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Is Youth Pessimism Good for the Environment? Insights from PISA 2015

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Abstract: In this study, we explore the potential of data from large-scale assessments to provide insights into how students' environmental knowledge could address the global challenge of environmental threats to humanity and the transition to sustainable development. We analyze data from the 2015 PISA survey to understand the extent to which 15-year old students in 54 countries are aware of these challenges. We find that students' science activities, self-efficacy and environmental knowledge are positively associated with their awareness about environmental challenges. Students' environmental awareness, in turn, is associated with environmental pessimism, or their outlook on the future of environmental

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issues. Students who are more engaged with environmental science are more aware about environmental issues and feel less optimistic that environmental issues will improve in the future. Such pessimistic attitudes about the future may be a precursor to pro-environmental behavior. Our results provide a cross-national picture of students' engagement with environmental issues and insight into the potential of large-scale assessment data to inform environmental education policies promoted by individual countries and international organizations.
Keywords: international large-scale assessments; environmental education

¿El pesimismo de los jóvenes es bueno para el medio ambiente? Perspectivas de PISA 2015

Resumen: En este estudio, exploramos el potencial de los datos de evaluaciones a gran escala para proporcionar información sobre cómo el conocimiento ambiental de los estudiantes podría abordar el desafío global de las amenazas ambientales para la humanidad y la transición al desarrollo sostenible. Analizamos los datos de la encuesta PISA de 2015 para comprender hasta qué punto los estudiantes de 15 años de 54 países son conscientes de estos desafíos. Descubrimos que las actividades científicas, la autoeficacia y el conocimiento ambiental de los estudiantes están asociados positivamente con su conciencia sobre los desafíos ambientales. La conciencia ambiental de los estudiantes, a su vez, está asociada con el pesimismo ambiental o su perspectiva sobre el futuro de los problemas ambientales. Los estudiantes que están más comprometidos con las ciencias ambientales son más conscientes de los problemas ambientales y se sienten menos optimistas de que los problemas ambientales mejorarán en el futuro. Estas actitudes pesimistas sobre el futuro pueden ser un precursor del comportamiento proambiental. Nuestros resultados brindan una imagen transnacional del compromiso de los estudiantes con los problemas ambientales y una idea del potencial de los datos de evaluación a gran escala para informar las políticas de educación ambiental promovidas por países individuales y organizaciones internacionales.
Palabras-clave: evaluaciones internacionales a gran escala; educación ambiental

O pessimismo da juventude é bom para o meio ambiente? Perspectivas do PISA 2015

Resumo: Neste estudo, exploramos o potencial dos dados de avaliações em grande escala para fornecer insights sobre como o conhecimento ambiental dos alunos pode enfrentar o desafio global das ameaças ambientais para a humanidade e a transição para o desenvolvimento sustentável. Analisamos os dados da pesquisa PISA de 2015 para entender até que ponto os alunos de 15 anos de 54 países estão cientes desses desafios. Descobrimos que as atividades científicas, a autoeficácia e o conhecimento ambiental dos alunos estão positivamente associados à sua consciência sobre os desafios ambientais. A consciência ambiental dos alunos, por sua vez, está associada ao pessimismo ambiental, ou sua visão sobre o futuro das questões ambientais. Os alunos que estão mais engajados com a ciência ambiental estão mais conscientes sobre as questões ambientais e se sentem menos otimistas de que as questões ambientais irão melhorar no futuro. Essas atitudes pessimistas sobre o futuro podem ser um precursor de um comportamento pró-ambiental. Nossos resultados fornecem uma imagem transnacional do envolvimento dos alunos com as questões ambientais e uma visão sobre o potencial dos dados de avaliação em grande escala para informar as políticas de educação ambiental promovidas por países individuais e organizações internacionais.
Palavras-chave: avaliações internacionais em grande escala; educação ambiental

I don't want you to listen to me. I want you to listen to the scientists. And then I want you to take real action.

Greta Thunberg in the United States Congress, September 18, 2019

Is Youth Pessimism Good for the Environment? Insights from PISA 2015

On August 28, 2019, Greta Thunberg, one of the voices of a global movement that has mobilized millions of young people to demand action against climate change arrived in the United States (US). Thunberg sailed across the Atlantic on a zero-emissions boat to speak in front of the U.S. Congress and to address the 2019 United Nations Climate Summit. As she told the attendees at the Davos World Economic Forum in January 2019: "I don't want your hope. I want you to panic…and act." (Workman, 2019)

At the time, Thunberg, who turned 16 in 2019, was approximately the same age as the majority of the students who participate in the Program for International Student Assessment (PISA) every three years. She lives in Sweden, which is among the highest rated countries on the Environmental Performance Index (EPI), a country-level measure of sustainable development in two areas: environmental health and ecosystem vitality. Likewise, according to data from the Program for International Student Assessment (PISA), Sweden has one of the highest shares of 15-year-olds who are aware of environmental challenges. Thunberg is in turn raising awareness among her classmates, students in other countries, and politicians about the effects of global warming and climate change. She is perhaps the most prominent representative of the youth activists who are organizing and demonstrating to make global warming and climate change a national and global priority (Sengupta, 2019). Thunberg's weekly protests inspired ongoing student strikes in more than 100 cities worldwide. In September 2019, approximately four million people in more than 150 countries joined a youth-led strike to demand actions to fight climate change because the world is getting hotter faster (WMO, 2019).

In this study we empirically test the relationship between environmental awareness and environmental pessimism among Thunberg's peers in 54 countries. We focus on environmental pessimism as an outcome that can potentially be linked to pro-environmental behavior (Kaida & Kaida, 2016). We demonstrate that environmental awareness stems in part from students' environmental knowledge and is strongly associated with engagement in science activities and science self-efficacy. We use science scores as a measure of environmental knowledge that is embedded in the PISA science framework (OECD, 2009). Our main research questions are: a) is students' pessimism about the future of the environment related to their awareness about environmental issues; and b) does this relationship vary between students, schools, and countries?

We make several contributions to the literature on students' environmental attitudes and behavior. In addition to confirming already established links between students' backgrounds, their science knowledge, and their environmental attitudes, our analysis extends these findings to include environmental pessimism as an outcome of interest. Environmental pessimism has been shown to lead to pro-environmental behavior (Blankenberg & Alhusen, 2019; Kaida & Kaida, 2016, 2019). Because individuals' environmental attitudes and concerns are strongly related to the wealth of their countries (Franzen & Meyer, 2010; Franzen & Vogl, 2013), we analyze a broad set of 54 countries and economies and demonstrate that the relationship between students' environmental knowledge,

awareness, and pessimism holds regardless of the social, economic, and political contexts of their countries.

We suggest that if environmental pessimism is conducive to pro-environmental behavior, then it can be fostered in schools by raising students' environmental awareness via increased science knowledge. We situate our study in the expanding literature on education for sustainable development. According to UNESCO, Education for Sustainable Development (ESD) is a holistic and transformational education that enables individuals to find solutions to sustainability challenges by integrating priority sustainability issues into interactive, user-centered teaching and learning activities. These issues include but are not limited to climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption. Accordingly, teaching and learning activities related to sustainable development should address issues such as climate change and biodiversity to encourage students to be responsible global citizens who will resolve challenges, respect cultural diversity, and contribute to creating a more sustainable world (UNESCO, 2019).

Background and Conceptual Model

Responding to the threat of climate change and other environmental challenges, a number of programmatic documents issued by international organizations, such as the United Nations (UN) and UNESCO have emphasized the importance of environmental education for sustainable development. One of the 246 targets of the 17 UN's Sustainable Development Goals (SDGs) adopted in 2015 by all UN member states explicitly states:

> By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development. (United Nations, 2019)

This target is the only one among the 12 targets for Goal 4 that does not outline possible indicators or a methodology[1] to measure country-level performance on that target. To date, data that could address this target have not been collected. At the same time, studies have found that most teachers do not have sufficient environmental knowledge (Plutzer et al., 2016; Stevenson et al., 2016) and the systemic support (Colston & Ivey, 2015; Sullivan et al., 2014; Wise, 2010) to support the environmental education activities associated with promoting sustainable development. Taken together, these factors may explain why in general, the global education community has not prioritized environmental education.

Increasing concern over climate change and other environmental issues caused by human behavior have prompted researchers to develop conceptual models that explain the relationship between environmental attitudes and behaviors. While no single model perfectly captures the relationship between individual awareness and pro-environmental behavior, researchers have drawn upon a range of frameworks including models of altruism, empathy, and prosocial behavior, the model of ecological behavior, and the theory of reasoned action (for a review, see Kollmuss &

[1] The definition of the indicator corresponding to target 4.7 of the SDGs is as follows: "Extent to which (i) global citizenship education and (ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in: (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment.

Ageyman, 2002). In general, these models suggest that individuals' environmental awareness or understanding of consequences (i.e., environmental knowledge) will lead to pro-environmental attitudes and behaviors (Casaló & Escario, 2018).

Across these models, researchers have identified groups of factors associated with pro-environmental attitudes: a) student background characteristics such as gender, parents' educational attainment, and socioeconomic status (Coertjens et al., 2010; Duarte et al., 2017), b) internal factors including environmental knowledge, values, environmental awareness, emotional involvement, responsibility and priority (Diekmann & Franzen,1999; Kempton et al.,1995), and c) external factors such as institutional, economic, and social conditions (Boehmer-Christiansen & Skea,1991).[2] Researchers have assessed which of these factors are critical for raising individuals concerned with sustainable development (UNICED, 1992), and which of these factors can explain pro-environmental attitudes and the potential for pro-environmental behavior among young people.

In our analysis, we expand the model described above by including a measure of environmental pessimism in our set of internal factors. As a form of constructive pessimism, environmental pessimism has been shown to be associated with pro-environmental behavior (Gifford et al., 2009; Hall et al., 2018; Kaida & Kaida, 2016; 2019), as is constructive hope (Ojala, 2012). While optimists tend to underestimate the possible risks associated with a problem or activity and as a result, take less action (Weinstein, 1980, 1984, 1989; Weinstein & Klein, 1996; Weinstein et al., 1998), defensive or constructive pessimism can reduce individuals' avoidance behavior (Norem, 2008; Norem & Chang, 2002). Likewise, constructive pessimists tend to prepare for events in the future and try to prevent mistakes (Maldonado, 1972). For example, people who experience lower levels of happiness and satisfaction (two dimensions of pessimism) are more likely to engage in political participation than their more optimistic counterparts (Oishi et al., 2007). In addition, we also account for possible cross-country differences in external factors using a broader set of countries than most existing studies that encompass the major population centers of the global north and south. Comparative and cross-national studies have demonstrated that individual pro-environmental behaviors and attitudes are influenced by the economic (Franzen & Meyer, 2010; Franzen & Vogl, 2013) and social and political contexts of countries (Hadler & Haller, 2011).

Literature Review

Students' background characteristics have been theorized to be significant predictors of environmental behavior (Kollmuss and Ageyman, 2002). A few studies have empirically tested and confirmed this hypothesis using data from PISA for multiple years and a range of countries. Duarte et al. (2017) documented a strong and positive relationship between European students' socioeconomic backgrounds and their attitudes towards environmental problems. Coertiens et al. (2010) documented that ESCS, an index variable that measures students' relative economic, social, and cultural status had a small, albeit significant effect on environmental attitudes among 15-year-olds in Belgium. The authors argued that the limited predictive power of ESCS may be due to the combined nature of the construct and suggested partitioning it into three variables (economic, social, and cultural) and assessing the influence of each on environmental attitudes separately.[3] In addition to ESCS, gender was related to environmental attitudes, with girls demonstrating more pro-

[2] None of the existing models of pro-environmental behavior include all possible explanatory factors, but, as Kollmus and Ageyman (2002) point out, a comprehensive model is not feasible and might not be useful.
[3] To address this methodological concern and multicollinearity between parental education and ESCS, in our analysis we use an index of wealth and parental education as separate measures of students' socioeconomic status.

environmental orientations compared to boys (Coertjens, et.al., 2010; Duarte, et.al., 2017). Finally, Turkish 15-year-old students' environmental pessimism was similar to that of their parents (Erbas & Teksoz, 2012).

While the findings vary across studies, researchers have also identified the positive relationship between scientific and environmental knowledge and pro-environmental attitudes and behaviors (Bybee, 2008; Levine & Sturbe, 2012; Meinhold & Malkus, 2005). Bybee (2008) highlighted the association between scientific knowledge and awareness of environmental issues among 15-year-olds living in the countries that participated in PISA 2006. Bybee (2008) also suggested that higher science scores were associated with decreased optimism about the environment. That is, the more students knew about science the more likely they would be pessimistic about environmental issues in the future.

Other studies analyzed whether school-level factors such as instructional practices are related to students' environmental attitudes and behavior. For instance, in Belgium, Coertjens et al. (2010) found that students' environmental awareness was higher if they reported that their schools taught science using a constructivist approach more frequently than students who reported less frequent participation in hands-on activities. Students' pro-environmental attitudes were associated with environmental learning activities in schools, and these relationships were independent of students' science knowledge. Lin and Shi (2014) found positive relationships between American and Canadian 15-year old students' environmental knowledge, environmental awareness and pro-environmental behavior (see also Kaya & Elster, 2018). While the way environmental education was incorporated to the curriculum (i.e., separate or infused) was not associated with higher environmental literacy, instructional methods such as engaging students in purposeful investigative work have enhanced some domains of environmental literacy. Likewise, Hadzigeorgiou and Skoumios (2013) highlighted the importance of environmental education for fostering students' environmental awareness. They argued that science learning had to be meaningful and focused on the natural environment and the relationships between the self and the natural world (see also Kaya & Elster, 2018).

While the PISA data is especially well-suited to answer questions about environmental attitudes and the factors that might predict them, other data have also been used to address these questions. Liefländer and Bogner (2018) studied the relationship between two environmental attitudes (preservation and utilization) and three environmental knowledge dimensions (system, action-based, and effectiveness knowledge) among German elementary school students. They found a strong relationship between knowledge and attitudes; students who were more knowledgeable about the environment had less exploitative attitudes towards the environment. Similarly, pro-environmental attitudes and behavior among high school students from three large cities on the West Coast of the United States (Los Angeles, Seattle, and Portland) were strongly related; students' environmental knowledge was a significant moderator of this relationship (Meinhold & Malkus, 2005). However, the relationships between environmental knowledge, attitudes, and pro-environmental behavior among U.S. college students is more complex. While students' environmental knowledge does not seem to be strongly related to attitudes or behavior, their intentions mediate the relationship between environmental attitudes and pro-environmental behavior (Levin & Strube, 2012). Finally, environmental values, awareness of environmental consequences and environmental concern were strongly related among the adult population in Sweden (Hansla et al., 2008). Specifically, concerns for self, others, and the biosphere were related to individuals' beliefs about the consequences of human activity on the environment. Overall, models that relate individuals' environmental knowledge, attitudes, and behaviors are complex and challenging to test empirically.

The major findings across different countries and age groups suggest that individuals' scientific and environmental knowledge is strongly related to their environmental attitudes such as environmental awareness that in turn predict environmental behavior. Drawing on the conceptual frameworks and research outlined above, our hypotheses are as follows:

H1: Students who are exposed to more intense science knowledge and activities are more aware about environmental issues than students with less exposure.

H2: Students who reported higher self-efficacy in science are more aware about environmental issues than students with less self-efficacy

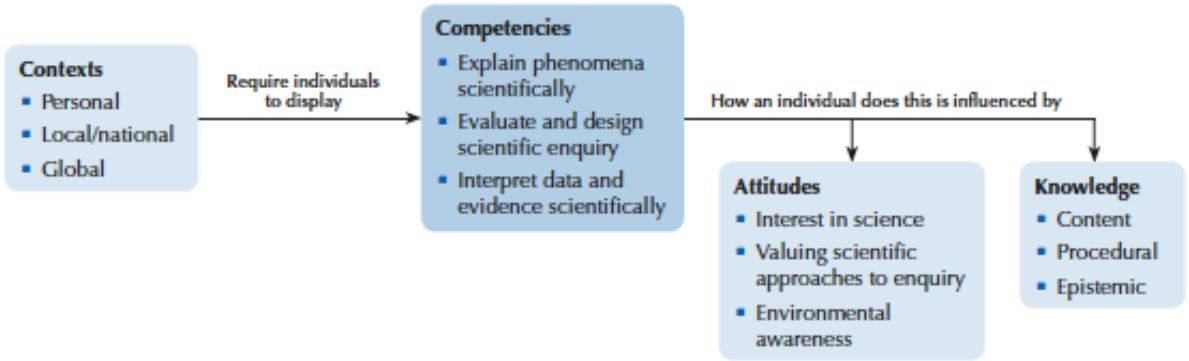
H3: Students with higher levels of environmental awareness have a higher level of pessimism about the future than students with lower levels of environmental awareness.

Data

We used data from the Programme for International Student Assessment (PISA) 2015 which was collected in 72 countries and economies (see Appendix Table 1). The PISA is a high-profile international assessment and the results are reported widely. Administered every three years since 2000 by the Organisation for Economic Cooperation and Development (OECD), PISA is intended to provide measures of the knowledge and skills young people will need to fully participate in the global economy and as citizens in modern societies when they are at the end of compulsory schooling (OECD, 2014a). According to the OECD, the PISA assesses how students can apply their knowledge to novel situations in and out of school settings (OECD, 2014b). While students are assessed in mathematics, reading, and science in each testing year, the focal subject rotates with each cycle. PISA 2015 was aimed at assessing students' scientific literacy and their experiences in science classes. Figure 1 presents the framework for measuring students' scientific literacy that in 2015 was defined as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OECD, 2017).

Figure 1

Framework for PISA 2015 Science Assessment



Source: OECD (2017).

PISA is one of the international large-scale assessments (ILSAs) that have expanded considerably over the last two decades. With each assessment year, PISA covers an increasing number of countries and jurisdictions. While ILSAs have been controversial (Pons, 2017), the data from ILSAs continue to be used at different levels of decision-making within and across countries (Fischman et al., 2019; Schleicher & Zoido, 2016). However, the 2015 PISA, which focused on

science, also provides a rich source of cross-country data about students' knowledge of and perceptions about the environment, which can be used to compare countries about the extent to which their science curricula address sustainable development, and how students' school-based knowledge might support climate activism.

Our final sample is comprised of 388,826 students in the 54 countries for which we have student-level data for all of the variables in the analyses.[4] The 54 countries represent a range of geographical locations, socioeconomic, educational and political systems, and policies about the environment and climate change.[5]

Dependent Variables

We used the students' responses to a set of environmental awareness questions to create two variables that provide indicators of students' awareness of a spectrum of environmental issues and students' level of pessimism about the future of these issues. For the first dependent variable, "environmental awareness," we used students' answers to a set of seven questions about major environmental issues: air pollution, deforestation, nuclear waste, the extinction of plants and animals, water shortages, greenhouse gases, and the use of genetically modified organisms. Each question asked "How informed are you about this environmental issue?" Students could select from four options ranging from zero awareness, "I have never heard of this" to "I am familiar with this and I would be able to explain this well." The middle options include "I have heard about this but I would not be able to explain what it is really about" and "I know something about this and could explain the general issue." For our index of environmental awareness, the scale reliability coefficient (Cronbach's alpha) was equal to 0.95 with an interim correlation between items of 0.75.

Our second dependent variable, an environmental pessimism scale utilized a second set of questions about the future of the environment. Students were asked about each of the seven issues listed above: "This issue will improve or get worse over next 20 years?" The response options were "Improve," "Stay about the same," and "Get worse." We combined students' responses into two indices – environmental awareness and environmental pessimism -- by averaging the seven questions for each item.[6] For both indexes, we recoded responses to assign higher weights to low and high values compared to the neutral values. In our analyses, we focus on these two variables as our dependent variables. The scale reliability coefficient for the pessimism scale (Cronbach's alpha) was 0.98 with an interim correlation of 0.89. While the OECD created an index of environmental optimism derived from the same question, we focused on environmental pessimism because it allowed us to test the hypothesis that was implied but not developed in prior research about the relationship between environmental awareness and environmental pessimism, both of which may be important precursors to environmental action.

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[4] In Appendix Table A1 we listed the countries that participated in PISA 2015 and have publicly available data. We combined: a) data from Perm (a region in Russian Federation) with data from the Russian Federation; b) data from the regions of Spain with data from Spanish national data; and c) data from Macao, Hong Kong, and B-S-J-G with national data from China. This reduced our sample of countries and jurisdictions from 72 to 67. We excluded 13 additional countries that did not have data on the variables we used in our analysis.

[5] The full PISA sample comprised 542,250 students. After eliminating cases listwise, the students in our analytic sample were clustered in 15,247 schools with an average of 26 students per school.

[6] The PISA data includes two derived indices of environmental optimism and awareness based on these questions that are centered at 0 indicating neutral answers. The PISA indices and the indices we constructed are highly correlated at 0.97 for both variables.

Exploratory Analysis Using the Environmental Performance Index

As an initial step, we conducted an exploratory analysis of the relationship between students' environmental pessimism, which we aggregated at the country level, and the Environmental Performance Index (EPI), a country-level measure of the extent to which a country's policies and practices are oriented toward sustainable development. The EPI ranks countries based on their performance on two dimensions of sustainable development, environmental health and ecosystem vitality (Wendling et al., 2018). The EPI summarizes 24 indicators: total carbon dioxide emissions, air quality, water and sanitation, wastewater management, fish stock status, and tree cover loss, among others. Countries with high scores on the EPI are closer to global environmental goals and accords such as the 2015 Paris Accord and the 2015 UN Sustainable Development Goals than countries with low scores.

Independent Variables for the Main Analyses

Our analysis includes three categories of independent variables that draw upon the findings in the studies outlined above: a) students' science self-efficacy, their participation in science activities, and PISA science test scores; b) students' backgrounds; and c) parental attitudes about environmental issues. Measures of self-efficacy in science and science activities are constructed from two questions in the student questionnaire. The science self-efficacy index (question ST129) consists of eight sub-questions where students were asked to rate how they would perform on different science tasks on a four-point scale with the categories "I could do this easily," "I could do this with a bit of effort," "I would struggle to do this on my own," and "I couldn't do this." The tasks included (a) recognizing the science question that underlies a newspaper report on health issues; (b) explaining why earthquakes occurs in some places more often than in others; (c) describing the role of antibiotics in the treatment of disease; (d) identifying the science question associated with the disposal of garbage; (e) predicting how changes to an environment will affect the survival of certain species; (f) interpreting the scientific information provided on the labelling of food items; (g) discussing how new evidence can lead you to change your understanding about the possibility of life on Mars; and (h) identifying the better of two explanations for the formation of acid rain. The responses were reverse-coded so that higher values indicate greater self-efficacy and the derived variable was scaled to have mean of zero which indicates the average level of self-efficacy. The scale reliability coefficient (Cronbach' alpha) for these eight items was 0.9.

The science activity index (question ST146) consists of nine sub-questions that asked students about their engagement with science, such as how often they watch TV programs about science, borrow or buy books on science topics, visit websites and read articles in newspapers and magazines on science topics, and visit websites on ecology organizations. Students were also asked: a) whether they follow news of science, environmental, or ecology organizations via blogs and microblogging, and b) if they simulate natural phenomena and technical processes in computer programs or virtual labs, and if they do, how often they do so. Higher values of the activity index correspond to higher levels of science activities, i.e., that students were engaged with the activities listed above very often or at least regularly. Similar to science self-efficacy, the science activity index is centered so that the mean is zero, which represents the average intensity of science activities. These nine items demonstrated high scale reliability with the reliability coefficient (Cronbach's alpha) of 0.93. The PISA science test score measures the scientific literacy of 15-year-olds in the use of scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues (OECD, 2019).

Student background variables include age, gender, age-expected grade, parental education, an index of family wealth,[7] and an indicator if students reported that they speak a language other than the test language at home. Age-expected grade is a relative measure that indicates whether a student is in a lower or higher grade relative to the expected grade for their age. Since grade levels for students of the same age differ by country, this relative measure allows us to make valid conclusions between students across countries. Parental education is measured in years of schooling; if both parents were present in a family, the highest level of education between both parents was reported. Wealth is an OECD-calculated index based on students' responses to survey questions asking them if they had their own rooms, a link to the internet, a DVD player, and three country-specific items (OECD, 2014d). The wealth index also includes the students' responses on series of questions that asked them how many cellular phones, televisions, and cars their families own, and the numbers of rooms with a bath or shower in their homes. The OECD standardized the wealth variable so that the OECD mean equals zero and the standard deviation is one.

For a small number of countries (see Appendix Table 1), we also have measures of parents' awareness of environmental issues and parents' optimism about the future of those issues drawn from parent surveys. We included these measures in one of the specifications of our model of students' environmental pessimism to control for environmental attitudes and behaviors within families that might be associated with student-level outcomes (Avvisati, 2019).

Methods

For our initial exploratory analysis, we correlated the EPI with our country-level average of our environmental pessimism index. The latter provides an indicator of how pessimistic 15-year-old students in a given country are about the future of the environment. For our main analyses, we estimated how much of the differences in environmental awareness and pessimism among 15-year old students is accounted for by differences within schools and countries. Given the nested structure of the data where students are nested in schools and schools are nested in countries, we used three-level hierarchical linear models (HLM) at the student, school and country levels to estimate the relationship between environmental awareness and students' science self-efficacy and science activities controlling for science test scores and background characteristics. We also used HLM to understand the relationship between environmental awareness and pessimism controlling for students' backgrounds. The equations for the three-level model when our dependent variable is student awareness are as follows:

Level 1 model: $Awareness = \pi_0 + \sum_1^n \pi_i X_i + \varepsilon$
Level 2 model: $\pi_0 = \beta_{00} + r_0$
Level 3 model: $\beta_{00} = \gamma_{000} + \gamma_{001} OECD + \upsilon_{00}$

The Level 1 model is our baseline model and allows us to evaluate differences in environmental awareness and pessimism between students. The variables for Level 1 include age, age-expected grade, wealth, parental education, science self-efficacy, and science activities as independent variables. This model includes a fixed intercept – an average value of pessimism π_0 for all students in the sample conditional on the set of covariates outlined above, X_i, and a random component, ε. Level 2 is the school-level model, which provides estimates of the variability in students' environmental awareness between schools within a country. The Level 2 model includes a

[7] PISA does not collect data on family income and instead uses a series of questions about home possessions to derive an index that serve as a proxy for student's family wealth.

fixed intercept, β_{00}, and a random component, r_0. The Level 2 model does not include any school-level fixed covariates for two reasons: a) our methodological approach accounts for variation between schools within countries, and b) the school-level variables collected by PISA were not theoretically or conceptually associated with students' environmental knowledge, attitudes or behaviors. Finally, the Level 3 model estimates the variance of country-level environmental awareness from the average awareness among students across all countries, in addition to the variation between schools within countries (the Level 2 model), and the variation between students within schools (the Level 1 model). Level 3, our saturated model, includes an indicator for each country and for OECD countries. Country is included as a random intercept and the OECD indicator is included as a fixed slope intercept.

In the models where we estimated the relationship between environmental pessimism and awareness, we used the same set of control variables, but excluded the measures of self-efficacy, science activities, and science knowledge as measured by the PISA science score. Instead, we used parents' environmental awareness and optimism; these variables allow us to assess another dimension of students' family background, their parents' attitudes about the environment, which are another possible influence on students' environmental awareness and pessimism.

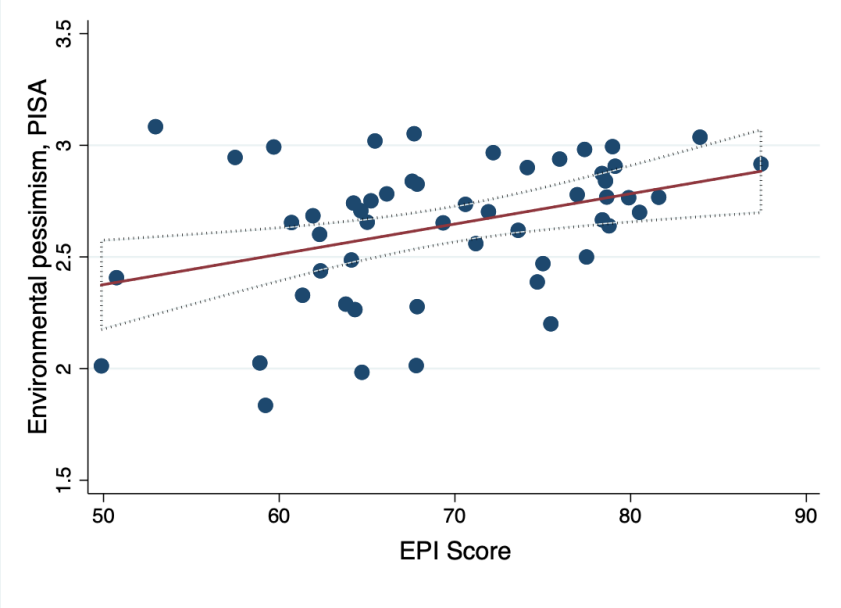
Results

Descriptive Statistics

As we suggested in the introduction, if environmental awareness and environmental pessimism are positively related, this could be a positive good for the future of the environment because ultimately pessimism, or a dark forecast about the future is likely to spur young people to engage in actions to prevent it. We present some initial cross-country evidence that shows the relationship between the EPI score and environmental pessimism among 15-year old students that supports this hypothesis in Figure 2.

Figure 2

The Relationship between Environmental Performance Index (2018) and the Average Level of Environmental Pessimism Among 15-year-olds (2015), with a 95% Confidence Interval



According to Figure 2, higher levels of environmental pessimism are associated with higher levels of environmental performance. The coefficient of correlation between the EPI score and pessimism for our sample of 54 countries is 0.4 (p-value<0.001). The statistically significant relationship between the two variables suggests that young peoples' concerns about the future could translate into actions aimed at influencing decision-making within their countries.

Who are these young people? In Table 1 we describe the sample for our analysis and present statistics for the entire sample and separately for OECD and non-OECD countries. The students from 54 countries and jurisdictions in our sample were just under 16 years old on average, and 51 percent were female. Fifty-six percent attended grade 10 or the equivalent in their respective countries. Twelve percent of students reported that they spoke a language other than the test language at home. On average, students in non-OECD countries came from families with slightly lower family wealth as indicated by the PISA wealth index. The students' parents had 14 years of education on average, which corresponds to some college.

One notable feature of the descriptive findings is that students in non-OECD countries had higher science self-efficacy and more engagement with science activities, but on average the science test scores in these countries were lower compared to students in OECD countries. Students in all countries expressed an average level of environmental awareness, i.e., for the most part students felt that they had some general ideas about each of the environmental issues addressed in the set of questions. Students also expressed a substantial degree of pessimism about the future of the environment as they saw it in 20 years from the time they took the test, and students in OECD countries were relatively more pessimistic. This finding is consistent with our initial country-level analysis of the relationship between the EPI and youths' environmental pessimism. While we do not have parents' responses to similar questions for all countries, in the smaller subsample, parents in non-OECD countries were more optimistic compared to OECD countries, and they also reported slightly lower levels of environmental awareness.

Table 1

Definitions, Metrics, and Descriptive Statistics

Variable	Definition / Metric	All countries*		OECD countries		Non-OECD countries	
		Mean	SD	Mean	SD	Mean	SD
Dependent Variables							
Environmental awareness: students	How informed are you about this environmental issue?" This question was asked about seven issues: air pollution, deforestation, nuclear waste, the extinction of plants and animals, water shortages, greenhouse gases, and the use of genetically modified organisms. Each item included four response categories: (1) I have never heard of this; (2) I have heard about this but I would not be able to explain what it is really	3.05	1.02	3.05	1.01	3.05	1.04

Table 1

Definitions, Metrics, and Descriptive Statistics

Variable	Definition / Metric	All countries*		OECD countries		Non-OECD countries	
		Mean	SD	Mean	SD	Mean	SD
	about; (3) I know something about this and could explain the general issue; (4) I am familiar with this and I would be able to explain this well. Higher values reflect higher level of environmental awareness. [Cronbach's alpha = 0.95]						
Environmental pessimism: students	This issue will improve or get worse over next 20 years? This question was asked about seven issues: air pollution, deforestation, nuclear waste, the extinction of plants and animals, water shortages, greenhouse gases, and the use of genetically modified organisms. Each item included four response categories: (1) Improve, (2) Stay about the same; (3) Get worse. Higher values reflect higher level of environmental pessimism. [Cronbach's alpha = 0.98]	2.63	1.19	2.76	1.09	2.40	1.31
Independent Variables							
Science self-efficacy	Respondents' self-perceived performance on science tasks. This index is based on eight items. Higher values reflect higher self-efficacy. Index is centered so that the mean is zero, indicating the average level of self-efficacy.	0.08	1.24	0.03	1.25	0.15	1.23
Science activities	Respondents' self-perceived involvement with science. This index is based on nine items. Higher values reflect higher level of engagement with science activities. Index is centered so that the mean is zero, which represents the average	0.18	1.16	-0.05	1.14	0.59	1.09

Table 1

Definitions, Metrics, and Descriptive Statistics

Variable	Definition / Metric	All countries*		OECD countries		Non-OECD countries	
		Mean	SD	Mean	SD	Mean	SD
	intensity of science activities.						
Science test score	Scientific literacy of the respondents in the use of scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues. Higher values reflect higher levels of performance on the science test.	487.56	94.69	503.04	90.25	460.71	96.19
Environmental awareness: parents	An OECD developed indicator of parental awareness calculated over seven 4-point Likert scale items with response options "this is a serious concern for me personally as well as others," "this is a serious concern for other people in my country but not for me personally," "this is a serious concern only for people in other countries," and "this is not a serious concern for anyone." Higher values of the indicator correspond to higher levels of parents' concerns regarding environmental topics. Topics included air pollution, extinction of plants and animals, clearing of forests for other land use, water shortages, nuclear waste, extreme weather conditions, and human contact with animal deceases. [PQENPERC]	0.22	1.05	0.25	1.01	0.10	1.16
Environmental optimism: parents*	An OECD developed indicator of parental optimism towards	0.07	1.17	-0.02	1.09	0.34	1.36

Table 1

Definitions, Metrics, and Descriptive Statistics

Variable	Definition / Metric	All countries*		OECD countries		Non-OECD countries	
		Mean	SD	Mean	SD	Mean	SD
	environmental topics (as above) calculated over seven three-point Likert scale items with the response options "improve," "stay about the same," and "get worse." The higher values correspond to higher levels of parents' environmental optimism. [PQENVOPT]						
Female	Percentage of female respondents.	51.16		50.65		52.04	
Age	Respondent's age in years.	15.79	0.29	15.79	0.29	15.79	0.29
Relative grade level	The relative grade index [GRADE] was computed by OECD to capture between-country variation. It indicates whether students are in the country's a modal grade i (value of 0) or whether they are below or above the modal grade (+x grades, -x grades).	-0.12	0.64	-0.11	0.54	-0.16	0.78
Grade 10	Percentage of respondents in grade 10.	56.00		59.42		50.05	
Speak language other than test language at home	Percentage of respondents who speak language other than test language at home.	12.11		12.10		12.13	
Wealth	OECD calculated index based on respondents' responses to questions asking about having own room, link to internet, DVD player, etc., for a total of 12 items. The OECD standardized the wealth variable so that the OECD mean equals zero and the standard deviation is one.	-0.17	1.14	0.06	0.97	-0.58	1.30
Parental education	Number of years of schooling of a respondent's parent, or the highest level of education between both parents.	13.52	3.13	13.74	3.04	13.16	3.24

Table 1

Definitions, Metrics, and Descriptive Statistics

Variable	Definition / Metric	All countries*		OECD countries		Non-OECD countries	
		Mean	SD	Mean	SD	Mean	SD
EPI index	Average of country-level measure of sustainable development in two areas: environmental health and ecosystem vitality (24 indicators total). A higher value reflects higher EPI performance.	69.51	8.65	73.29	7.62	62.16	5.08
N		388, 826		246,589		142,237	

Note. Descriptive statistics calculated for all countries for which we have data on environmental pessimism among students as indicated in Appendix Table 1. *Data for parents available for a smaller subsample, *n*=71,297.

The Relationship between Environmental Awareness, Science Activities and Self-Efficacy

Table 2 presents the results of the maximum likelihood estimation of the mixed effects model we described above. The specification in the first column is the null model that does not include any controls. This model measures the variance due to the clustering of students in schools and countries. According to our estimates, most of the variation in students' environmental awareness occurs between students. Across all models, the differences in students' awareness within schools and countries accounts for about 12% and 4% of the overall variation, respectively.[8] The magnitudes of the intraclass correlation coefficients are sufficient to warrant the use of linear mixed-effects model for the rest of our specifications.

Table 2

Hierarchical Linear Model of the Relationship between Environmental Awareness and Student Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5
Average environmental awareness	3.010*** (.027)	2.119*** (0.291)	.528 (.353)	.324 (.354)	.173 (.505)
Science activities		.092*** (.001)	.098*** (.001)	.096*** (.001)	.124** (0.003)
Science self-efficacy		.244*** (.001)	0.241*** (.001)	.238*** (.001)	.251*** (.003)
Science test score		.002** (.001)	.002** (.001)	.002** (.001)	.002** (.001)
Female			.008** (.003)	.012*** (.003)	.010 (.007)

[8] The intraclass correlation coefficient (ICC) is the ratio of the intraclass variance to the overall variance and shows the proportion of the overall variance in the dependent variable accounted for by clustering. Values of ICC close to or smaller than 0.1 or 10% would indicate that the mixed-effects model might not be necessary. The size of the ICC in our models is modest and we repeated the analysis using fixed effects linear models (with schools and countries) and the results were largely the same.

Table 2

Hierarchical Linear Model of the Relationship between Environmental Awareness and Student Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5
Age			-.021***	-.014***	-.003
			(.005)	(.005)	(0.012)
Grade			.191***	.181***	.163***
			(.003)	(.003)	(.006)
Language other than test language at home			-.076***	-.068***	-.038***
			(.006)	(.005)	(.014)
Parental education				.021***	.018***
				(.001)	(.001)
Wealth				-.0003	.006***
				(.0004)	(0.002)
Parental environmental concerns					.019***
					(.003)
Parental environmental optimism					-.024***
					(.003)
OECD indicator		-.008	-.030	-.032	-.025
		(.061)	(.072)	(.072)	(.119)
LR test vs. linear regression, p-value	.000	.000	.000	.000	.000
ICC (schools)	.12	.11	.11	.11	.08
ICC (countries)	.04	.03	.04	.04	.04
N, countries	54	54	54	54	16
N, schools	15,224	15,224	15,224	15,224	2,988
N, observations	388,826	388,826	388,826	388,826	71,297

Note. Model 1 is a null model that includes an intercept only and represents the average value of environmental awareness among all students in the data. Model 5 includes data for parental awareness and optimism available in a smaller subsample of countries.
* denotes *p*-value <0.10, ** *p*-value<0.05, ****p*-value<0.01.

In column 2 of Table 2 we explored the relationship between students' environmental awareness and science activities and science self-efficacy controlling for science test scores (H1 and H2). Both science activities and self-efficacy are strongly associated with students' environmental awareness and indicated that on average, students who reported a higher intensity of science activities and higher self-efficacy were also more aware about the set of environmental concerns addressed in the PISA questionnaire than their peers with lower intensity of science activities and self-efficacy. Students' science test scores were also significantly and positively associated with environmental awareness. Consistent with our predictions in H1 and H2, students' general science knowledge measured by test scores, and their self-reported efficacy and engagement with science via science activities are strong predictors of students' environmental awareness. While these relationships vary by school and country, most of the differences in environmental awareness that we observe in the data are between students irrespective of school and country.

Next, we added a number of fixed parameters to enrich the model with a) student background characteristics and b) information about parental education and family level of wealth. The results are presented in columns 3 and 4 of Table 2, respectively. With the inclusion of these parameters, self-efficacy and science activities remained strong predictors of environmental awareness with almost no change in the magnitude of the association. On average, female students reported higher levels of environmental awareness compared to male students. Students who were in higher grades also reported higher environmental awareness, but older students tended to be less aware. Students who spoke a language different from the language of the test at home were slightly but significantly less aware of environmental issues. Higher levels of parental education were positively and statistically significantly associated with higher environmental awareness among children. Looking at the magnitude of the coefficients, we noted that the estimates for science activities, science self-efficacy, and science scores are larger in magnitude compared to parental education and wealth, where the latter were not precisely estimated. This suggests that students' engagement in science activities and self-efficacy play a more significant role in students' environmental awareness compared to parental education or wealth. We also controlled for the country's membership in OECD but did not find statistically significant differences in students' environmental awareness depending on the country's OECD membership.

The Relationship between Environmental Pessimism and Awareness

After establishing that there is a statistical relationship between environmental awareness and science knowledge, activities, and self-efficacy, we analyzed how students' pessimism about major environmental issues in the future is related to environmental awareness (H3). To answer our second research question, we estimated a three-level mixed effects model with environmental pessimism as the dependent variable (Table 3). Similar to our model for environmental awareness, the variation among students accounts for most of the differences in pessimism rather than differences by school or country. The intraclass correlation coefficients for the models with pessimism are similar to the ones for the models with awareness as the dependent variable. Within-school variation accounts for about 12% of the overall variation in students' environmental pessimism and within-country variation accounts for another seven percent. Overall, one fifth of the variation in students' pessimism about the environment is explained by within-school and country differences.

Table 3

Hierarchical Linear Model of the Relationship between Environmental Pessimism, Environmental Awareness, and Student Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5
Average environmental pessimism	2.623*** (.043)	1.915*** (.063)	2.197*** (.450)	.787 (.480)	0.071 (.607)
Environmental awareness		.161*** (.002)	.207*** (.002)	.195*** (0.002)	.165*** (.005)
Science activities			-.124*** (.002)	-.119*** (.002)	-.094*** (.004)
Science self-efficacy			-.036*** (.002)	-.036*** (.002)	-.031*** (.004)
Science test score			-.001 (.001)	-.0004 (.001)	.002 (.001)
Female				.131***	.152***

Table 3

Hierarchical Linear Model of the Relationship between Environmental Pessimism, Environmental Awareness, and Student Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5
				(.004)	(.008)
Age				-.021***	-.017
				(.007)	(.014)
Grade				.167***	.150***
				(.004)	(.007)
Language other				-.022***	.015
than test language				(.007)	(.016)
Parental education					.002
					(.001)
Wealth					-.001
					(.002)
Parental				.	.009**
environmental					(.004)
concerns					
Parental					-.192***
environmental					(.004)
optimism					
OECD indicator		.338***	.285***	.271***	.037
		(.078)	(.094)	(.098)	(/143)
LR test vs. linear regression, p-value	.000	.000	.000	.000	.000
ICC (schools)	.13	.10	.10	.10	.06
ICC (countries)	.07	.05	.05	.06	.04
N, countries	54	54	54	54	16
N, schools	15,224	15,224	15,224	15.224	2,988
N, observations	388,826	388,826	388,826	388.826	71,297

Note. Model 1 is a null model and includes an intercept only that represent an average value of environmental pessimism among all students in the data. Model 5 includes data for parental awareness and optimism available in a smaller subsample of countries. * denotes *p*-value <0.10, ** *p*-value<0.05, ****p*-value<0.01.

As we proposed in H3, as students' awareness about environmental issues increases, their pessimistic views about the future of these issues also increases. In other words, students who know more about environmental issues and can explain them to others in detail also believed that these issues will be worse 20 years from now (or by 2035 given that the test was administered in 2015). Female students were more likely to hold pessimistic views about the environment compared to male students. Students who were in higher grades were also more likely to perceive that the environment is getting worse in the future. Students who spoke a language different from the language of the test were less pessimistic on average. Wealth was negatively associated with the degree of environmental pessimism but the magnitude is small; the size of the association between pessimism and awareness is 77 times larger than the association between environmental pessimism and wealth. Children of more educated parents are more likely to be pessimistic about the future of the environment. We also noted that when both awareness and science variables (activities, self-efficacy, and score) are included, the coefficients on all three science variables have the negative sign. To understand the relationship between environmental pessimism and science activities, self-

efficacy, and science score, we estimated the same model but without students' environmental awareness (not presented in Table 3). In that model, all of the variables associated with learning and science knowledge —science self-efficacy, test score, and engagement in science activities—were statistically significant and positive, indicating that awareness serves as a mediating factor between learning and engagement with science and environmental pessimism.

For a small subsample of countries, we also included measures of parental environmental concerns and optimism (Model 5). As we expected, children of more optimistic parents were on average also more optimistic, but children of parents who were more concerned about environmental topics expressed more pessimism about these topics in the future. When included in the model with parental attitudes towards the environment, parents' education and family wealth were not significant predictors of students' pessimism. This might be because environmental awareness and attitudes towards the future among parents are associated with their education and wealth.

Discussion and Conclusions

In this study, we analyzed the relationship between environmental awareness, environmental pessimism, and science knowledge, activities, and self-efficacy among 15-year-old students in 54 countries. Drawing on the model of ecological behavior and the theory of reasoned action, we developed two hypotheses about the factors associated with environmental awareness and pessimism and the relationship between them. Our first hypothesis was that students who engage in more intense science activities and who reported higher self-efficacy in science would be more aware of environmental issues than their peers with lower exposure and self-efficacy. Our second hypothesis was that students with higher levels of environmental awareness would be more pessimistic about the future of the environment than their peers with lower levels of awareness. We found support for both of our hypotheses. Specifically, we established that students' environmental awareness and pessimism are strongly related even after accounting for differences between schools, countries, and student background characteristics. Indeed, the relationship between awareness and pessimism does not change once we control for these sets of variables. There are slight differences between students in their levels of pessimism about the future of environmental issues by gender, grade, parental education, and wealth. While statistically significant, the magnitudes of these latter differences are not policy relevant.

At the country level, the average student environmental pessimism is related to environmental performance as measured by the EPI. If environmental pessimism prompts social activism, and environmental awareness is associated with environmental pessimism, then what are the policy-relevant determinants of environmental awareness? We hypothesized that 15-year old students' environmental awareness is strongly related to their science knowledge as measured by their PISA science scores, self-reported intensity of science activities, and science self-efficacy. As with environmental pessimism, these relationships remain strong after controlling for student background as well as school and country-level differences. Moreover, the magnitude of these relationships is larger than student background factors which are also associated with environmental awareness such as wealth and parental education.

Our analysis has a number of limitations. First, the variables we used to create the science activity index comprise a broad range of in- and out-of-school activities so we cannot directly assess the role of students' school activities in fostering environmental knowledge, although our school-level model suggests there are independent effects of schooling on environmental awareness and pessimism, which we were able to confirm with our subsample analysis that included measures of parental concerns and optimism. Second, the data for some of the countries that participated in

PISA in 2015 is missing for the variables that we used in our analysis. If the countries with missing data have different relationships between environmental awareness, pessimism and scientific knowledge, then our estimates cannot be generalized beyond this set of countries. However, the country-level effects on students' environmental awareness and pessimism was relatively small (5-7% of the overall variation) which suggests that adding these countries to the sample would not change our results substantially. Likewise, our sample of 54 countries contains a wide range of political and cultural systems including the major population centers in the global north and south, so we are reasonably confident that the relationships we document here would not be substantially different even if we included additional countries in the analysis.

There are number of policy-relevant implications of our analyses. Unlike student background characteristics, science activities and science knowledge are policy malleable factors that can be changed at the school or country levels. For example, a strategic science curriculum that requires students to learn new skills and knowledge about the environment that fosters changes in students' environmental attitudes and behaviors may spur students to participate in activities aimed at mitigating climate and other environmental changes. Our analysis suggests that environmental knowledge among teenagers is associated with environmental attitudes via increased awareness about environmental issues. Our analysis also indicated that 15-year old students' environmental pessimism is related to their awareness about environmental issues, and awareness is significantly associated with their science knowledge and how students engage with and learn about environmental science. While our variables do not directly address school-related science activities, our analysis does provide insights into the possible efficacy of school-based curricula and activities in increasing students' science knowledge, which is one of the pathways to environmental activism. Future studies might expand the model described here to directly address the relationship between environmental awareness, pessimism, and activism.

Environmental education can enable students and their communities to make informed decisions and take actions against climate change and for sustainable development, as many young people like Thunberg are already doing. At the same time, as we have mentioned at the outset of our paper, there is uneven support for sustainability education at the local (i.e., teachers and schools), country, and global levels. Our analysis suggests that formal education is a major untapped resource to address climate change (Anderson & Strecker, 2012). In addition, the education sector is a fruitful site through which other sectors such as health, labor, finance, urban planning, and transportation could come together to solve environmental challenges. This suggests the need for a strategic and cross-sector agenda among global agencies and national governments to increase their efforts around promoting environmental knowledge in schools. These agencies should engage educators who have a long tradition of educating for social change and who could use their expertise to influence students' knowledge, skills, attitudes, and behaviors related to the environment and climate change (Anderson, 2010).

In addition, in subsequent administrations of the PISA, the survey items associated with large-scale assessments could be expanded to include school-based activities that will help us better understand how schools can foster greater environmental knowledge among their students and measures of students' engagement in activities aimed at promoting sustainable development. Finally, given the current lack of appropriate indicators that measure countries' progress in education for sustainable development, the data from international assessments could be fruitfully adapted to address that challenge.

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Appendix

Table A1

List of Countries that Participated in PISA 2015 and Data Availability

	Country	Science Activities	Pessimism	Parental Awareness/Optimism
1	Albania	No	No	
2	Algeria	No	No	
3	Argentina	No	No	
4	Australia*			
5	Austria*			
6	Belgium*			Yes
7	Brazil			
8	Bulgaria			
9	Canada*			
10	Chile*			Yes
11	China			Yes
12	Chinese Taipei			Yes
13	Colombia			
14	Costa Rica			
15	Croatia			Yes
16	Czech Republic*			
17	Denmark*			
18	Dominican Republic			Yes
19	Estonia*			
20	Finland*			
21	France*			Yes
22	Georgia	No	No	Yes
23	Germany*			Yes
24	Greece*			
25	Hungary*			
26	Iceland*			
27	Indonesia	No	No	
28	Ireland*			Yes
29	Israel*			
30	Italy*			Yes
31	Japan*			
32	Kazakhstan	No	No	
33	Jordan	No	No	
34	Korea, South			Yes
35	Lebanon	No	No	
36	Latvia*			
37	Lithuania*			
38	Luxembourg*			Yes
39	Malaysia			
40	Malta	No	No	Yes
41	Mexico*			Yes

Table A1

List of Countries that Participated in PISA 2015 and Data Availability

	Country	Science Activities	Pessimism	Parental Awareness/Optimism
42	Moldova		No	
43	Montenegro			
44	Netherlands*			
45	New Zealand*			
46	Norway*			
47	Peru			
48	Poland*			
49	Portugal*			Yes
50	Qatar			
51	Romania	No	No	
52	Russian Federation			
53	Singapore			
54	Slovak Republic*			
55	Vietnam	No	No	
56	Slovenia*			
57	Spain*			Yes
58	Sweden*			
59	Switzerland*			
60	Thailand			
61	Trinidad and Tobago	No	No	
62	United Arab Emirates			
63	Tunisia			
64	Turkey*			
65	United Kingdom*			Yes
66	United States*			
67	Uruguay			

Note. * denotes OECD countries.

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