SOCIAL SCIENCES

Amazon conservation and students' interests for biodiversity: The need to boost science education in Brazil

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Brazilian high school students took part in an international research program in the period 2007–2014, and a data bank with national significance was created. SPSS TwoStep clustering analysis indicated two homogeneous groups regarding the level of interest for the surrounding biodiversity. Amazonian students were among the high-interest group and would like to study more deeply local living beings, contrary to the tendency to favor large exotic animals in Brazilian biology curricula. Students from the southeast were grouped in the low-interest group. However, students from both regions agree upon the urgent need for actions to protect the environment and strongly disagree that this is a role expected from rich countries only. Given the importance of the local communities in conservation and the current prominence of young people in environmental issues, a boost in science education is needed in Brazil, enhancing the study of rainforest biota in the Brazilian curricula.

INTRODUCTION: CONSERVATION AND SCIENCE EDUCATION

There is a well-established consensus that conservation relies on local capacity building, and education is central to this goal, as it is one of the key measures proposed by the Convention on Biological Diversity (CBD) ever since its ratification in 1992, and in the Aichi Biodiversity Targets. Without local acceptance of biodiversity and a deeper understanding of the need for conservation, no gains will be long-lasting (*1*).

Many authors agree that either interest in nature or knowledge about species is important to raise interest and understanding of biodiversity, environmental problems, and sustainability (*2*, *3*). A large study carried out in Switzerland investigated how children and youngsters appreciated animals and plants, finding a significative correlation, as the more wild animals and plants were studied in their natural environment, the more they appreciated these organisms (*4*).

An extensive meta-analysis revealed that classroom educational interventions are, by far, more effective than interventions in nontraditional settings regarding the improvement of environmental concerns and behavior. In addition, the study revealed that environmental education interventions were more effective when students were 18 or younger (*5*). Cognitive knowledge and environmental values are considered to be particularly relevant for promoting sustainable behavior (*6*).

Conservation-effective actions depend on many variables. Among them, two are key factors: public support and the involvement of local communities who live in and around the sites important for biodiversity. Working with local actors requires respect for their knowledge, values, and beliefs guiding a true dialog, as a combination of local and scientific knowledge may empower local communities to monitor and respond to environmental change. Participatory approaches are alternatives to the top-down, science-led transfer of technology paradigm (*7*). Therefore, there is an objective need for empirical research to know local students' values and attitudes regarding their environment and their views about the ways science and technology may contribute to conservation.

We report here a nationwide survey presenting results about these interests and attitudes toward biodiversity and conservation, revealing a very important picture. We compared students' interests from north Brazil with those from the industrialized areas of the country, in the south/southeast. We will argue that the key findings have to be analyzed taking into consideration the fact that urban students of the north live in a sociocultural atmosphere that vividly brings the presence of biodiversity, with links with the native peoples' heritage. These considerations are relevant due to the particular tradition of school curricula in Brazil. Animals and plants from the Amazon forest and indigenous people's knowledge are almost absent from local schools. Biology textbooks "tend to favor large, exotic, charismatic megafauna (e.g. polar bears, elephants, giraffes, lions, penguins, etc.) native to other countries over local and less popular animals such as insects in students' backyards" (*8*).

Knowledge of young people's interests and attitudes about science and technology subjects such as biodiversity and the environment are important to improve science education, and a large-scale study was conducted. The Relevance of Science Education (ROSE) project involved some 40 countries since 2004, focusing on 15-year-old students. In the Swedish context, the ROSE study had a nationwide sample of 751 students from 29 schools and revealed that students find school science less interesting than other subjects. Few want to become scientists, and most students do not want to seek employment in technology (*9*). A completely different picture was found in countries with low Human Development Index (HDI), like Uganda, Bangladesh, and Zimbabwe, where students had far more interest in learning science topics than those from Norway, Finland, and Japan, with high HDI (*10*–*11*).

Thus, research has been carried out in all regions of Brazil to know the opinions of young people about science, biodiversity, and conservation, leading to the construction of a large database, comprising three data collections (2007, 2010–2011, and 2014). Key findings are reported and discussed here.

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MATERIALS AND METHODS

The ROSE project has developed a questionnaire that students can answer freely, with no need for background information, expressing their views and opinions on several aspects related to the way school science is presented to them. Contrary to other tests, like the Programme for International Student Assessment (PISA) students are informed that there are no "right" or "wrong" answers. Hence, items are grouped into several different sections, such as "What I want to learn about" (section A, and the first part of section E), "Me and the Environmental Challenges" (section C), and "My opinions about Science and Technology" (the second part of section E), which are the focus of the present report. Each section consists of some short statements prompted by a general question such as "To what extent do you agree with the following statements about problems with the environment?" A four-point instrument Likert-type scale was used asking for interest/agreement, where 1 (one) means very low, 2 (two) means low, 3 (three) means high, and 4 (four) means very high, with no neutral point. Therefore, scores above 2.5 show high agreement/interest: The closer to 4, the higher are the agreement/interest in the topic.

The ROSE questionnaire neither is based on a precise hypothesis for a research question nor is a qualitative tool open to surprises and new ideas. Their creators define the questionnaire as being in between of these two valid research designs. It is quantitatively and statistically oriented but tries to combine these properties with the openness of qualitative studies. Its main aim is to explore some affective qualities of science teaching and learning in a cross-cultural perspective. It has been conceived with lessons learned from previous projects with similar aims (*10*), which revealed interesting findings for the wording of items related to the focus on context, content, and activity. For instance, when students were asked about their interest to study "acoustics and sounds" or "light and optics," their answers were less enthusiastic than when asked about "music" or "the rainbow and sunsets" (*10*). Therefore, a classification by content and context was structured in different areas, allowing different data analysis, trying to find which could be more effective for engaging particular groups of students to study science (*10*, *11*).

Other than investigating what are the interests of the students, the questionnaire had a specific section focused on activities regarding environmental challenges. The rationale of the section is based on the assumption that science educators develop knowledge and awareness about these challenges to make students equipped to meet environmental problems. There were few studies about students' attitudes and priorities regarding these problems and how they could be related to their interests in science and technology. Items of this section relied on some assumptions considering that students should be interested and motivated to engage in conservation actions, have some hope and visions for the future, have some confidence in the effectiveness of their possible actions, and think that environmental protection is important for society. The notion underlying the interest in environmental issues linked to decision making or action is knowledge, in the sense that involvement with these issues requires the relevant scientific consideration. However, expert environmental knowledge and advice are frequently considered alongside practical knowledge that is tested and validated against individual and collective experiences (*12*). Detailed methodological issues regarding the development of the original ROSE questionnaire, its validation, reliability, and a discussion of the limitations of the adopted form of the Likert-type scale can be found in the reference literature (*10*, *11*).

Data collection in the 2007 pilot test included two magnet schools, one in the state of São Paulo (southeast, $n = 358$) and the other in the state of Mato Grosso (center-west, $n = 267$). In the southeast, the school was located in a major town in the metropolitan area of São Paulo, São Caetano do Sul, which then and now has the highest municipality HDI in the country (HDI-M = 0.862). The other school was located in Tangará da Serra, in the state of Mato Grosso, a regional center for agriculture with a large rural area (HDI-M = 0.620). In the subsequent two runs, the research was carried out all over the country following strict sampling procedures. The two HDI-M indexes mentioned above refer to the available figure at the time according to official records of the Brazilian Institute of Geography and Statistics (IBGE). As the pilot study did not collect data from northern Brazil, our analysis of attitudes toward conservation in the northern region is based on two samples, rather than the three samples used in the analysis of the southeast.

All sampling procedures for 2010 onward followed the PISA 2009 protocol for Brazil (*13*), which included three explicit stratification variables (State/Grade 9 status/Certainty), with a total of 82 explicit strata, and three implicit stratification variables (origin of funding/urban/rural/HDI level). For operational reasons, the Brazilian Ministry of Education excluded schools that served indigenous populations in the rural area of the north region from the sample. The same happened with schools that exclusively served students with special needs, as well as international schools that exist in some large urban centers, as they do not teach their classes in the students' mother tongue, as this is one of the premises for participation according to PISA standards (*13*). Our randomized sample in the two runs included three rural schools only, with no one from the north region.

In this piece of research, we tried to group these students according to their interests in biodiversity and to investigate the correlation between their level of interest and the different Brazilian geographic regions. Also, we sought to verify the attitudes of these students toward the environment, considering the period 2007–2014.

The 2010–2011 and 2014 runs used a random subsample of the national PISA 2009 sample (*14*). Project ROSE protocol (*10*) was followed within all schools in all runs, with a minimum of 25 students per school. In the 2010–2011 run, 2365 students took part, but only students aged 14 to 16 who answered all selected items on biodiversity were considered for the analysis, reaching 1803 valid cases (Table 1), comprising 460 from northern Brazil, from all states and 18 localities and 22 different schools, all of them situated in urban areas (detailed data can be found in the Supplementary Materials). As the questionnaire was abridged in the following run, items referring to learning about biodiversity were removed, but not the ones about environmental problems, which allow us to infer tendencies in the period. The abridged questionnaire of the 2014 data collection was pretested in a field trial in two schools in São Paulo city, which were not part of the original sample; slight changes in the translated phrasing were introduced after qualitative research methods were used. The number of students aged 14 to 16 in the 2014 run was 2368, with 471 students from the north, belonging to 15 schools from 14 localities, all of them situated in urban areas. Contrary to what was done in other countries in the ROSE project, research forms were machine-read in Brazil in the 2010–2011 and 2014 data collections, lowering the level of error of the database.

Statistical analysis

The IBM SPSS (v.26) TwoStep Cluster Analysis was used to identify groupings in the 2010–2011 sample. The IBM SPSS cluster feature (CF) extends the basic concept of two-stage clustering methods

Table 1. Level of interest of Brazilian students (2010–2011). Means of the answers of Brazilian students aged 14 to 16 years old ($n = 1803$) to the question (top, left), showing their level of interest to study different subjects (1 = not interested/4 = very interested). Blue numbers indicate interest ($x > 2.5$), contrary to red numbers.

How interested are you in learning about the following?		Group						
		Disinterested		Interested		Total		
		Average	SD	Average	SD	Average	SD	*P* value (Mann-Whitney test)
A3	The inner part of Earth	2.12	1.02	2.76	1.00	2.40	1.06	<**0.0005**
A15	How plants grow and reproduce	1.87	0.86	2.80	0.91	2.28	0.99	<**0.0005**
A16	How people, animals, plants, and the environment depend on each other	2.34	0.98	3.12	0.89	2.68	1.02	<**0.0005**
A27	Dangerous and poisonous animals	2.53	1.00	3.38	0.76	2.90	1.00	<**0.0005**
A28	Poisonous plants in my area	2.01	0.99	3.08	0.87	2.48	1.08	<**0.0005**
E18	Medicinal use of plants	2.13	1.02	3.25	0.84	2.62	1.10	<**0.0005**
E24	Animals in my area	1.80	0.82	3.32	0.70	2.46	1.08	<**0.0005**
E25	Plants in my area	1.58	0.64	3.18	0.71	2.28	1.04	<**0.0005**

proposed by the Balanced Iterative Reducing and Clustering using Hierarchies (BIRCH) (*15*), as either continuous or categorial attributes can be handled and the number of clusters can be automatically determined (*16*). The algorithm constructs a modified CF tree and then determines clusters in the following step, either automatically or matching the predetermined number, as in our case. Table 1 brings the result of Mann-Whitney *U* test, a nonparametric test that verified how different were the two groups resulting from the previous analysis. Table 2 shows the results of the significant association between the two groups of students aged 14 to 16 years old comparing their interest to topics related to biodiversity and the region where they live in Brazil. Table 3 brings the code and the text of each item. Tables 4 and 5 were tested using the Kruskal-Wallis *H* test, a nonparametric test that can verify whether the different samples have different distributions or not. In both tests, significant *P* values appear in bold numbers (Tables 1, 4, and 5). For further information, please refer to the Supplementary Materials.

RESULTS

The database corresponding to the year 2010–2011, with the nationwide sample ($n = 1803$ valid cases), was analyzed using the IBM SPSS TwoStep Cluster Analysis tool, focusing on the answers about how interested students were to learn topics stated in eight items related to animals and plants of local biota (items A3, A15, A16, A27, A28, E18, E24, and A25; see Table 1 for items phrasing). As a result, 788 students (43.7%) were included in the group "interested in biodiversity" and 1015 students (56.3%) in the group "disinterested in biodiversity." Table 1 presents the profile of each of these groups with eight selected items (for further details, see also fig. S1; table S1 shows details of every statement in all regions).

Results of the level of interest of these students about biodiversity-related items show higher averages in the group of interested students than in the group of the disinterested, corroborating the existence of these two groups. The descriptive level (*P* value) of the Mann-Whitney test is less than 0.0005 for each item, indicating that the group distributions are statistically significant.

The difference between the groups is greater in the items "E25 Plants in my region" and E24 "Animals in my region." Therefore, students interested in biodiversity are more curious about getting to know animals and plants in their locality, while such themes are not attractive to the students of the "Disinterested" group.

However, the distribution of the two student groups in the different geographic regions of Brazil revealed an important association, as students from the north and southeast show significant differences (Pearson's χ^2, $P < 0.0005$). Table 2 brings details.

More than half (50.4%) of the respondents' students who live in the Amazonian region are willing to study plants and animals in their region, whereas some 33.1% show the same level of interest in the southeast. The northeast region also stands out with the second largest relative number of respondents motivated to know the diversity of organisms in their region (46.9%).

The data bank allows investigating the changes in the level of students' interests and attitudes considering a longer time frame and a larger number of items related to the environment and their views about the relation of environmental problems with science and technology. Table 3 brings the 14 items that were presented to students all over Brazil, as part of other sections of the same research forms prepared by the ROSE project mentioned above. In the two sections, students could agree or disagree, fully or partly, with the statements about the environment and the role played by science and technology in this regard.

Table 2. Interest to study biodiversity in different regions of Brazil (2010–2011). Association between the two groups of students aged 14 to 16 years old comparing their interest to topics related to biodiversity and the region where they live in Brazil ($n = 1803$; Pearson's χ^2, $P < 0.0005$).

Region	*N*/(%)	Groups		Total
		Disinterested	Interested	
North	*N*	228	232	460
	%	49.6%	50.4%	100%
Northeast	*N*	252	223	475
	%	53.1%	46.9%	100%
Center-West	*N*	148	112	260
	%	56.9%	43.1%	100%
Southeast	*N*	259	128	387
	%	66.9%	33.1%	100%
South	*N*	128	93	221
	%	57.9%	42.1%	100%

Table 3. Selected items about conservation action answered by Brazilian students from north and southeast Brazil. These 14 items were part of the ROSE project, presented to students around 15 years old in schools of several countries, Brazil included. Students could agree or disagree, fully or partly, to each one with scores 1 (fully disagree) to 4 (fully agree). The "C" session brought items about the environment and other themes.

Item code	Items stating the need of individual and collective conservation actions
C29	I can personally influence what happens with the environment
C30	We can still find solutions to our environmental problems
C31	People should care more about the protection of the environment
C32	I am optimistic about the future
C33	The natural world is sacred and should be left in peace
C35	I think each of us can make a significant contribution to environmental protection
E65	I am willing to have environmental problems solved even if this means sacrificing many goods
	Items stating the overselling of individual and collective actions for conservation
E54	Science and technology can solve nearly all problems
C28	Science and technology can solve all environmental problems
C34	People worry too much about environmental problems
C37	Environmental problems should be left to the experts
C38	It is the responsibility of the rich countries to solve the environmental problems of the world
C40	Threats to the environment are not my business
C41	Environmental problems are exaggerated

We present items grouped considering positive and negative attitudes toward environmental actions. The upper part shows items that imply students' active participation, whereas the lower part present items that tend to point to other people the initiative to take actions for conservation or refusal to recognize the importance of the problem, such as "Environmental problems are exaggerated." As the 2007 pilot study did not include the north region, Table 4 brings the results of the variation of the average level of interest and attitudes of all students from northern Brazil's sample in the period 2010–2011 and 2014 considering the answers of all 14 items.

On the one hand, all items with positive statements about the importance of real actions to protect the environment received a higher level of agreement ($x > 2.5$). The statement "People should care more about the protection of the environment" (C31) not only increased in a significant manner but also reached a very high average score ($x = 3.82$), the highest degree of agreement, combined with the lowest SD, meaning that there was almost no disagreement. On the other hand, items with negative statements were all, with no exception, on the side of disagreement ($x < 2.5$), and some showed a significant increase in rejection. This is the case of the statement "Threats to the environment are not my business" (C40), which received the lowest score ($x = 1.34$) and the lowest SD, indicating nearly full disagreement, decreasing in the most significant way, all items considered. There was also significantly increased disagreement with related statements (C34, C38, C41).

However, item E65 ("I am willing to have environmental problems solved even if this means sacrificing many goods") showed some inconsistency, as there was a decreasing tendency to agree with the statement, although the mean was kept in the side of the agreement. Besides, students do not agree that science and technology will provide all solutions neither for "all problems" (E54) nor for environmental problems (C28), and showed disagreement with the idea that "experts" should be the only people involved to find ways to deal with environmental problems (C37). However, there is an optimistic view of the future, as there would be still time left to find solutions to these problems (C30; Table 4).

The data bank from Brazil's southeast included a previous sampling carried out in 2007, in one municipality only (abovementioned), with the highest per capita gross national product (GNP) in the country. Samples of 2010–2011 and 2014 had nationwide and regional significance. Southeastern students proved to be even more enthusiastic about taking part in conservation actions (Table 5).

Table 4. Northern Brazilian students' tendencies about conservation actions in the period 2010/1–2014. Tendencies of students' attitudes and values about conservation actions (1 = fully disagree/4 = fully agree) in the northern region of Brazil in the period 2010–2014 showing their level of agreement regarding 13 statements (see Table 3 for phrasing). Numbers in blue show agreement ($x > 2.5$), and numbers in red show disagreement ($x < 2.5$). *P* value bold numbers show significant variation in the period.

Items	2010/1		2014		2010–2014		*P* value (Kruskal-Wallis test)
	Average	SD	Average	SD	Tendency	Valid cases	
Items stating the need of individual and collective conservation actions							
C29	3.01	1.08	**3.09**	1.07		889	0.224
C30	3.53	0.86	**3.66**	0.69		890	0.059
C31	3.66	0.73	**3.82**	0.56	⇧	892	**<0.0005**
C32	2.74	1.09	**2.86**	1.08		884	0.076
C33	**3.19**	0.98	3.03	1.11		882	0.074
C35	3.63	0.74	**3.63**	0.75		894	0.739
E65	**3.06**	1.06	2.91	1.11	⇩	887	**0.038**
Items stating the overselling of individual and collective actions for conservation							
E54	2.23	1.06	**2.31**	1.03		877	0.260
C28	2.08	1.09	**2.11**	1.05		893	0.500
C34	**1.93**	1.08	1.58	0.97	⇩	883	**<0.0005**
C37	1.56	0.90	**1.62**	0.96		889	0.422
C38	**2.29**	1.15	1.69	1.03	⇩	892	**<0.0005**
C40	**1.72**	1.12	1.34	0.86	⇩	894	**<0.0005**
C41	**2.46**	1.21	2.24	1.21	⇩	888	**0.009**

The picture from this part of the country is dynamic, with significative approval of the rule of personal action to prevent and solve environmental actions, as some items showed a very high level of agreement ($x > 3.5$). This is the case of items C30, C31, and C35. This last item ("I think each of us can make a significant contribution to environmental protection") found a high agreement in both regions and an increasing tendency in the last two runs in southeastern Brazil, almost reaching the high agreement found in the north.

Following the picture of the northern Brazilian students, there is strong disagreement in the southeast regarding statements minimizing environmental problems (C34, C38, C40, and C41; Tables 4 and 5). The statement saying that rich countries only are responsible to solve environmental problems also faced a strong rejection (C38). Besides, there is a significant increase in disagreement with these four statements in both regions (C34, C38, C40, and C41; Tables 4 and 5). However, science and technology are not seen as providers of readymade solutions for all related problems (E54 and C28; Tables 4 and 5), following the same pattern seen above, with students from the north, although southern students are significantly diminishing their disagreement on this regard (E54 and C28; Table 5), but still disagree with the old top-down, science-led paradigm (*7*).

This study showed that students from the Amazonian region and southeastern Brazil highly regard their participation in actions aiming at protecting the environment. This can be seen taking into account the combined results of high disagreement with statements C34 ("People worry too much about environmental problems"), C41("Environmental problems are exaggerated") and C38 ("It is the responsibility of the rich countries to solve the environmental problems of the world") on the one hand and the high agreement with C29 ("I can personally influence what happens with the environment"), C31 ("People should care more about the protection of the environment"), and C35 ("I think each of us can make a significant contribution to environmental protection") on the other hand (Tables 3 to 5).

Therefore, despite the differences of interest regarding the inclusion of the surrounding environment as part of school curricula, students from both regions firmly agree about their role to face environmental problems. They strongly reject the idea that the rich countries have to solve all environmental problems of the world and show an increasing disagreement toward statements that minimize environmental problems. In the Amazon region, the participatory approach to conservation finds more support, as all positive items had higher scores, in the two runs. We argue that these two patterns may have connections and could be further scrutinized.

Table 5. Southeastern Brazilian students' tendencies about conservation actions in the period 2007/2010–2011/2014. Tendencies of students' values and attitudes (1 = fully disagree/4 = fully agree) in the southeastern region of Brazil in the period 2007–2014 showing their level of agreement regarding 14 statements (see Table 3 for phrasing). Numbers in blue show agreement ($x > 2.5$), and numbers in red show disagreement ($x < 2.5$). Tendency arrows consider national samples only (2010–2011 and 2014, see text and the Supplementary Materials). *P* value bold numbers show significant variation in the period considering the three samplings.

Items	2007		2010–2011		2014		2010–2014		*P* value (Kruskal-Wallis test)
	Average	SD	Average	SD	Average	SD	Tendency	Valid cases	
Items stating the need of individual and collective conservation actions									
C29	**3.15**	0.93	2.91	1.04	2.98	1.07	↑	1.096	**0.010**
C30	3.36	0.88	3.35	0.88	**3.54**	0.77	↑	1.101	**0.003**
C31	3.45	0.84	3.55	0.78	**3.75**	0.62	↑	1.102	**<0.0005**
C32	2.54	1.04	2.67	1.03	**2.70**	1.05		1.092	0.104
C33	**3.15**	0.99	2.97	0.98	2.86	1.07	↓	1.089	**<0.0005**
C35	3.34	0.95	3.38	0.90	**3.57**	0.77	↑	1.102	**0.001**
E65	**3.01**	0.98	2.79	1.05	2.87	1.06		1.094	**0.018**
Items stating the overselling of individual and collective actions for conservation									
E54	2.03	0.93	2.21	0.94	**2.32**	0.98	↑	1.093	**<0.0005**
C28	1.97	0.92	1.99	0.98	**2.20**	0.97	↑	1.100	**0.001**
C34	1.73	0.96	**1.82**	0.99	1.49	0.86	↓	1.097	**<0.0005**
C37	**1.72**	0.92	1.59	0.88	1.59	0.92		1.100	**0.019**
C38	**2.15**	1.03	2.12	1.04	1.70	0.94	↓	1.097	**<0.0005**
C40	1.57	0.96	**1.64**	1.00	1.26	0.70	↓	1.101	**<0.0005**
C41	2.11	1.03	**2.29**	1.09	2.02	1.12	↓	1.093	**0.001**

DISCUSSION

The Brazilian tradition on educational research does not highly praise quantitative methods. Considering the large educational community, encompassing more than 50 million students, it is surprising to find a few such published works in the last decades, normally authored by "outsiders," such as economists or sociologists (*17*). Our study relied on statistical grounds, with nationwide samples, and showed that although there are significant differences in the level of interest of high school students in studying local biota between northern and southeastern regions, there is a common commitment toward engaging in conservation actions. This is surprising, as recent literature argues that background knowledge about biodiversity seems to be a basic factor to enhance the interest for conservation actions. The inequalities of educational achievement level among the different regions in Brazil are well known, and a considerable number of studies have shown that around the world schools or school factors are not the main factor to explain these differences, leading to the famous paroxysm "schools do not matter," since the renowned and controversial Coleman Report (*18*), that led to the elaboration of the concept of a different form of "capital," in a cultural and social dimension (*19*), as a metaphor to describe the advantages of certain families other than in the strict economic sense.

This theoretical thrust has been very influential in econometrician research in Brazil (*20*), despite criticism mainly from the educational community (*21*). However, there is abundant literature showing that social origin, socioeconomic status, and family factors are, by far, more important predictors of student educational performance in Brazil and other countries, although some school factors, such as teacher academic profile, level of indoor noise, classroom atmosphere, and other variables, have been shown to affect student achievement (*22*). In Brazil, not only are there marked regional differences in educational opportunities; there are also enormous inequalities even

within each region, and an urgent need to implement the successful actions taken in advantaged areas to disadvantaged ones as well (*23*).

Different indicators have shown that the academic performance of Brazilian students is remarkably low, and the most recent results of the Organisation for Economic Co-operation and Development (OECD)/PISA exams confirm that they are among the lowest performing students. Approximately 43.2% of students are below the level of minimum proficiency not only in science but also in mathematics and reading. This is actually a very low achievement, compared with other countries taking part in the exam, where the average percentage of low performance scores is 13.4% (*22*). The disciplinary climate in language-of-instruction lessons is one of the worst compared to other PISA-participating countries and economies, and there is a shortage of teaching staff in socioeconomically disadvantaged schools. A high number of students report noise and disorder in the classroom, difficulties to listen to what the teacher says, and other related problems. Moreover, socioeconomic status is a strong predictor of student performance, and the gap between advantaged and disadvantaged students is widening, taking into account the 2009 and 2018 OECD/PISA results (*24*). Students of our 2014 sample also answered questions about biology, which were not part of the ROSE protocol; the biology scores were remarkably lower than those of Italian students, and showed a very limited knowledge of basic concepts related to evolution, with a considerable correlation between socioeconomic indicators and achievement (*14*).

One key finding reported here points to a lower interest in studying elements of biodiversity in the wealthier region of Brazil, and an opposite situation in the north of Brazil. We argue here that the results can be interpreted under a theoretical framework other than the concept of cultural capital, and should instead consider a broader sociocultural perspective. First, it should be relevant to consider that school opportunities have experienced considerable growth in the last decades in the country, despite the fact that the effect of social origins remained an important influence along the educational trajectory in the period 1981–2008 (*23*). In addition, student knowledge related to biodiversity is, by no means, restricted to school contents. Therefore, low academic achievement could not be a major obstacle to developing curiosity about plants and animals of the surrounding environment. Students who live in Amazonia are immersed in a sociocultural atmosphere rich in indigenous and local knowledge (ILK) related to biodiversity, and this fact could be an additional variable to be considered (*25*). Schools should approach ILK and scientific knowledge through actions aimed at boosting science education; otherwise, positive attitudes toward conservation may not be long-lasting (*25*).

The differences observed in interest in studying local biota should be properly addressed. On the one hand, it is necessary to infer the possible reasons for the high interest shown by students from the north and, on the other hand, to find ways to stimulate students of the other regions to develop a higher attentiveness toward the fauna and flora of their own region and beyond. Despite the fact that all northern schools that took part in the sample were located in urban areas, it is important to consider that almost all localities have indigenous people in their population records (table S1, Supplementary Materials). There are also long-established local communities in the river margins, known as "ribeirinhos," whose communities were legally recognized as traditional people in the year 2007, with similar rights as the indigenous people, and have been regarded as a distinct cultural identity (*25*). Using a qualitative approach, a 2009 research study followed the daily life of a small school in the region of Parintins, in central Amazonia. This study found a notable production of local knowledge that was not part of the school curriculum (*25*), which relied mostly on standard textbooks.

A few localities in the 2010–2011 sample were "modern Amazonian cities," places created after 1970 as part of a deliberate plan to create farms in the Amazon through the attraction of immigrants from other parts of the country (table S1, Supplementary Materials). For instance, one of the localities in the sample, Machadinho d'Oeste, in the state of Rondonia (southwest Amazonia; Fig. 1, #1), was first settled in 1982. This town has 40,000 inhabitants and five high schools and is very close to indigenous peoples' reserves and protected areas, such as the Jaru Biological Reserve. In these urban places, the importance of the indigenous and local culture is undeniable, despite the tough disputes between indigenous people and local farmers and other economic and political agents, since the early 1980s (*26*).

The invisibility of indigenous people in contemporary urban areas in Amazonia is not restricted to modern cities and hides a complex situation of local political power, even in cities built on top of old indigenous settlements, such as Feijó and Jutaí, (west Amazonia; Fig. 1, #2 and #3), Manaus (central Amazonia; Fig. 1, #4), Oiapoque, and Cametá (east Amazonia; Fig. 1, #5 and #6), which were also included in our sample (see Fig. 1 and table S1).

Some of the Amazonian municipalities have recognized some civil rights of the indigenous populations in recent times, such as São Gabriel da Cachoeira, in northwestern Amazonia (Fig. 1, region A), which approved three native languages—Baniwa (Arawak family), Tukano (Tukano family), and Nheengatu (Tupi-Guarani family)—as its official idioms along with Portuguese, in 2003 (*27*). In other words, the youth in all of Amazonia, mainly in older cities, have close contact with several aspects of the indigenous cultures, which are impregnated with knowledge about the rich local biodiversity. The rich variety of fruits and vegetables from the forest available in the cities, is sometimes barely recognized as part of the rich indigenous heritage. Indigenous people are embedded within a complex network of interests, and the invisibility of their presence, culture, and suffering result from the long and enormous asymmetry of political power (*26*–*28*).

Thus, young people in urban areas in northern Brazil have a very distinct contact with nature compared with students from urban and even rural settings in the south and southeast. For instance, the myth of a living giant mammal called "mapinguari" is widely mentioned throughout Amazonia. The Karitiana people in northern Rondônia call *Owojo* or *Kida harara* in their language and report frightening encounters in the jungle (*29*). Mapinguari became the name of a National Park in the state of Amazonas, created in 2008. The "ribeirinhos" of central Amazonia are also acquainted not only with the "mapinguari" legend but also with many others drawn from indigenous cultures that incorporate elements of various forest animals, such as "curupira," "cobra grande," and "boto" (*25*). One can hardly find anything similar in southern Brazil, even in the west part of Santa Catarina, where the presence of indigenous people is important, especially the Guarani and Kaingang cultures (see Fig. 1, region B) (*28*). As is well known, that region of Brazil received massive European immigration in the late 19th century, and faced enormous difficulties in interactions between immigrants and indigenous peoples, resulting in the isolation of these groups from each other (*28*).

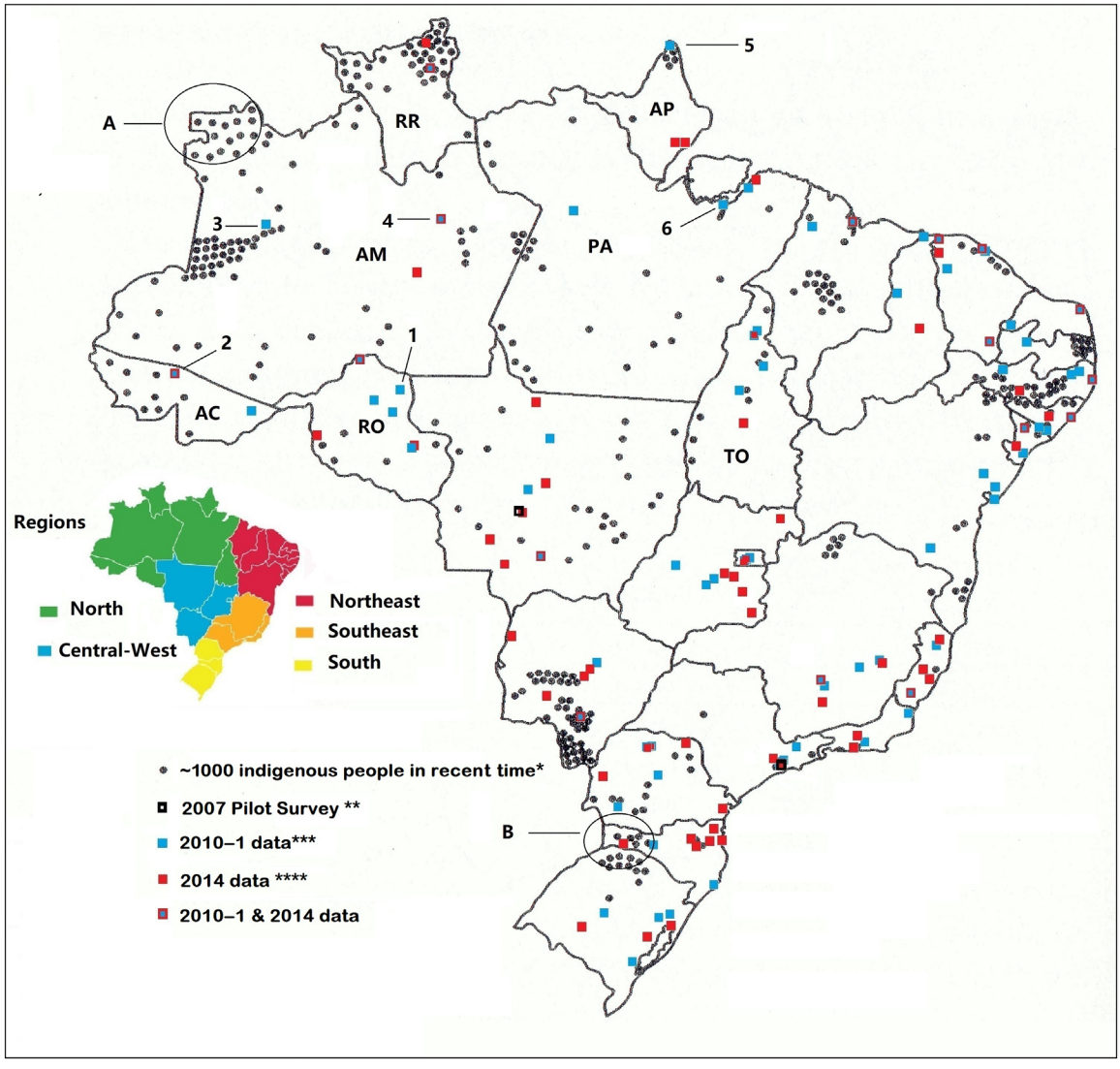

Fig. 1. Map showing the density of indigenous peoples in the turn of the 20th century and localities of the three samples (2007, 2010–2011, and 2014). Localities mentioned (see text): 1, Machadinho d'Oeste (RO); 2, Feijó (AC); 3, Jutaí (AM); 4, Manaus (AM); 5, Oiapoque (AP); 6, Cametá (PA). Region A corresponds to São Gabriel da Cachoeira area (see text). Region B corresponds to west Santa Catarina [see (*30*)]. Sources of information: *, (*28*); others, see table S1.

A recent study of 270 high school students in that region (Fig. 1, region B), from urban and rural schools, brought elements that support the overall picture of our findings and inferences (*30*). Students were asked to make drawings about animals and plants of the surrounding Atlantic forest, and results showed that few specific plants were named. Many animals, especially native birds, were mentioned, as the region has a rich biodiversity; also, however, a considerable number of exotic species were represented as native, including lions (n = 48), tigers (n = 22), buffalo (n = 15), and koalas (n = 13). A considerable lack of knowledge about native species was found in both rural and urban areas, although students who live in strictly urban settings show more limited knowledge of the surrounding biota (*30*).

We do not want to imply that schools from Amazonia are all "rural-like," and schools from the south are all "urban-like." We argue that not only is indigenous and local culture pervasive in urban Amazonia but also that personal contact with different phenomena linked to environmental problems is frequent. For instance, facing a dark sky during the day due to smoke from forest burns is not rare in urban areas of Amazonia (unfortunately). People from São Paulo, in the industrialized southeast, more than 1000 km away, recently experienced this situation for the first time, in August 2019 (*31*), triggering environmental concerns. Although there is little intact rainforest left in the southeast, but there are other sorts of problems, related to air pollution, drinking water availability, etc. Although students from both regions may have a high level of commitment toward conservation, these two regions have different kinds of environmental problems and challenges.

Given the recognized role played by local communities in the success of effective conservation policies and the particular importance of young people in these actions, this study provides sound evidence for the urgent need to change some traditions in science education in Brazil. Basic education should experience important changes introducing the study of the local indigenous peoples' knowledge related to the native biota (*25*). In the recent public call for

school textbooks for high school level to be adopted in public schools all over the country in the period 2021–2023, the Brazilian Ministry of Education does not refer to this issue (*32*). Some relevant keywords, such as "Amazon" and "biodiversity" are completely absent from the parameters that publishers must meet; indigenous cultures are mentioned only in a general way, alongside mention of "women," "Africans," and "Afrobrazilians" (*32*: appendix VII, p. 99), in ethical discussions regarding treatment of minorities (*32*: #2.1.2, p. 51) or in authorship of literary books.

Science education learning materials distributed by the Ministry of Education are the same for all schools in the country. The local Amazonian biota is often absent in science classes in Brazil, and it is easier to find pictures of Old World large mammals rather than native South American animals and plants in the bestselling biology textbooks (*8*). This possible link with standard textbooks was also raised in the discussion of the abovementioned research in southern Brazil (*30*). The study of the "ribeirinhos" school in central Amazonia also raised the issue of the lack of local context in standard textbooks (*25*). Students from the Amazon would need particular materials with a deeper study of animals and plants that are familiar for them, studying the local ecological complexity (e.g., the pollination of Brazilian nuts), whereas students from the south and southeast could have a broader range of rainforest animals and plants, raising their interest in that biome, and in the many similarities of that biome with the Atlantic forest.

It would be worthwhile to reflect upon the universality of aspects of the indigenous peoples' cultural heritage, which includes many aspects related to biodiversity. For instance, more importance could be given to indigenous myths of creation explaining botanical characters of different plants, which are worldwide known, such as manioc and guarana. This could be an important ingredient to foster curiosity for the teaching of botany. The first drug used to fight malaria in Europe is part of indigenous traditional knowledge and is currently in use around the world (*33*), and has been tested for COVID-19, with no mention of its origin. Students learn about Amazonia as a past human desert forest, with a strictly natural distribution of trees, and recently occupied by indigenous people, ignoring the huge population thought to have existed there (*34*). Neither the long history of human occupation in the Amazon (*35*) nor the pre-Columbian agriculture activities, including species domestication (*36*), are part of Brazilian curricula, with no major attention to the area and its history in the recently approved Brazilian National Curriculum. The nearest approach to the theme says students should learn about "The structuring of the Viceroyalty in the Americas, Indigenous resistance, invasions and expansion in Portuguese America" (*37*).

Therefore, there is an urgent need to provide a different approach to local biodiversity and conservation to students and the public in Brazil, especially in the Amazon region. The shift in the federal government and the aggressive policies implemented toward indigenous people and their lands are well known (*31*). Item C38 corresponds to the official position of the ruling Brazilian government, whose president is a climate change skeptic, and dismissed the results of the COP15 climate talks in Madrid as a "commercial game" played by the "rich European nations." Brazil's Environment Minister took part in the conference and published in his Twitter soon after: "Rich countries did not want to pay up" (*38*). We offer concrete evidence that students sharply rejected this position at least since 2010, in either the north or southeast Brazil, with a significant growing rejection (C38; Tables 4 and 5), following a national tendency (see also the Supplementary Materials, table S3).

Engagement with environmental issues requires not only knowledge about, interest in, and motivation for but also confidence, in the sense that citizens believe that they can contribute to real change acting in individual and/or collective ways. Previous research using the same ROSE questionnaire showed a somewhat different picture with English students, as they did not regard so highly learning about environmental problems; however, they disagreed about a supposed "exaggeration" of environmental problems (*39*). Researchers have warned that the pessimism of young people can have a deeper meaning than what has been generally acknowledged, leading to an approach to life based on instant gratification or apathy (*10*, *11*). Anyway, Brazilian students are very optimistic about the future (score above 3.5, SD < 0.8), with a significant growing tendency in the southeast region about time left to find solutions (item C30), almost reaching the high agreement found among northern students.

It is fair to conclude that students from both regions may rely to some extent on science and technology to understand the complexity of the environment's web, regarding their active participation in conservation actions at a high degree. However, they are skeptical about leaving to experts the role of sorting out sustainable ways to explore the environment. These results may be interpreted as a realistic view about participatory approaches and a rejection of the old top-down, science-led paradigm. Experts play an important role in science, but practical solutions must consider values and beliefs, and common citizens should take part in the decision-making processes as well (*7*).

Another important issue that allowed gathering all data discussed here is the collaboration between high schools and universities, planning mutual benefits so that long periods of interactions can be developed (*40*). ROSE project surveys are "snapshots" and students' opinions and attitudes can change over time (*10*, *11*); therefore, both institutions should recognize that their needs are in some way met with cooperative work. A new round of the ROSE project has been planned for the near future, with data gathering around the world.

More research is needed for monitoring students' interests and attitudes toward the environment all over the country, as well as for providing suitable means to include local biodiversity in the curriculum. Indigenous and local people's knowledge related to biodiversity should also be respected and considered in the school curricula, especially in the Amazon region (*25*). Taking into account the major cuts in science and education that have been announced in Brazil recently, and the problems currently faced by public universities, international collaboration could be an important pathway for conducting more research aimed at improving the quality of education in public schools, and maintaining synergistic effects with conservation actions in the region.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/6/35/eabb0110/DC1

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