO_2), is used to synthesise organic compounds (carbohydrates). Photosynthesis is the only biologically important process capable of carrying out this conversion. All organisms, including the producers, benefit from the energy stored in carbohydrates to boost the cellular processes, releasing CO_2 into the atmosphere and water to the cell through

[Digite aqui] [Digite aqui]

cellular breathing. Moreover, a significant fraction of the energetic resources of the planet produced both today (biomass) and before (fossil fuel) results from photosynthetic activity.

The information on obtaining and transforming natural resources through the vital processes of photosynthesis and respiration, described in the text, allows us to conclude that

a- CO_2 and water are molecules with high energy content.

b- carbohydrates convert solar energy into chemical energy.

c- life on Earth depends ultimately on the energy coming from the Sun.

d- the respiratory process is responsible for the withdrawal of carbon from the atmosphere.

e- the production of biomass and fossil fuel per se is responsible for increased atmospheric CO_2.

Question 23

About 1% of urban garbage is made of solid waste containing toxic elements. Among those elements are heavy metals such as cadmium, lead, and mercury, components of cells and batteries that are hazardous to human health and the environment. When discarded in ordinary trash, cells and batteries go to sanitary landfills or open dumps. The leakage of their components contaminates the ground, rivers, and groundwater, reaching flora and fauna. Moreover, as they are bioaccumulative and not biodegradable, those metals arrive in the accumulated form to the human beings through the food chain. The legislation in force (Resolution CONAMA n. 257/1999) regulates the destiny of cells and batteries after their energetic exhaustion and determines to the manufacturers and/or importers the maximum amount allowed of those metals in each type in cell/battery. However, the problem persists.

A measure that could contribute to definitively ending the problem of environmental pollution by heavy metals reported in the text would be to

a- stop consuming electric gadgets that use cells or batteries as a source of energy.

b- use only long lifespan cells or rechargeable batteries and avoid ingesting contaminated foods, especially fish.

c- after exhaustion of the stored energy, return cells and batteries to the specialised technical assistance network to be transferred back to the manufacturers and/or importers.

d- create in the cities, especially in those with over 100,000 inhabitants, strategic points of collection of batteries and cells, for a posteriori transference to the manufacturers and/or importers.

e- demand that the manufacturers invest in research to replace those toxic metals with less harmful substances to the humans and the environment, and that are not bioaccumulative.

[Digite aqui]   [Digite aqui]