PEL Pensamiento Educativo. Revista de Investigación Educacional Latinoamericana
2013, 50(2), 97-112

Pontificia Universidad Católica de Chile
Facultad de Educación

Explanatory Factors of Environmental Science Literacy in Chilean Students

Factores explicativos de la alfabetización científica en medio ambiente en estudiantes chilenos

Marianela B. Navarro C.

Centro de Medición MIDE UC, Pontificia Universidad Católica de Chile

Abstract

This study aims to analyze variables with explanatory power of both students and schools on environmental science literacy. The database of the PISA 2006 is used. Two hierarchical linear models are estimated, each one with two levels: one of the index of environmental scientific literacy and the other of this index, controlled by the reading skills of students. The results show that in the first model, the variables that best explain the variance of the student's index of the environmental literacy are reading comprehension, gender and peer effect of students. In the second model, the social, economic and cultural status emerges as one of the variables that significantly explains individual differences, but with a lower weight than reading comprehension in the previous model.

Keywords: scientific literacy, environmental science literacy, PISA 2006, science teaching, environmental education, hierarchical linear models

Post to:
Marianela B. Navarro C., Centro de Medición MIDE UC, Pontificia Universidad Católica de Chile
Avda. Vicuña Mackenna 4860, Macul. Santiago, Chile
Email: mbnavarr@uc.cl
This work has been funded with support from a Doctoral Fellowship from the National Commission for Scientific and Technological Research (CONICYT).
The author is grateful to Professor Erika Himmel for her assistance in reviewing the manuscript of this work and for her valuable suggestions.
This article was originally written in Spanish.

ISSN: 0719-0409 DDI: 203.262, Santiago, Chile
doi:10.7764/PEL.50.2.2013.6

Resumen

Este estudio tiene como objetivo analizar variables, tanto de los estudiantes como de las escuelas, con mayor capacidad explicativa en la alfabetización científica en medio ambiente. Para este efecto se emplea la base de datos de la prueba PISA 2006 y se realiza una estimación de los modelos lineales jerárquicos en dos niveles del índice de alfabetización científica en medio ambiente y de dicho índice, controlado por la competencia lectora de los estudiantes. Los resultados del estudio revelan que, en el primer modelo, las variables que mejor explican la varianza del desempeño en medio ambiente de los alumnos son: la competencia lectora, el sexo y el efecto pares. En el segundo modelo emerge el estatus socioeconómico y cultural como una de las variables que dan cuenta de las diferencias individuales, pero con menor peso que la competencia lectora en el modelo precedente.

Palabras clave: alfabetización científica, alfabetización científica en medio ambiente, PISA 2006, enseñanza de la ciencia, educación ambiental, análisis jerárquico

The presence of humans on planet Earth has left its mark and caused a substantial modification of the terrestrial landscape (OECD, 2009a; SEMARNAT, 2008). Chile is no exception, as a country that has experienced rapid economic growth with its concomitant adverse impact on natural resources, biodiversity, and air quality (ECLAC/OECD, 2005). In fact, Chile has some of the most dangerous levels of air pollution among OECD countries (OECD, 2011).

Two needs arise from this critical scenario. First, people must gain an understanding of the increasingly complex environmental issues that are continually discussed in the media, and second, current and future generations must be more aware of environmental problems and make daily decisions that foster a society that is respectful of resources and the natural environment (Bybee, 2008).

Therefore, education in general, and science education in particular, has a responsibility to address these needs. Today the challenge goes beyond simply training more environmental scientists. Above all, the goal is to mold informed, motivated, and scientifically literate citizens who able to understand and interpret scientific theories and whose actions and decisions consistently show respect for the environment and for future generations (Robinson & Crowther, 2001).

Environmental science literacy is a determining factor in people's decisions and actions, since it defines how they relate to their surroundings. Thus the environment is a fundamental component of scientific literacy (Bybee, 2008; Robinson & Crowther, 2001).

In short, the need for environmentally literate citizens is evident in light of the scientific consensus that identifies human beings as primarily responsible for altering the ecosystem that sustains life on Earth (Covitt, Junckel, & Anderson, 2009).

Despite the importance of environmental science literacy, there have been few studies that evaluate and analyze it. The PISA 2006 measurement provides a good approximation of environmental science literacy among 15-year-old students, due to the emphasis PISA has placed on this issue (Bybee, 2008, OECD, 2008). In fact, the study *Green at fifteen?* (OECD, 2009a), derived from the PISA 2006, analyzes the performance of students from countries that participated in the environmental aspect of the measurement. It reveals that the majority of 15-year-old students in OECD countries perform above the average environmental score, while in Latin American countries they generally perform below this parameter. Of all the countries participating in the PISA 2006, Chile ranks 41 out of 57 countries in terms of environmental performance.

While Chilean students achieved the highest average score among Latin American countries (OECD, 2009a), analysis of the performance levels in the *Green at fifteen* study shows that 31% of Chilean students are at level D (minimum). Level D is defined as the basic level of competence, in which students begin to demonstrate an understanding of the environment that allows them to effectively and productively participate in daily life situations related to environmental science. More specifically, students who reach level D are able to answer a question on the environment where the necessary information to answer is given, but they cannot answer questions, for example, that require an understanding of the interrelationships of an ecosystem, as their knowledge does not enable them to solve a new problem. More troubling is the fact that 26% of students performed below the minimum level, meaning that they do not have the environmental science skills necessary to complete PISA's simplest tasks. At this level students are not able to interpret a chart or demonstrate a basic knowledge of the environment. At the other extreme, students who achieve level A (maximum) can solve more complex problems by employing an extensive knowledge of environmental science and are able to understand, explain, and interpret complex environmental processes such as acid rain, population dynamics, and the evolution of species. Unfortunately, only 9% of Chilean students are at this level.

These facts indicate a clear need to more specifically analyze environmental science literacy in Chilean students by identifying the variables in the Chilean reality that explain the differences between the groups with the most developed scientific literacy and the groups who are far behind. Therefore, the aim of this study is to explain the observed variability in the environmental science literacy of 15-year-old Chilean students based on variables specific to the student and his or her family and on school-specific variables. To date, there are no studies in Chile that have analyzed the environmental science literacy of Chilean students, let alone studies that use a multilevel analysis methodology to explain their environmental performance.

Environmental science literacy

The concept of environmental literacy arose in the context of the International Year of Environmental Literacy as a basic functional education that provides all people with the basic knowledge and the skills and motivations to address environmental needs and contribute to sustainable development (UNESCO, 1989). This constitutes the first approach to the concept.

Years later, other authors (Coyle, 2005; Marcinkowski, & Rehrig, 1995; Moody & Hartel, 2007; Roth, 1992) built upon the concept. In particular, Coyle establishes three ascending categories of environmental awareness, where the third is called *environmental literacy*. Coyle defines environmental literacy as an understanding of basic scientific principles and the skills necessary to research the environment, plus knowing how to use these principles and skills in both science and in everyday life and environmental policies. This definition has become a benchmark for subsequent authors (Anderson et al., 2006; Covitt et al., 2009; OECD, 2009a), who build on this concept to create a definition of environmental science literacy.

With this foundation, the study *Green at fifteen?* (OECD, 2009a) arrives at this definition of environmental science literacy: scientific knowledge and the use of this knowledge to identify issues, acquire new knowledge, explain scientific phenomena related to the environment, and draw conclusions based on environmental evidence; an understanding of the characteristics of environmental science as a form of human knowledge and research; an awareness of how environmental science shapes the use of Earth's resources, environmental sustainability policies, and the future responsibility for the quality of environment; and a willingness to engage in environmental science and its ideas as a reflective citizen and responsible consumer of natural resources.

Given its importance, environmental science literacy is a major goal of science education in schools (Navarro, 2012; OECD, 2009a).

PISA 2006 and the environment

The PISA 2006 paid special attention to the environment, since PISA considers this a core issue to be incorporated into all educational programs, in order to foster the development of citizens who are capable of making personal and social decisions about future environmental challenges based on scientific evidence.

Indeed, environmental issues are present in the PISA 2006 in the various aspects of its science assessment framework: a) knowledge (energy conservation, biodiversity, sustainability, global climate, etc.); b) areas of application (environment and natural resources); c) evaluation contexts (personal, social, and global); and d) attitudes toward environmental stewardship (responsibility, awareness, and willingness to act to maintain a sustainable environment). In addition to these four elements, PISA explores school curriculum coverage of environmental issues via information provided by principals.

Therefore, the PISA 2006 is an opportunity to evaluate environmental science literacy, since it provides information about personal, family, and institutional factors that may account for the differences between individual performances in Chile.

Variables related to performance in the sciences and the environment

In general, academic performance can be considered the result of different variables that influence the student learning process. According to Redondo and Navarro (2007), these variables may be related to characteristics of the school and its surroundings, characteristics of the classroom, the teachers, and the student's peers, socioeconomic and cultural aspects, and characteristics specific to the student and his or her family context.

Variables specific to the student and his or her family context

Within these variables, a student's socioeconomic status has been defined as the main factor explaining differences in learning. It exerts a powerful influence on performance (Ho, 2010; Hogrebe & Tate, 2010; Navarro & Förster, 2012; OECD, 2008). International evidence provided by transnational measurements such as the PISA and TIMSS and Chilean measurements like the SIMCE[1] and PSU[2] confirm this trend. Also, in the study *Green at fifteen?* (OECD, 2009a), an analysis of environmental performance based on socioeconomic and cultural status shows a positive association with environmental science literacy. This is consistent with the results of Pe'er, Goldman, and Yavetz (2007) and Negev, Sagy, Garb, Salzberg, and Tal (2008). Schools in Chile group children with homogeneous socioeconomic conditions and, in this context, Trevino, Donoso, and Bonhome (2009) establish that the association between science learning outcomes and socioeconomic status is clearer at the school level (*peer effect*) than at the individual level. However, there are no studies that explore the relationship between the peer effect and environmental science literacy.

Student sex is another factor that is linked to performance in science, and inequity in science education that is unfavorable to women is an international problem (Buccheri, Gurber, & Bruhwiler, 2011). The TIMSS, for example, shows that boys score higher than girls, and in order of magnitude, Chile has the second highest difference in this regard (IEA, 2004). On the PISA science test, on the other hand, there is not a clear international trend for this issue. Nonetheless in Chile boys score 22 points higher than girls on average, a statistically significant difference ($p < 0.05$) (MINEDUC, 2007). The national measurement SIMCE also reveals sex differences in scientific performance favorable to males (SIMCE, 2010). In terms of sex differences for environmental performance, boys have a higher performance in most countries, but the most significant gap is found in Chile (OECD, 2009a).

Reading is another variable proven to have a strong association with scientific knowledge performance (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; O'Reilly & McNamara, 2007; Uribe, 2009). Indeed, Smith, Holliday, and Austin (2009) note that university students, despite an intensive use of science books, are unable to understand informational texts. Their teachers share this perspective (Norris et al. 2008). Based on this evidence it can be surmised that low reading skills make it difficult to understand the language used in the test items, which affects performance in science (Maerten-Rivera, Myers, Lee, & Penfield, 2010). Therefore improving reading comprehension skills for science texts could improve long-term scientific performance (Cromley et al., 2010) and even compensate for some knowledge deficits (O'Reilly & McNamara, 2007). Other authors (Guzzetti & Bang, 2011; Norris et al., 2008) advocate

[1] The Chilean Quality of Education Measurement System (SIMCE - Sistema de Medición de la Calidad de la Educación de Chile) is a set of tests given across Chile in grades 4, 8, and 10 in the areas of math, language arts, and science.

[2] Chile's University Selection Test (PSU - Prueba de Selección Universitaria de Chile) is a test given at the end of secondary education as a requirement for admission to the universities belonging to the Council of Rectors.

the integration of science and reading because the latter is so central to scientific work. In fact, scientists spend about two thirds of their time reading, and it is the first resource for stimulating scientific creativity. In regards to teaching science, proposals that promote the teaching of reading in science classes exist; however, science teachers see reading as a tool and not as a core element in their discipline (Norris et al., 2008).

School variables

One school-specific variable that may have an impact on student performance is teacher quality. This factor may even be able to account for 30% of the variance in outcomes (Hattie, 2003). A study in Chile shows that the students of favorably evaluated teachers score higher on the SIMCE (Bravo, Falck, González, Manzi, & Peirano, 2008). For science education specifically, Trevino et al. (2009) state that good teaching practices help students progress from a common sense understanding of phenomena to understanding the scientific explanations thereof. Taking this into account, the availability of good science teachers is crucial for learning outcomes.

Furthermore, the characteristics of the students in a class can exert an influence on learning, through group work, for example, or by influencing teacher motivation (Hanushek, Kain, Markman, & Rivkin, 2003; Valenzuela, Bellei, Sevilla, & Osses, 2009). This promising concept indicates that a student's cultural capital depends not only on the initial socioeconomic conditions that the child brings from his or her home, but also on the influence exerted by his or her classmates or school (Vanderbergue, 2002). This phenomenon is known as the *peer effect*. According to Hattie (2003), the peer effect can account for 5% to 10% of the variance in learning achievement. Similarly, student selection is another school-specific factor considered to be a determining factor in learning outcomes (Hanushek, Kain, Markman, & Rivkin, 2003; Treviño, Donoso, & Bonhome, 2009).

Methodology

Sample design

The study is a secondary analysis of PISA 2006 data,[3] using the study *Green at fifteen?* as a reference framework (OECD, 2009a). The population of the PISA 2006 for Chile consists of 15-year-old Chilean students enrolled in educational institutions throughout the country, with different administrative formats and educational methods.

The sampling is stratified and random, with probability proportional to school size, and a two-stage design. The first stage is the selection of a random sample of schools with 15-year-old students and the second stage is the random selection of approximately 35 students from the previously selected schools. The Chilean sample is composed of 173 schools and 5233 students, and is representative of the 15-year-old school population in Chile (OECD, 2009a).

This study used 4970 students distributed among 144 schools. This reduction is due to the subtraction of cases where it was not possible to calculate an environmental score. The socioeconomic and cultural status (M = -0.7; SD = 1.18) is lower than that of the OECD (M = 0; SD = 1). The sample is 46% female and 54% male, approximately. As for levels of education, 2% of students are in the 7th to 8th year of primary education, 92% in the 1st to 2nd year of secondary education, 3% in the 3rd to 4th year of scientific-humanistic secondary education, and 3% in the 3rd to 4th year of technical-professional secondary education.

Of the schools, 48% are public institutions (municipal schools) and 52% private institutions (subsidized private and paid private). It was not possible to establish the separation between municipal and subsidized private schools due to a high percentage of missing data in this category.

[3] Data from 2006 was used because this particular measurement focused on scientific skills, and thus provided a number of items related to environmental science skills.

Variables

To determine environmental science literacy in Chilean students, the environmental index used is that created in the *Green at fifteen?* study (OECD, 2009a). This index is based on the Rasch model (IRT) and uses 24 PISA 2006 items related to environmental issues. For the first analysis, the index was used as is, and for the second studentized residuals of the index were used, controlling for reading (which in turn is controlled for ESCS).

The explanatory variables were selected after a correlational analysis, taking into account the magnitude of the intercorrelations between the independent variables to control for collinearity between them, as well as their correlation with the dependent variable and overall science or environmental learning performance. Thus the explanatory variables were grouped into two sets: a) student variables: reading score, sex, ESCS;[4] and b) school variables: peer effect, academic selectivity, type of school (public or private), school activities that promote learning of environmental issues, shortage of qualified science teachers in the educational establishment.

In general the indices constructed by the PISA 2006 were chosen over single indicators, because they are more reliable and combine information (OECD, 2008). Missing data were imputed by the mean. For data imputation in student-level variables, school-level information was used, and when the school data was missing, country-level data was used. Furthermore, categorical variables were recoded into dummy variables.

The variables, their descriptive statistics, and their recoding into dummy variables for categorical variables are presented in Table 1.

Table 1
Variables in the analysis with descriptive statistics

Variable	Codification	Mean	D. T.	Min.	Max.
Student level					
Reading	Continuous v.	446.26	93.72	97.82	728.26
Sex (ref.: male)	1 = Yes; 0 = No	0.46	0.50	0.00	1.00
ESCS	Continuous v.	- 0.68	1.18	- 4.50	2.50
School level					
Peer effect	Continuous v.	- 0.68	0.88	- 2.36	1.58
School activities to promote learning of environmental issues	Continuous v.	- 0.16	9.87	- 22.70	13.90
Type of school (ref.: private)	1 = Yes; 0 = No	0.42	0.49	0.00	1.00
Shortage of qualified science teachers (ref.: little)	1 = Yes; 0 = No	0.09	0.29	0.00	1.00
Academic selectivity (ref.: low)	1 = Yes; 0 = No	0.21	0.41	0.00	1.00

[4] The ESCS, or 'Economic, Social and Cultural Status,' is created using the socioeconomic index of the occupational status of the father and mother (the highest), the educational level of the parents (the highest), and the level of resources in the home. The scores are derived from a principal component analysis, where items are grouped into a single factor, with 60% of variance percentage explained for Chile. Scores are standardized, with an average of 0 and a standard deviation of 1.

Data analysis procedure

In order to analyze the behavior of the different variables in the Chilean sample and evaluate a potential collinearity, before conducting the hierarchical analyses a Pearson correlation analysis was performed, first between potential explanatory variables, and then with the environmental score.

Then two hierarchical models were done. Hierarchical analysis is an extension of linear regression, but takes into account the hierarchical structure of the data, enabling an exploration of the variability in the environmental learning achievements of students using different level variables. Thus it is possible to differentiate between the variability in learning attributable to student characteristics and the variability explained by school factors (Raudenbush & Bryk, 2002; Snijders & Bosker 1999), which is essential for the Chilean education system, where students who attend the same school have very similar social and cultural conditions (Consejo Asesor Presidencial, 2006; OECD, 2004).

This analysis was performed using the indications in the *PISA 2006 Technical Report* (OECD, 2009b).

First, the weights were normalized by the variable W_FSTUWT, which weighs each student in the sample according to the sample's stratification. Moreover, all the variables were centered on their mean; thus the intercept is interpreted as the environmental score achieved by a student who has the national mean on all variables included in the model.

Two two-level hierarchical linear models were estimated, using as dependent variables the environmental index (model 1) and the residuals of the environmental index after controlling for reading comprehension[5] (model 2). For both models there were three steps. The first consisted of the variance decomposition through the null or unconditional model (no predictors), calculating the intraclass correlation coefficient[6] (ICC). The second step was to create two sub-models: a) with variables at the level of the student and his or her context and b) with school-level variables. For each sub-model, the variables were entered individually so as to evaluate each variable's contribution to the model using the Akaike information criterion (AIC[7]), choosing models with the lowest AIC. The third and last step was creating the final model, using only those variables that were statistically significant in the previous sub-models ($p < 0.05$).

For all the models the slopes are considered fixed and the intercepts random, primarily because there is no slope variation hypothesis. Therefore, the most parsimonious model is used.

Results

The correlation analysis allowed for an evaluation of the magnitude of the relationship between the environmental index and the potential explanatory variables. The most significant correlations in order of magnitude include: peer effect ($r = 0.38$; $p < .01$); ESCS ($r = 0.32$; $p < .01$); sex (1 = female; 0 = male) ($r = -0.17$; $p < .01$); public school ($r = - 0.17$; $p < 0.01$). For its part, reading shows a significant correlation with the environmental index ($r = 0.57$; $p < 0.01$) and a partial correlation, controlling for ESCS, of a similar order of magnitude ($r = 0.50$; $p < 0.01$). This indicates that there is a common factor between reading and environmental performance that goes beyond the ESCS. Similarly, the correlation between the environmental index and the PISA 2006 science score, which measures scientific literacy, was analyzed, and a close relationship was found ($r = 0.68$; $p < 0.01$), indicating that the environment is a component of scientific literacy.

---

5 For the second model, the dependent variable corresponds to the studentized residuals of the environmental score after controlling for the reading score. The reading variable, in turn, corresponds to the residuals of the reading score after controlling for ESCS. This way both the effect of reading and the ESCS is subtracted from the dependent variable of model 2.

6 $$\rho = \frac{\sigma^2_{between-school}}{\sigma^2_{between-school} + \sigma^2_{within-school}}$$

The intraclass correlation coefficient (ρ) is the proportion of the total variance that corresponds to the between-school variance.

7 The AIC (Akaike information criterion) is a global fit statistic that indicates to what extent the proposed model is able to represent the variability. The smaller the AIC value, the better the fit (Pardo, Ruíz, & San Martín, 2007).

Hierarchical model 1

Step 1: null model. The null (or unconditional) model allows for decomposition of the variance of the environmental index in the between-school variance and the within-school variance. Based on these two variance components, the ICC was estimated, and turned out to be 0.18 for the environmental index. In other words, 18% of the variability in the environmental index scores (dependent variable 1) corresponds to between-school variability and 82% to within-school variability. The intercept of the null model proved equal to 460.08 points in the environmental score ($SD = 3.71$; $p < 0.001$).

Step 2: model with variables specific to the student and his or her context and the environmental index as the dependent variable. Three models were examined as an alternative to the null model, in which the student level predictors were incorporated step by step and whose contribution was assessed by AIC. The third model showed that the statistically significant variables were reading, sex ($p < 0.001$), and the ESCS ($p < 0.05$). These variables accounted for 93% of the between-school variability and 21% of the within-school variability.

The key variable explaining the differences in environmental performance was reading proficiency, which alone accounts for 89% of the between-school variability (16% of the total variance) and 19% of the within-school variability (16% of the total variance). Next, both sex (second place) and the ESCS (third place) were statistically significant; however, their contribution to the model accounts for a much smaller portion of the variability. It is worth noting that the *sex* variable (1 = female, 0 = male) showed a negative regression coefficient, which reveals a lower environmental performance in women than in men.

Model with school-specific variables and the environmental index as the dependent variable. Two models were created as alternatives to the null model, and in the second model statistically significant variables were the *peer effect* ($p < 0.001$) and *selectivity* ($p = 0.001$), which together explain 78% of the variability between schools (14% of the total variability). The peer effect proved to be the predictor with the most weight (13% of total variability) and selectivity had a much smaller contribution (< 1%). These two predictors failed to account for the within-school variability. Other school variables (school activities to promote learning of environmental issues, type of school, and shortage of qualified science teachers) did not have a statistically significant contribution in the models ($p > 0.05$).

Step 3: final model. The final model was obtained from the integration of the variables that were statistically significant in Step 2, with the student and student context variables and the school variables. The ESCS was no longer statistically significant, and neither was the *selectivity* variable ($p > 0.05$). By contrast, reading, sex, and the peer effect continued to be predictor variables, contributing to the explanatory model ($p < 0.001$) (Table 2).

Table 2
Hierarchical model 1

Model	Null	1	2	3	4
Intercept	460.08 (3.71)	459.59 (1.61)	459.59 (1.50)	459.53 (1.43)	459.49 (1.39)
Reading		0.54 (0.01)	0.56 (0.01)	0.54 (0.01)	0.53 (0.01)
Sex (Ref: male)			- 27.15 (2.13)	- 26.42 (2.13)	- 26.69 (2.11)
Economic, social and cultural status				3.62 (1.09)	--
Peer effect					8.06 (1.79)
Within-school variance	7759.49	6290.97	6118.49	6086.96	6012.87
Between-school variance	1681.88	179.24	139.63	121.22	99.45
ICC	0.18	0.03	0.02	0.02	0.02
AIC	61972.04	60678.20	60520.60	60487.50	60503.74
% Within-school variance	0.00	0.19	0.21	0.22	0.23
Change		0.19	0.02	0.00	0.01
% Absolute		15.55	1.83	0.33	0.78
% Between-school variance	0.00	0.89	0.92	0.93	0.94
Change		0.89	0.02	0.01	0.01
% Absolute		15.92	0.42	0.19	0.23

$N = 4970$

Figure 1 illustrates the final model 1, which accounts for the variability of the environmental index (dependent variable 1). This model explained 94% of between-school variability (17% of the total variance) and 21% of within-school variability (17% of the total variance). Meanwhile 66% of the variance remained unexplained, which breaks down to 1% of between-school variability and 65% of within-school variability. The complete model was able to explain 34% of the total variability.

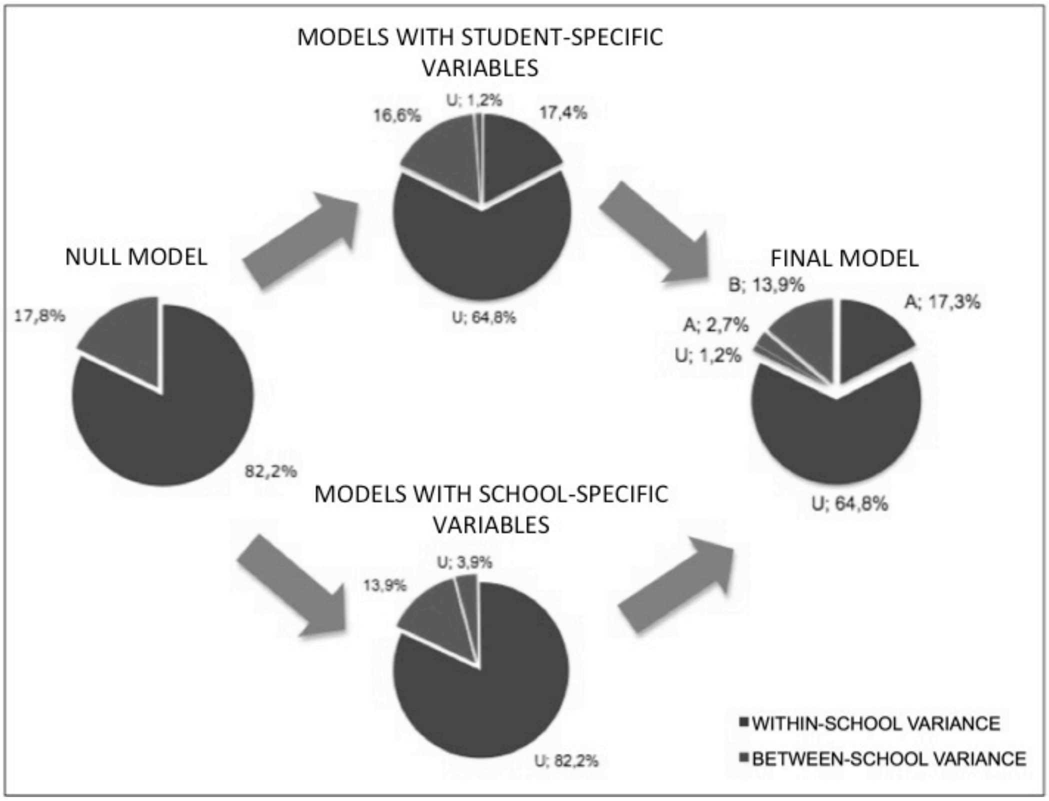

Figure 1. Final model 1: explained variance of environmental index. A, B, C, and U represent: A: variance explained solely by the variables of the student and his or her context (reading and sex); B: variance explained jointly by the student variables and the school variables; C: variance explained solely by the school variables (peer effect); U: unexplained variance.

Hierarchical model 2

Step 1: null model. For dependent variable 2 (residuals of the environmental score, controlled for reading), the ICC was 0.08; in other words, 8% of the variability corresponded to between-school variance and 92% to within-school variance. For this case, the intercept was 0.03 points ($SD = 0.03$, $p = 0.337$), and was not statistically significant. It was observed that when comparing the ICC of hierarchical models 1 and 2 (0.18 and 0.08, respectively), schools were more uniform when the environmental index was controlled for reading.

Step 2. Model with variables specific to the student and his or her context and the environmental index controlled for reading proficiency as the dependent variable. In parallel, two models were developed as alternatives to the null model, where the contribution of the variables incorporated one by one was evaluated by AIC. In the second model the variables that proved statistically significant ($p < 0.001$) were sex and the ESCS. These variables explain 85% of between-school variability and 7% of within-school variability, or 6% and 7% of the total variance, respectively.

Unlike previously (dependent variable 1), the ESCS variable was the most explanatory.

Model with school-specific variables and the environmental index controlled for reading proficiency as the dependent variable. Only one alternative model to the null model proved statistically significant. In this model the peer effect variable ($p < 0.001$) was entered and accounted for 85% of the between-school variability (7% of the total variability). As in the previous case (dependent variable 1), this school level variable cannot explain the variability within the school.

Also, variables that were not statistically significant ($p > 0.05$) were: type of school, school activities to promote learning of environmental issues, and shortage of qualified science teachers.

Step 3: final model. Figure 2 illustrates the situation for dependent variable 2 (environmental index controlled for reading). This final model 2 kept the same variables that were statistically significant in the models with student/student context variables and school variables: ESCS, sex, and peer effect ($p < 0.001$).

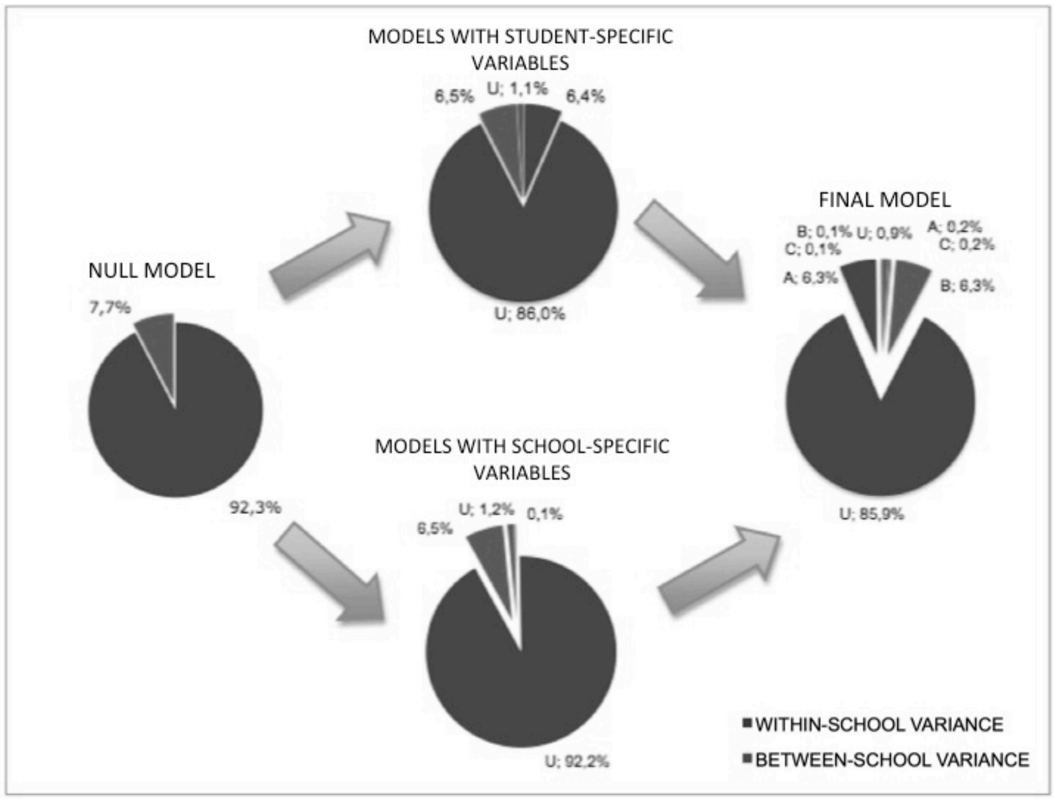

Figure 2. Final model 2: explained variance of environmental index controlled for reading. A, B, C, and U represent: A: variance explained solely by variables of the student and his or her context (reading and sex); B: variance explained jointly by the variables of the student and his or her context and school variables; C: variance explained solely by school variables (peer effect); U: unexplained variance.

The final model 2 was able to account for 88% of between-school variance and 7% of within-school variance. That leaves 87% of the variance unexplained, which breaks down to 1% between-school variability and 86% within-school variability. The complete model accounted for 13% of the total variability (Table 3).

Table 3
Hierarchical model 2

Model	Null	1	2	3
INTERCEPT	0.03 (0.03)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
Economic, social and cultural status		0.31 (0.01)	0.30 (0.01)	0.26 (0.02)
Sex (ref.: male)			-0.34 (0.03)	-0.34 (0.03)
Peer effect				0.09 (0.03)
Within-school variance	1.24	1.18	1.15	1.15
Between-school variance	0.10	0.02	0.02	0.01
ICC	0.08	0.02	0.01	0.01
AIC	16249.47	15879.75	15744.73	15735.62
% Within-school variance	0.00	0.05	0.07	0.07
Change		0.05	0.02	0.00
% Absolute		4.20	2.15	0.06
% Between-school variance	0.00	0.82	0.85	0.88
Change		0.82	0.03	0.02
% Absolute		6.29	0.24	0.18

$N = 4970$

To sum it up, reading proficiency is the variable with the greatest explanatory power in environmental science literacy, and the ESCS in this case does not have a significant weight (model 1). In the second model, where the environmental index was controlled for reading comprehension, the ESCS emerges as a differentiating variable in environmental science literacy. A variable that appears in both models is student sex, with less favorable scores for women, as mentioned above. With respect to the differences between students, in both models the peer effect is statistically significant. The final models can be represented mathematically as shown in Table 4.

Table 4
Regression equations for final models 1 and 2

	Equation
Final model 1	$Y_{ij} = \beta_{0j} + \beta_{1j}(Reading) - \beta_{2j}(Sex) + \beta_{3j}(Peer - effect) + \varepsilon_{ij}$ $\beta_{0j} = \gamma_{00} + U_{0j}$
Final model 2	$Y'_{ij} = \beta_{0j} + \beta_{1j}(ISEC) - \beta_{2j}(Sex) + \beta_{3j}(Peer - effect) + \varepsilon_{ij}$ $\beta_{0j} = \gamma_{00} + U_{0j}$
Symbols	Y_{ij}: environmental score of student *i* in school *j* Y'_{ij}: environmental score (controlled for reading) of student *i* in school *j* β_{0j}: intercept of school *j* γ_{00}: general intercept ε_{ij}: student residual or idiosyncratic error U_{0j}: school residual or school effect

Discussion and conclusion

The analysis shows that the predictors of environmental performance are reading, sex, the ESCS, and the peer effect. Of these, reading is the most explanatory factor of differences in environmental skills.

Reading as a differentiating factor between schools in terms of environmental performance becomes more meaningful when looking at the science items in the PISA. The questions in this test are inserted into a context—a table, a figure, a graph, a text—which requires reading fluency to successfully comprehend, as was recognized by science teachers who analyzed PISA items (Pinto & El Boudamoussi, 2009). In this context, Maerten-Rivera et al. (2010) suggest that low-level readers have difficulty understanding the language used in the test questions and that reading ability can affect science performance.

While no specific research was found specifically linking reading with environmental performance, there are studies that connect reading abilities to greater science achievements, with a focus on scientific literacy (Maerten-Rivera et al., 2010; O'Reilly & McNamara, 2007; Uribe, 2009; Webb, 2010). The work of Uribe (2009), which is based on the PISA 2000 measurement, identified reading as the main predictor variable of scientific literacy among Chilean students, with an explanatory power of 26% of the total variance, a result consistent with the observations of the present study. The association of reading with scientific proficiency has been demonstrated in quasi-experimental studies (Fang & Wei, 2010; Greenleaf et al., 2009). In particular, O'Reilly and McNamara (2007), state that reading proficiency is a significant predictor of science performance and helps to offset certain deficits in scientific knowledge or even socioeconomic status (Greenleaf et al., 2009).

In order to incorporate reading in science teaching, the need to include other domains of knowledge (reading) that lay beyond factual knowledge or scientific laws must be recognized. While students do have science texts that could build their reading skills, these texts are expository in nature and present facts with minimal evidence to support the conclusions (Yarden, 2009). Fortunately, science teachers are beginning to recognize the importance of this interdisciplinary perspective (Pinto & El Boudamoussi, 2009) and are showing themselves open to incorporating reading into their teaching. One way to integrate these two areas is through reading print media or electronic texts related to environmental challenges, or by using the students' own textbooks, but through the investigative, analytical, interpretive, and critical reading that is characteristic of literacy (Guzzetti & Bang, 2011; Norris et al., 2008). In short, if environmental science literacy is a goal of science education, it is necessary to integrate reading in science class (Norris et al., 2008). This aspect can be incorporated at an early age, through, for example, work with texts on scientific findings (Ho, 2010).

Meanwhile, the economic, social and cultural status expressed in the ESCS index accounts for a much smaller portion of the differences between schools. This result is somewhat different from that seen in most school performance studies, in which socioeconomic status is found to be the most discriminating factor between schools (OECD, 2008; Treviño et al., 2009). In fact, the peer effect, which measures the socioeconomic and cultural conditions of students' families, has a greater effect on environmental performance than individual socioeconomic status does, which is consistent with the findings of other studies (Treviño et al., 2009; Vanderbergue, 2002). Indeed, in analyzing the peer effect variable, the economic, social and cultural status of the student ceases to be statistically significant. Thus it can be said that the greater the *peer effect*, the greater the benefit in terms of environmental science literacy. Hanushek, Kain, Markman, and Rivkin (2003) have pointed this out in primary school studies, and Vanderbergue (2002) has done so for mathematics and science learning outcomes. Having more heterogeneous groups in terms of economic, social and cultural status would benefit the lower-level students, and also the higher-level students, since the formation of diverse groups fosters collaborative learning, integration, and equity in learning opportunities (Manzi, 2007).

With respect to gender influence, this analysis shows that women score 27 points less than men, which clearly shows the outstanding debt of science education in Chile regarding gender equality. However, this is not just a local problem. Inequity in science education based on the sex of the student is a cross-cutting issue of science teaching globally (Buccheri et al., 2011). However, if the most important predictor of environmental learning outcomes is reading, and women have a better performance in this domain than men, considering reading as an integral part of science teaching could help advance environmental science literacy, and could not only compensate for inequities in socioeconomic status, as suggested by Greenleaf et al. (2009), but also gender inequities.

Four variables were not used in the models, as two of them were not statistically significant: type of school (public) and school activities to promote environmental learning, which could have showed collinearity with the economic, social and cultural status index of (r = - 0,47; p < 0.001 and r = 0.31; p < 0.001, respectively). Specifically, the fact that the type of school variable was not statistically significant may have a second explanation: the dichotomization of *public* and *private* schools, in which the latter includes privately managed state-subsidized institutions, helps bring the results of public institutions and private institutions closer together. The other two variables, *academic selectivity* and *shortage of qualified science teachers* may not have made the cut for not presenting a high variability; in both variables one of the categories groups 41% and 44% of cases, respectively.

In short, the factors explaining environmental science literacy are reading, sex, economic, social and cultural status, and the peer effect. Among these, reading is the most promising, since it can be developed in school and is a significant focus of student learning. As stated by Webb (2010), promoting reading while "doing science" plays a vital role in the effectiveness of teaching and learning. Knowing how to read and understand specific discourses on environmental science promotes increased participation in public debate and its relationship with society and the environment, key aspects of scientific literacy.

The original article was received on March 28th, 2013
The revised article was received on June 18th, 2013
The article was accepted on July 8th, 2013

References

Anderson, C., Mohan, L., Jin, H., Chen, J., Piety, P., Chen, H., Draney, K., Choi, J., & Lee, Y. (2006). *Learning progressions toward environmental literacy: carbon cycling*. Paper presented at The National Association for Research in Science Teaching, San Francisco, CA.

Bravo, D., Falck, D., González, R., Manzi, J., & Peirano, C. (2008). *La relación entre la evaluación docente y el rendimiento de los alumnos: evidencia para el caso de Chile. Centro de Microdatos de la Universidad de Chile*. Retrieved on August 3, 2011 from http://www.microdatos.cl/docto_publicaciones/Evaluacion%20docentes_rendimiento%20escolar.pdf

Buccheri, G., Gurber, N., & Bruhwiler, C. (2011). The impact of gender on interest in science topics and the choice of scientific and technical vocations. *International Journal of Science Education, 33*(1), 159-178.

Bybee, R. (2008). Scientific literacy, environmental issues, and PISA 2006: The Paul F-Brandwein lecture. *Journal of Science Education and Technology*, *17*, 566-585.

Cepal/OECD (2005). *Evaluaciones del desempeño ambiental*. Chile: Cepal/OECD.

Consejo Asesor Presidencial para la Calidad de la Educación (2006). *Informe final*. Santiago, Chile.

Covitt, B., Junckel, K., & Anderson, C. (2009). Students' developing understanding of water in environmental systems. *The Journal of Environmental Education*, *40*(3), 37-51.

Coyle, K. (2005). *Environmental literacy in America: What ten years of NEETF/Roper research and related studies say about environmental literacy in the U. S. The National Environmental Education & Training Foundation*. Washington, D.C.: The National Environmental Education & Training Foundation.

Cromley, J., Snyder-Hogan, L., & Luciw-Dubas U. (2010). Reading comprehension of scientific text: A domain-specific test of the direct and inferential mediation model of reading comprehension. *Journal of Educational Psychology, 102*(3), 687-700.

Fang, Z., & Wei, Y. (2010). Improving middle school students' science literacy through reading infusion. *Journal of Educational Research, 103*(4), 262-273.

Greenleaf, C., Hanson, T., Herman, J., Litman, C., Madden, S., Rosen, R., Boscardin, C., Schneider, S., & Silver, D. (2009). Integrating literacy and science instruction in high school biology: impact on teacher practice, student engagement, and student achievement. *American Educational Research Journal, 48*(3), 647-717.

Guzzetti, B., & Bang, E. (2011). The influence of literacy-based science instruction on adolescents' interest, participation, and achievement in science. *Literacy Research and Instruction, 50*(1), 44-67.

Hanushek, E., Kain, J., Markman, J., & Rivkin, S. (2003). Does peer ability affect student achievement? *Journal of Applied Econometrics, 18*, 527-544.

Hattie, J. (2003). *Teachers make a difference: What is the research evidence?* Keynote presentation at the Building Teacher Quality: The ACER Annual Conference, Melbourne, Australia.

Ho, E. (2010). Family influences on science learning among Hong Kong adolescents: What we learned from PISA. *International Journal of Science and Mathematics Education*, *8*(3), 409-428.

Hogrebe, M., & Tate, W. (2010). School composition and context factors that moderate and predict 10th grade science proficiency. *Teachers College Record, 112*(4), 1096-1136.

IEA (2004). *TIMSS 2003 International Science Report*. Boston College. USA: TIMSS & PIRLS International Study Center, Lynch School of Education.

Maerten-Rivera, J., Myers, N., Lee, O., & Penfield, R. (2010). Student and school predictors of high-stakes assessment in science. *Science Education, 94*(6), 937–962.

Manzi, J. (2007). Selección de estudiantes en el sistema escolar chileno: ¿la buena educación debe ser sólo para los mejores? In J. Brunner, & C. Peña (Eds.), *La reforma al sistema escolar: aportes para el debate* (pp. 203-216). Santiago, Chile: Universidad Diego Portales and Universidad Adolfo Ibáñez.

Marcinkowski, T., & Rehrig, L. (1995). The secondary school report: A final report on the development, pilot testing, validation, and field testing of the Secondary School Environmental Literacy Assessment Instrument. In R. Wilke (Ed.), *Environmental education literacy/needs assessment project: Assessing environmental literacy of students and environmental education needs of teachers: Final report for 1993–1995,* (pp. 30-76). Stevens Point: University of Wisconsin-Stevens Point.

Mineduc (2007). *PISA 2006: Rendimiento de estudiantes de 15 años en Ciencias, Lectura y Matemática. Unidad de Curriculum y Evaluación*. Santiago, Chile: Mineduc.

Moody, G., & Hartel, P. (2007). Evaluating an environmental literacy requirement chosen as a method to produce environmentally literate university students. *International Journal of Sustainability in Higher Education*, *8*(3), 355-370.

Navarro, M. (2012). *La alfabetización científica en medio ambiente en estudiantes chilenos: factores explicativos oportunidad de aprender.* (PhD thesis). Pontificia Universidad Católica, Santiago, Chile.

Navarro, M., & Förster, C. (2012). Nivel de alfabetización científica y actitudes hacia la ciencia en estudiantes de secundaria: comparaciones por sexo y nivel socioeconómico. *Pensamiento Educativo. Revista de Investigación Educacional Latinoamericana*, *49*(1), 1-17.

Negev, M., Sagy, G., Garb, Y., Salzberg, A., & Tal, A. (2008). Evaluating the environmental literacy of Israeli elementary and high school students. *The Journal of Environmental Education*, *39*(2), 3-20. doi: 10.3200/JOEE.39.2.3-20

Norris, S., Phillips, L., Smith, M., Guilbert, S., Stange, D., Baker, J., & Webwr, A. (2008). Learning to read scientific text: Do elementary school commercial reading programs help? *Science Education, 92*(5), 765-967.

OECD (2004). *Revisión de políticas nacionales de educación: Chile*. Paris: OECD Publishing.

OECD (2008). *Informe PISA 2006. Competencias científicas para el mundo del mañana*. Paris: OECD Publishing.

OECD (2009a). *Green at fifteen? How 15 year olds perform in environmental science and geoscience in PISA 2006*. Paris: OECD Publishing.

OECD (2009b). *PISA 2006 technical report*. Paris: OECD Publishing.

OECD (2011). *How's life? Measuring well-being*. Paris: OECD Publishing.

O'Reilly, T., & McNamara, D. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional "high-stakes" measures of high school students' science achievement. *American Educational Research Journal*, *44*(1), 161–196.

Pardo, A., Ruíz, M., & San Martín, R. (2007). Cómo ajustar e interpretar modelo multinivel con SPSS. *Psicothema*, *19*(2), 308-321.

Pe'er, S., Goldman, D., & Yavetz, B. (2007). Environmental literacy in teacher training: attitudes, knowledge, and environmental behavior of beginning students. *The Journal of Environmental Education*, *39*(1), 45-59.

Pinto, R., & El Boudamoussi, S. (2009). Scientific processes in PISA tests observed for science teachers. *International Journal of Science Education, 31*(16), 2137-2159.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. London: Sage.

Redondo, S., & Navarro, E. (2007). Estudio sobre el rendimiento en matemáticas en España a partir de los datos del informe PISA 2003. Un modelo jerárquico de dos niveles. *REICE Revista Electrónica Iberoamericana sobre Calidad, Eficacia y Cambio en Educación, 5*(3), 118-136.

Robinson, M., & Crowther, D. (2001). Environmental science literacy in science education, biology & chemistry majors. *The American Biology Teacher*, *63*(1), 9-14.

Roth, C. (1992*). Environmental literacy: Its roots, evolution and directions in the 1990s*. OH: ERIC Clearinghouse for Science, Matemathics and Environmental Education, Columbus.

Semarnat (2008). *Impacto humano en el medio ambiente*. México: Secretaría de Medio Ambiente y Recursos Naturales.

SIMCE (2010). *Resultados nacionales 2009*. Santiago, Chile: Unidad de Curriculum y Evaluación Ministerio de Educación.

Smith, B., Holliday, W., & Austin, H. (2009). Student's comprehension of science textbooks using a question-based reading strategy. *Journal of Research in Science Teaching, 47*(4), 363-379.

Snijders, T., & Bosker, R. (1999). *Multilevel analysis. An introduction to basic and advanced multilevel modeling* (1ª Ed.). London: SAGE Publications Ltd.

Treviño, E., Donoso, F., & Bonhome, M. (2009). ¿Cómo las escuelas chilenas pueden mejorar el aprendizaje en ciencias? In Mineduc (Ed.), ¿Qué nos dice *PISA sobre la educación de los jóvenes en Chile?* (pp. 71-103). Santiago, Chile: Unidad de Curriculum y Evaluación.

UNESCO (1989). Environmental literacy for all. *Connect*, *15*(2), 1-2.

Uribe, M. (2009). *Factores explicativos de los resultados de alfabetización científica en estudiantes de 15 años: estudio basado en la medición PISA 2000*. (PhD thesis). Pontificia Universidad Católica, Santiago, Chile.

Valenzuela, J., Bellei, C., Sevilla, A., & Osses, A. (2009). ¿Qué explica las diferencias de resultados PISA Matemática entre Chile y algunos países de la OCDE y América Latina? In Mineduc (Ed.), ¿Qué nos dice *PISA sobre la educación de los jóvenes en Chile?* (pp. 105-148). Santiago, Chile: Unidad de Curriculum y Evaluación.

Vanderbergue, V. (2002). Evaluating the magnitude and the stakes of peer effects analysing science and math achievement across OECD. *Applied Economics, 34*(10), 1283-1290.

Webb, P. (2010). Science education and literacy: Imperatives for the developed and developing world. *Science, 328*(5977), 448–450. doi: 10.1126/science.1182596

Yarden, A. (2009). Reading scientific texts: Adapting primary literature for promoting scientific literacy. *Research in Science Education, 39*(3), 307-311.