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Scientific literacy in biology and attitudes towards science in the Chilean education system

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ABSTRACT

Background: The development of scientific literacy in young people is seen as important in several countries. In recent decades, Chile's educational reforms aimed at performance have led to a market-oriented funding and management system, worsening social inequality and segregation.

Purpose: The study looked at biology literacy and science attitudes in Chilean secondary school students, considering two aims: 1) to analyse the level of scientific literacy in biology and attitudes toward science posed by secondary school students, making comparisons by gender, age, socio-economic status (SES), and type of school; and 2) to evaluate the relationship between scientific literacy in biology and attitudes towards science.

Sample: 612 secondary school students in a central southern region of Chile, took part in the study.

Design & Methods: A quantitative method was used to analyse the students' responses on two validated and adapted instruments; A test to measure biological knowledge (TOSLS) and Likert Scale Science-related (LSSr) to measure attitude towards science. These instruments were administered to secondary students, and descriptive and inferential analyses were conducted.

Results: The adapted TOSLS showed significant differences in SES, school type and slight variations by gender and age, although, no illiteracy level in biology was found among the Chilean students. The adapted LSSr showed significant differences concerning attitudes toward science were found in school type, and variations by SES and age, and gender. Also, the correlation analysis shows a weak positive relationship between scientific literacy in biology and attitudes towards science, although of moderate magnitude.

Conclusion: This study found that scientific literacy in biology does not necessarily impact attitudes towards science. However, SES and type of school can affect understanding and views of science and its role in society, which aligns with previous findings on social inequality in Chilean education.

KEYWORDS
Scientific literacy; attitudes toward science; students' outcomes; science education; Chilean secondary education

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1. Introduction

It is frequent to find papers highlighting the relevance of science disciplines as a crucial aspect to consider in society (Borquez 2014; Camus 2009; Harlen 2010; Millar 2008; Montes, Ferreira, and Rodríguez 2022; Navarro and Forster 2012). However, studies in science education also show high rates of conceptual errors among students, teachers and the general public regarding basic biological principles and science theories (e.g. Cofre et al. 2010; Gutierrez 2009; Kim and Nehm 2011), which it is evidenced by the low number of citizens who accept concepts related to this field and associate these as contentious.

Chile's education system has achieved impressive outcomes and comes close to meeting European standards (Mourshed, Chijioke, and Barber 2010). However, the country has shown a segregated education system, including state, voucher, and private schools, corresponding to different socio-economic classes. Despite offering opportunities to access state schools and participate as active citizens (Sectorial Mansfield and Reiss 2020; MINEDUC 2019), the education system is market-oriented (Bellei 2000; García-Huidobro and Bellei 2003). Several studies have measured scientific literacy, knowledge of science, and attitudes towards science in educational contexts (Bayer, Luberda, and Roca 2016; Cofre et al. 2013). For example, a study in Santiago, Chile, found that SES, scientific literacy, and attitudes towards science are positively correlated (Navarro and Forster 2012), showing that higher SES and scientific literacy levels were associated with better attitudes towards science, with SES affecting the emotional component of attitudes towards science.

Other studies showed that gender differences in career aspirations start appearing around 14, making it crucial to foster interest in science as a subject and career choice early on (Archer et al. 2012). A survey of over 11,000 girls and young women in Europe found that many lose interest in science by age 15 (Microsoft and Kesar 2018). Thus, refraining from including diversity in students' attitudes could result in a lack of motivation and negative attitudes towards science (Bravo González and Reiss 2021; Osborne, Simon, and Collins 2003). Through a quantitative design, this study focuses on scientific literacy in biology and attitudes towards science among secondary students in Chile, aiming to determine their understanding of scientific theories and the impact of non-academic factors. The goal is to gather data to understand better how students use biological concepts to explain the natural world and make informed decisions.

1.1. Theoretical framework

1.1.1. Chilean curriculum and science education

Since 1980, the educational system in Chile has had a massive structural curriculum reform established by the military coup (1973–1989). As part of the policies, the government decentralised state school administration, transferring the authority from the central government to the mayor of the towns, and modified the funding formula for state and private schools, creating a privatised educational system that has increased schools' autonomy and segregation during the last decades (Bellei 2009). Chile, accordingly, is one of the countries in Latin America with the highest private participation in the schooling system (Valenzuela, Bellei, and Ríos 2014), which created a highly segregated education system that includes state, voucher, and private schools, which corresponds roughly to low, middle, and upper socio-economic, which embodies a market-oriented education system (García-Huidobro and Bellei 2003).

Researchers in the field reported that the market-oriented reforms in Chilean education had a small or null impact on improving the quality (Bellei 2011; Drago and Paredes 2011). Indeed, these policies implemented have had a negative impact, for example, increasing the test score gap between low and high SES among students as well as grading student's performance and discipline, affecting states schools (Auguste & Valenzuela 2004; Contreras et al. 2010; Carrasco and San Martín 2012) primarily.

During the following years, the Ministry of Education (Mineduc) implemented changes in the curriculum through laws that sought to redefine the state's role. Notably, in 2019, the Chilean Curriculum and Assessment Sections approved a new version of the school science curriculum. Chile has stated that the focus of science education is the scientific literacy of students, which implies that they can participate in an informed way in the decisions and actions that affect their personal as well as society's well-being (MINEDUC 2019). It has also been declared that the learning objectives and the aims of science education in Chile must cover a vast amount of scientific knowledge; students should be shown science in an integrated way to take advantage of the limited time for learning. The ministerial document in science education declares that 'to contribute to scientific literacy, it is key to understand the concepts and core ideas in science which allow new knowledge to be built' (MINEDUC 2019, 30–31).

Although the market-oriented educational policies supported by the neoliberal model have significantly influenced Chilean education through economic reforms, which has grown the economy of Chilean society compared to countries in Latin America (Mundy 2005; Tuchman 2011) but causing concern, notably in the education sector because school segregation has sources beyond the educational system (Valenzuela, Bellei, and Ríos 2014), within this context, the concern for SES school segregation has recently started to emerge in Chile; nevertheless, this issue has barely been empirically studied (Elacqua 2009; Valenzuela et al. 2014). Figure 1 presents an overview of the Chilean education system's structure.

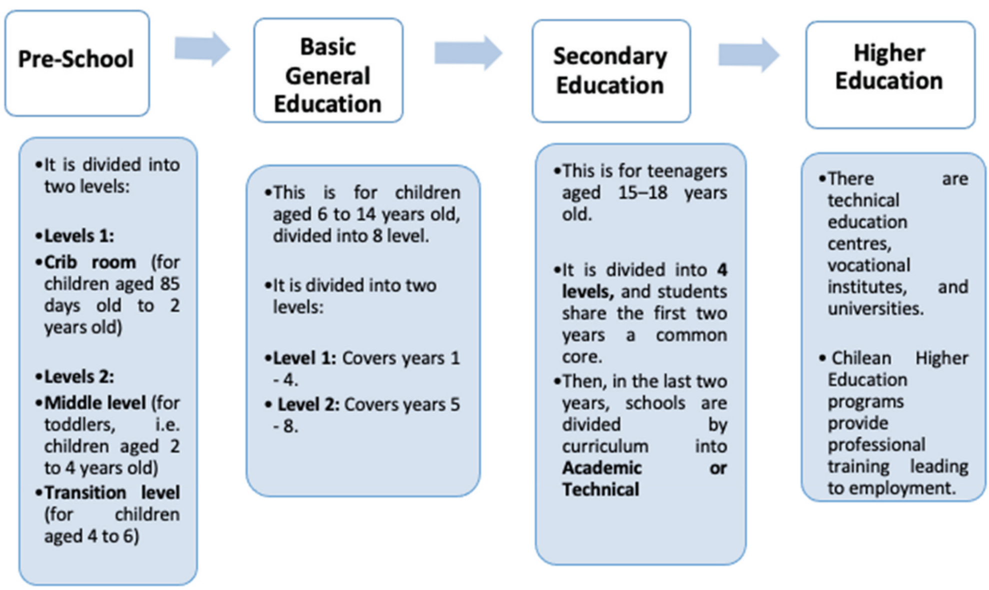

Figure 1. Chilean education structure and levels.

1.2. Scientific literacy

The notion of 'scientific literacy' has emerged as a common aim of school science curricula, but debates about the term's meaning persist (Roberts 2007); agreement among researchers in the field described its importance in developing responsible future decision-makers and encourages sustainability development (Lau, Ho, and Lam 2015; Mansfield and Reiss 2020; Reiss 2007) in societies, which shows that scientific literacy has been acknowledged as one of the central aims of science education since its inception, extending beyond its fundamental meaning (Guerrero and Torres-Olave 2021).

In Latin America, there is little evidence and research available on how the conceptualisations and visions are integrated into the curriculum. However, a few studies have provided a critical analysis of how a nation's economic and political systems are connected to the curricular visions and hypotheses in scientific literacy (Norambuena-Meléndez, Guerrero, and González-Weil 2023). Chile has included scientific literacy in its curriculum for over 20 years emphasising its importance in learning and explaining phenomena and everyday problems within science programs (MINEDUC 2019).

Aligning with the USA National Research Council (NRC), scientific literacy is viewed as the capacity to 'use evidence and data to evaluate the quality of science information and arguments set forth by investigators and in the media' (National Research Council/NRC/ 1996, 40). Also, the Programme for International Student Assessment (American Association for the Advancement of Science AAAS 1993) described scientific literacy as 'the ability to use scientific data to identify problems and to draw evidence-based outcomes in order to learn and improve decisions about the natural world and the changes made to it through human activity' (OECD 2003, p. 15). These two definitions are the framework for this investigation, working on the concept of scientific literacy evaluated in the national biology program for Chilean students in the last year of secondary education. Additionally, it is considered part of the framework for defining and classifying scientific literacy in biology as part of the subset of scientific literacy.

Uno and Bybee (1994) described that scientific literacy in biology is not a single endpoint that can be attained within one biology course but is a continuum over which a person's understanding develops throughout their life. The importance of understanding and developing scientific literacy, particularly in biology, and attitudes towards science are relevant aspects of society. Citizens who are able to make informed decisions make them not just for individual benefit but also in light of their role in the more significant global economic marketplace and impacting the development of nations (Alexander and Choi 2015; Mansfield and Reiss 2020). From this perspective, it can be seen from the literature that cultural and political integration is essential to have a democratic society; increasingly scientifically literate people could address more complex and demanding tasks (Mansfield and Reiss 2020; Reiss and White 2013).

1.3. Scientific literacy in biology

Biological knowledge has had an important place in society to understand life at every level, from molecular to global interactions (Duncan and Boerwinkel 2018; Reiss 2017). Studies in this area have shown that scientific literacy's role in biology establishes connections that affect personal and social spheres by combining structure and nature-based sources. For example, when people apply biological principles to their activities, they can better understand the surrounding world (Jenkins and Nelson 2005; Semilarski and Laius 2021). Consequently, scientific literacy in biology or biological literacy (Narguizian 2019; Uno and Bybee 1994) is a subset of scientific literacy, focusing mainly on biological context and striving to widen the horizons of biology education (Semilarski and Laius 2021), recognised; it mostly has the same characteristics but strictly refers to biological knowledge; however, defining the boundaries of biological knowledge is seen as challenging (Dorfner and Neuhaus 2020).

Uno and Bybee (1994) presented a model that applies to high schools and colleges and is compatible with Chilean science education. Miller et al. (2006) and the International Council for Science (ICSU, 2011) reported that understanding biological concepts and their implications in people's lives can lead to improved social, economic, political, and cultural spheres. Consequently, being biologically literate allows individuals to apply scientific knowledge in real-world contexts and make informed decisions based on analysis, reasoning, and critical thinking (Uno and Bybee 1994). Moreover, scientific literacy is essential for students studying multiple science disciplines. Developing scientific literacy in biology can be challenging but rewarding as it helps individuals comprehend daily issues and global societal problems. MINEDUC (2019) is trying to enhance Chile's science programs to equip students with the ability to understand and discuss the changes caused by human activities in the natural world.

1.4. Attitudes towards science

Oppenheim (1992) discussed the problem of definition and concluded that that attitude is 'normally a state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli, reinforced by beliefs (the cognitive component), often attract strong feelings (the emotional component) which may lead to particular behavioural intents (the action-tendency component)' (p. 175). One's knowledge shapes attitudes, emotional response to that knowledge, and how these factors impact one's probable actions, emphasising the importance of gathering information in all three aspects. Since attitude is a construct that cannot be directly observed, it must be inferred; data must be gathered from various sources (Bennett 2001).

Past studies have shown that the classroom and home environments impact attitudes toward science. For example, Simpson and Oliver (1990) observed a high correlation between student self, school, family, and attitude. Other studies showed that gender can affect the attitudes of pupils of different ages towards science, but the research findings on this topic are inconclusive. For instance, a study indicated that male pupils have a more positive attitude towards science than female pupils (Hanson, Westerlund, and Vaughan 2020), while other studies found no difference between the genders (Mhladza, Durana, and Doan 2011; Ogawa and Shimode 2004).

Also, research has shown that a student's attitude towards science plays a crucial role in their persistence in the subject, their course choices, and their ability in science (Caspi et al. 2020). Following this view, the purpose of this study is on the attitudes toward science based on some attitude inventories which have focused respectively on secondary school students' attitudes or perceptions toward subjects (Dalgety, Coll, and Jones 2003; Kitchen et al. 2007) due to lack of studies in Chile focused on attitudes towards science nor biology principles.

2. Materials and methods

2.1. Research questions

What is the relationship between students' levels of scientific literacy in biology and their attitudes towards science in secondary schools? The main aims of this paper are:

(1) To analyse the level of scientific literacy in biology and attitudes toward science posed by secondary school students, making comparisons by gender, socioeconomic status (SES), and type of institution
(2) To evaluate the relationship between scientific literacy in biology and attitudes toward science, specifically biology.

2.2. Recruitment and sampling

The study was conducted with Chilean secondary schoolers in a central southern region of Chile (Bio-Bio), where science was a primary subject. The sample selection was based on representative sociodemographic features of Chile's educational systems, meaning that the type of school is strongly linked with distinct socio-economic groups in neighbourhood schools.

In Chile, education is mandatory for students ages 6 to 18. The participants in this study were 612 (427 boys and 185 girls) secondary students in the eleventh-grade classes, which means the end of their formal and mandatory educational process in Chile. The group consisted of students between 16 and 20, with an average age of 17. However, there was a variation in ages within this sample, which could be linked to differing administrative policies among the types of schools that could show variations in age ranges, charging school fees and screening students.

The 16 urban schools took part from 21 possible schools were a mix of state (6), voucher (5, subsidised by the government and private companies) and private (5) schools. Consequently, the schools came from various socio-economic levels (upper, middle and working class). Additionally, private and voucher schools may add specifications to science programs compared to state schools, but all schools follow the same national curriculum. Students were randomly selected from secondary schools in this southern region. However, a criterion such as high scores on a national test (SIMCE: outcomes in secondary schools) in Language and Communication topics was used to control the incidence of reading comprehension on the results of both instruments. Figure 2 shows the attributes in detail of the students surveyed in the study.

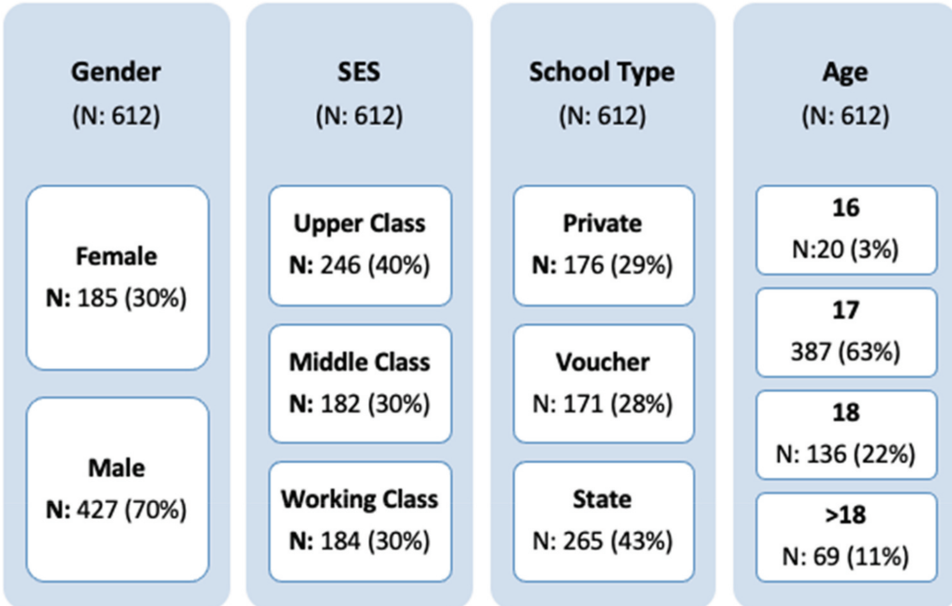

Figure 2. Description of students based on age, gender, SES, and type of school in central southern region of Chile.

2.3. Instruments

Measuring scientific literacy in biology and attitudes towards science involves identifying and/or creating instruments to explore the theoretical background and value of information collected to analyse the data accurately. This study used two validated tests, and the selection was based on accuracy with the Chilean education curriculum and the lack of national instruments to measure these topics. The first was the Test of Scientific Literacy Skills (TOSLS) by Gormally, Brickman, and Lutz (2012), and the second was Likert Scale Science-related (LSSr) based on the work of Fraser (1981) and Johnston (1997). These tests show an acceptable high level of reliability; Cronbach's alpha over $\alpha = 0.7$ (Tavakol and Dennick 2011) and align with the Chilean education curriculum.

Furthermore, the Delphi method (Peeraer and Van Petegem 2015; Yeh & Cheng 2015) was used in this study as an iterative consultation process with experts (Keeney, Hasson, and McKenna 2006) from two local Chilean universities and three secondary schools (state, voucher, private) in the central southern region. The purpose was to validate the coherence with the educational context and the practicality of these two tests, as described by Blasco, López, and Mengual (2010); experts provide consensus and accurate information through judgmental analysis. The instruments were fine-adjusted for accuracy in both biology and language, and experts also reviewed translations of both tests, and the panel provided a classification (See Figure 3) based on Uno and Bybee's (1994). The researcher used feedback to ensure appropriate biological content and test structure for the Chilean education context. Then, a pilot study was used to trial the final version, and the adapted versions were analysed.

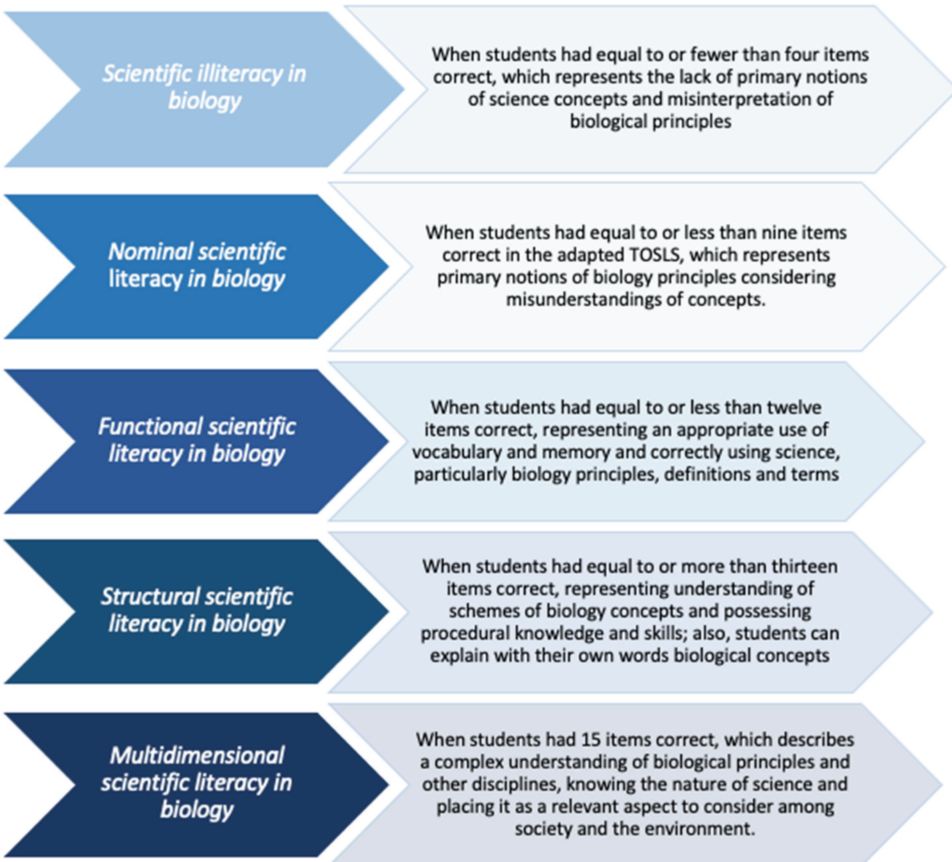

Figure 3. Five cut-off scores based on Uno and Bybee's taxonomy (1994).

2.4. Data collection and analysis

After receiving approval from the University of York Ethics Committee, 21 possible schools were contacted in the central southern region of Chile; however, 16 urban schools participated in a study involving 612 eleventh-grade students. Consent and assent forms were collected, and demographic information was obtained from the schools. The participants completed both tests in 120 minutes, and other demographic information was obtained directly from the school, including aspects related to socioeconomic background. The TOSLS and LSSr were analysed for reliability using alpha Cronbach and Guttman Lambda 4 tests; the scored values were over 0.6, which indicated consistency and accurate measurement of the sample (Fan and Geelan 2013). Furthermore, these adapted instruments showed an abnormal distribution, which indicated that the null hypothesis (the sample comes from a normally distributed population) was rejected, $p < 0.05$, suggesting a significant deviation. Nonparametric tests were used to explore the data further. The study involved two types of analysis: A descriptive analysis looked at measures of central tendency and dispersion and the normality of the distribution of scores for adapted tests. Also, an inferential analysis compared students' scientific literacy and attitudes towards science based on the variables. Chi-square test and One-way ANOVA tests were used for gender, type of school and SES differences, and

Spearman's correlation analyses measured the relationship between scientific literacy and attitudes towards science. SPSS 28.0 was used with a 5% statistical significance level.

3. Results

This section presents an analysis of data from different perspectives to examine the relationship between the levels of scientific literacy in biology among students and their attitudes towards science in central southern secondary schools in Chile. Variables like type of school, SES, and gender are considered to get a comprehensive understanding. There is an overview of the dimensions presented in both instruments, followed by an analysis of items that showed significant differences between variables, helping to identify specific areas of knowledge, skills, or understanding of students' attitudes towards a particular statement that require greater emphasis or clarity based on the current Chilean education system.

3.1. *Aim one: to analyse the level of scientific literacy in biology and attitudes toward science posed by secondary school students, making comparisons by gender, socioeconomic status (SES), and type of school (state, voucher or private)*

The adapted TOSLS (see Appendix D for a translation into English) had different difficulty levels for students. The analysis shows highly statistically significant differences between levels of scientific literacy and SES ($F\ (2, 611) = 44.75$, $p < .001$). For example, students from the upper class ($M = 4.30$, $SD = .46$) and middle class ($M = 4.34$, $SD = .53$) have more correct responses in the adapted TOSLS version than the working-class students ($M = 3.90$, $SD = .57$). Likewise, significant differences were found between the type of schools ($F\ (2, 611) = 31.17$, $p < .001$) where private schools ($M = 4.33$, $SD = .47$) and voucher schools ($M = 4.33$, $SD = .48$) had better results in this version of TOSLS compared to state schools ($M = 3.99$, $SD = .59$). Students from high SES attending private schools have better biology literacy than working-class students in state schools. Upper-class students show multidimensional literacy and can apply knowledge to complex situations. Chilean students vary in biology literacy, but none are scientifically illiterate.

The adapted LSSr (see Appendix E for a translation into English) with seven dimensions was used to evaluate their opinions and beliefs. The analysis showed a significant difference in SES ($F\ (2, 611) = 5.04$, $p = .007$) when examining items of Dimensions, such as I (Views of science and scientists), IV (Relevance of science), V (Classroom & teachers' insights), and VII (Social implications of science). However, there was no significant difference observed in other Dimensions and SES. Concerning the type of school, there was a highly significant difference when computing all Dimensions, mainly when calculating items in Dimension II, which refers to attitude to scientific inquiry ($F\ (2, 611) = 7.90$, $p < .001$. Age group did not have a significant impact on most dimensions, except for Dimension VII which relates to the social implications of science ($F\ (4, 611) = 2.65$, $p = .33$). No gender differences was found. State school students had a positive view of science and scientists, while voucher school students had more stereotypical views. Private school students also had a positive view. Older students had a more positive view of science's social impact compared to younger students.

3.1.1. Adapted TOSLS Chilean version

The analysis of the adapted TOSLS version considered fifteen items from the original test designed by Gormally, Brickman, and Lutz (2012), which has 28 items. This adjustment was based on the criteria of keeping the two dimensions of the original test and the nine skills and only the items that could show compatibility with Chilean science programs (biology) for secondary education, ensuring accuracy by the panel of experts consulted. The items had different difficulty levels linked to the nature of the two scientific dimensions; Understanding methods of inquiry that lead to scientific knowledge (D.I) and Organisation, analysis, and interpretation of quantitative data and scientific information (D.II). An example of the test structure that Chilean students answered is shown in Figure 4.

The bar chart (Figure 5) shows the responses of 612 secondary students who took an adapted Test of Scientific Literacy Skills (TOSLS) in a central southern region of Chile. A few trends are evident. For example, items 1, 3, 8, 9, and 15 had the highest frequency of incorrect responses compared to the rest of the items in the test due to their complexity and difficulty levels. The rest of the items were approached with more limited challenges by these students, suggesting that none of the Chilean students was classified as scientifically illiterate in biology, meaning that they answered at least four questions correctly, demonstrating a basic comprehension of scientific concepts and biological principles.

Table 1 presents an overview of the analysis performed on the 15 dichotomous items of the adapted TOSLS based on its two dimensions. Dimension one (D.I) ranged from 1 to 8, while dimension two (D.II) ranged from 1 to 7. The maximum score for DI is 8, and for DII, it is 7. Instead of using the mean, which can be skewed by extreme values or non-symmetric distributions of scores, the median was used to interpret these dimensions. The median provides a more accurate representation of the central point of the distribution based on the analysis of the Chi-square test.

The results showed that students who attended private schools and came from wealthier backgrounds scored the highest in both dimensions (I and II). On the other hand, students from the middle and working classes who attended voucher and state schools had lower scores on the same test. These results indicate that students with access to private education tend to perform better on the test due to their proficiency in biology vocabulary, understanding biological models, analysing data and graphs, and solving problems presented in TOSLS items. Gender had no significant impact on students' performance on the TOSLS test, except for a slight difference in the first dimension among 17 and 19-year-old students, where males scored better than females.

In Figure 6, the TOSLS version results revealed that most students scored between 7–15 correct items, indicating varying levels of biological literacy. Upper and middle-class students performed better, with 74% and 51.6%, respectively, scoring over or equal to 14 questions correctly. Private schools had the highest percentage of students answering correctly at 72.7%, while state schools had the lowest at 25.3%. Gender-wise, no significant differences were found, as both male and female students scored similarly, with an average of 13.13 points.

To thoroughly understand the adapted TOSLS, each item was analysed using one-way ANOVA, considering SES, school type, and gender to identify those items that yielded statistically significant to understand better areas of knowledge developed by Chilean students in their last year of secondary education. Appendix A provides further analysis.

The test results showed that students from upper and middle-class backgrounds tended to perform better on item 1, which tested valid scientific arguments, than students from working-class backgrounds. This difference was highly significant for both socioeconomic status (F (2, 611) = 18.21, $p < .001$) and the type of school attended (F (2, 611) = 21.45, $p < .001$). Specifically, students from the upper class (*M* = 1.96, Sd = .207) and middle class (*M* = 1.96, SD = .476) answered more correctly than students from the working class (*M* = 1.76, SD = .451). Additionally, private schools (*M* = 1.95, SD = .21) and voucher schools (*M* = 2.00, SD = .42) demonstrated better performance compared to state schools (*M* = 1,78, SD = .44).

Item 15, which asks for identifying a plausible hypothesis to explain the results presented in a graph, showed a highly significant difference in SES (F (2, 611) = 119.64, $p < .001$) and type of school (F (2, 611) = 47.66, $p < .001$). Students from the upper class (*M* = 2.00, SD = .26) and middle class (*M* = 2.06, SD = .60) scored higher than the working-class students (*M* = 1.37, SD = .60). Likewise, private schools (*M* = 2.00, SD = .30) and voucher schools (*M* = 1.99, SD = .33) showed better performance compared to state schools (*M* = 1.56, SD = .74). It was also found statistically significant in gender (F (2, 611) = 6.52, $p = .002$), where female students (*M* = 1.93, SD = .63) tended to answer more correctly than male students (*M* = 1.75, SD = .55).

Regarding item 8, which asks for the most accurate conclusion drawn from a graph, there are significant statistical differences in three areas: SES (F (2, 611) = 108.47, $p < .001$), type of school (F (2, 611) = 69.14, $p < .001$), and age group (F (4, 611) = 2.59, $p = .036$). Students from higher and middle-class backgrounds tended to answer more accurately (*M* = 3.95, SD = .31 and *M* = 3.91, SD = .38, respectively) than those from working-class backgrounds (*M* = 3.31, SD = .72). Private and voucher schools also performed better (*M* = 3.94, SD = .33 and *M* = 3.45, SD = .33, respectively) than state schools (*M* = 3.45, SD = .70). Additionally, students aged 20 (*M* = 4.0, SD = .00) answered more correctly than those aged 16 (*M* = 3.70, SD = .47).

A significant difference was found in item 9, which discusses two studies estimating the caffeine content of an energy drink. Students were asked to choose which statement was true. Statistical differences were found regarding SES (F (2, 611) = 5.16, $p = .006$), type of school (F (2, 611) = 4.38, $p = .013$), and age group (F (4, 611) = 2.89, $p = .022$). In this case, students from the working class (*M* = 1.57, SD = .76) responded more correctly than the upper class (*M* = 1.37, SD = .65) and middle class (*M* = 1.40, SD = .70). Furthermore, state schools (*M* = 1.54, SD = .73) showed better performance than private school (*M* = 1.36, SD = .65) and voucher school (*M* = 1.39, SD = .66). Also, students from the age of 19 (*M* = 1.65, SD = .85) keen to giving more correct answer than 16 (*M* = 1.10, SD = .31). Chilean private school and upper-class students had higher scientific literacy levels in biology than state and working-class schools. Middle-class students in voucher schools had a strong grasp of biology concepts. Working-class public-school students accurately used scientific vocabulary and showed no illiteracy levels. Age and gender had slight variations, but no differences were found based on gender. All students recognized the importance of science in society and the environment.

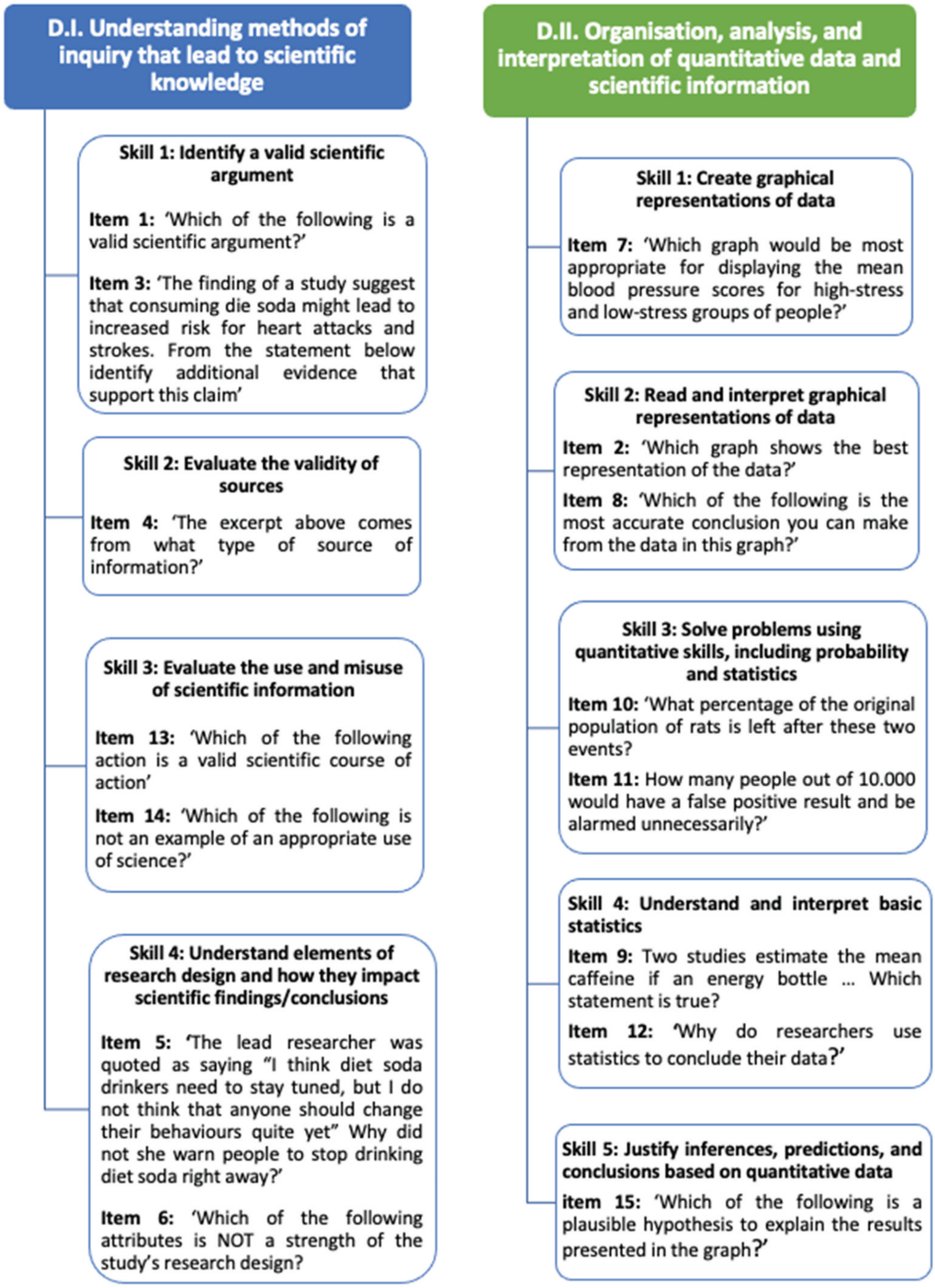

Figure 4. Overview of the adapted TOSLS, considering the description of those items used in the Chilean test version.

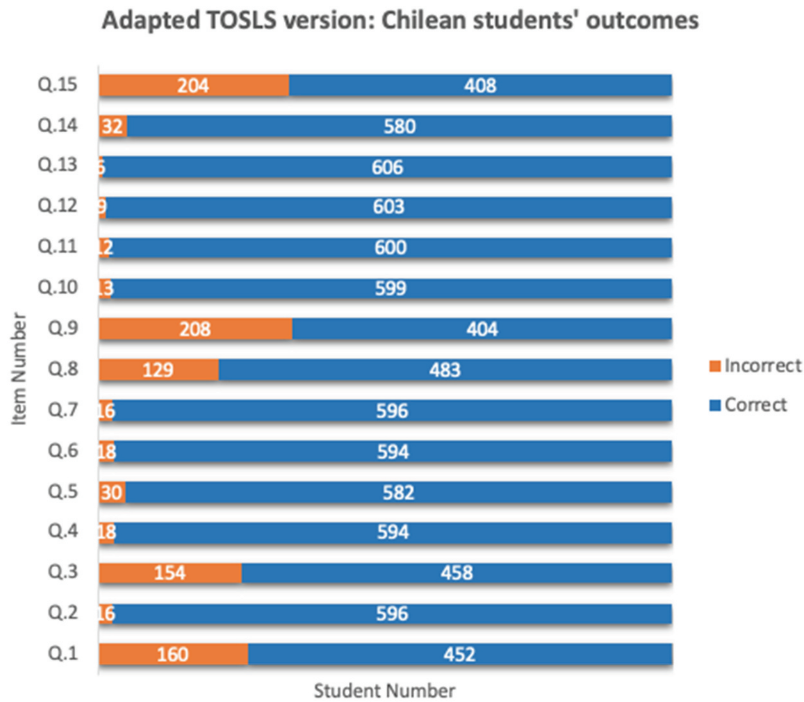

Figure 5. Outcomes from Chilean students who took the adapted TOSLS version ($N = 612$).

Table 1. Adapted TOSLS: Median frequency table by SES, type of school and age.

	Upper Class		Middle Class		Working Class					
SES/Gender	Female	Male	Female	Male	Female	Male				
Median D1	8.0	8.0	7.0	7.0	7.0	7.0				
Median D2	7.0	7.0	6.0	6.0	6.0	5.0				
Total Score	**15**	**15**	**13**	**13**	**13**	**12**				
	Private School		State School		Voucher School					
Type of school/Gender	Female	Male	Female	Male	Female	Male				
Median D1	8.0	8.0	7.0	8.0	7.0	7.0				
Median D2	7.0	7.0	6.0	5.0	7.0	7.0				
Total Score	**15**	**15**	**13**	**13**	**14**	**14**				
	16		17		18		19		20	
Age/Gender	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Median D1	8.0	8.0	7.0	8.0	8.0	7.0	7.0	8.0	8.0	8.0
Median D2	6.5	6.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0
Total Score	**14.5**	**14.5**	**13**	**14**	**14**	**13**	**13**	**14**	**14**	**15**

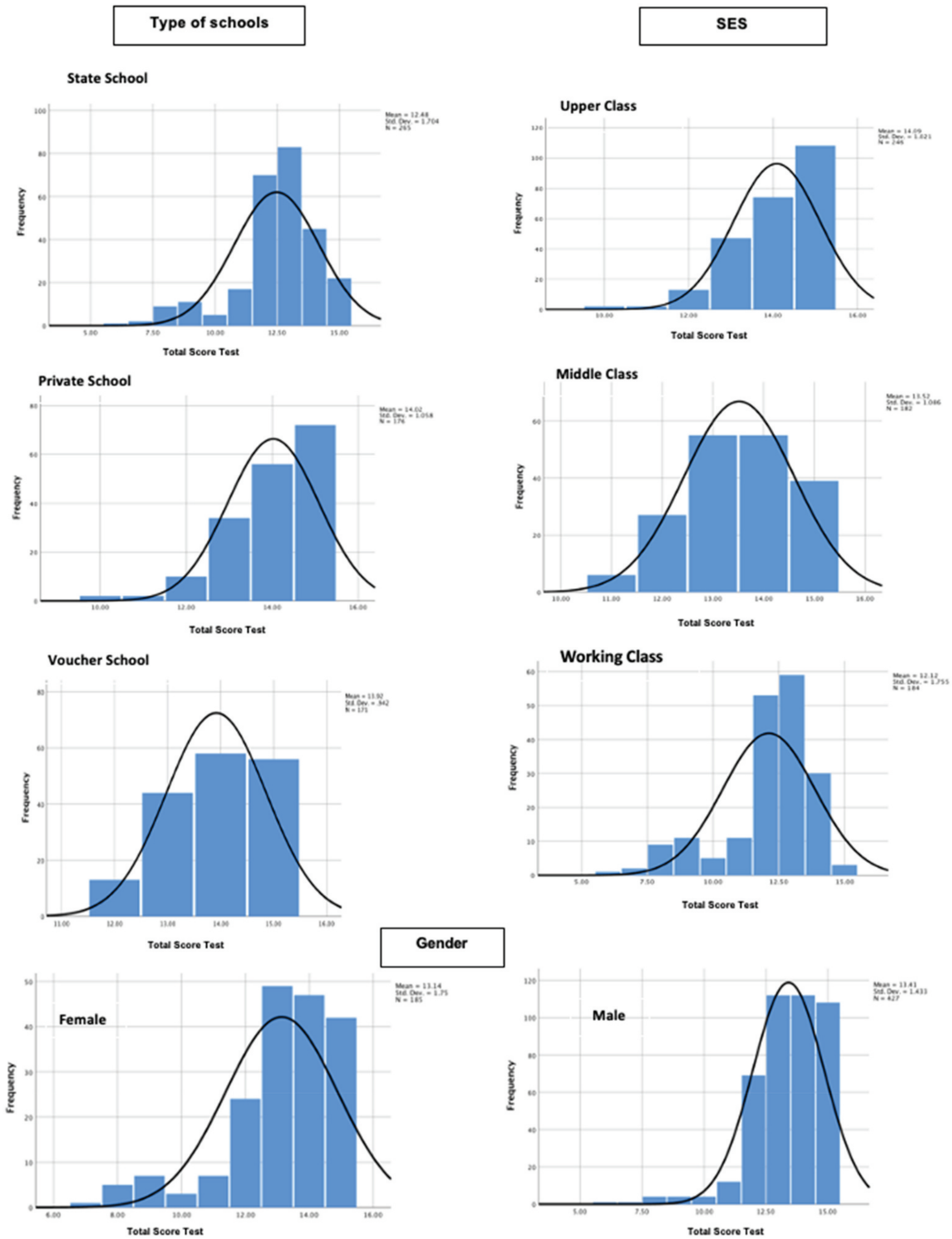

Figure 6. Summary of student results according to the adapted version of TOSLS, considering school type, SES, and gender.

3.2.1. *Adapted Likert scale (LSSr)*

Considering the Scale of attitudes related to science by Fraser (1981) and Johnston (1997), an adapted Likert Scale Science-related (LSSr) was developed to evaluate the attitudes of Chilean students towards science, focusing primarily on biology topics.

This version has seven dimensions, with a total of 38 items ranging from 1 to 5, with 1 and 2 representing very favourable attitudes, 3 indicating uncertainty, and 4 and 5 showing a negative trend towards science. Prior to the statistical analysis, negative items were reversed. These items ranged from −4 to + 4 on a five-point scale, where a positive change indicated an improvement in attitude or opinion. Figure 7 shows the LSSr structure that Chilean students used to answer a question about their attitudes towards science.

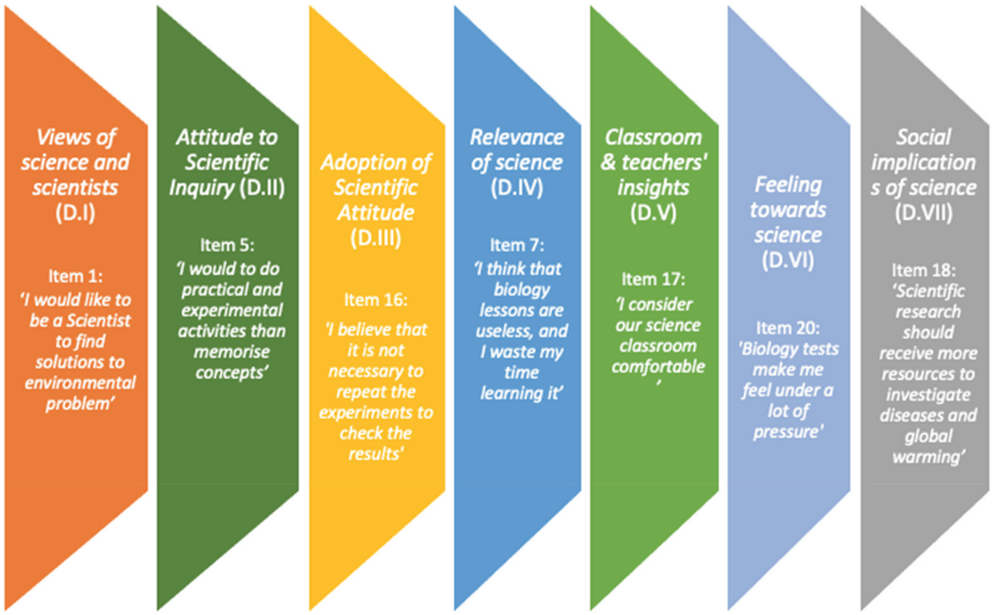

Figure 7. Adapted LSSr description and an example of items within dimension used in the Chilean educational context.

Table 2 summarises the analysis performed on the adapted LSSr across its seven dimensions. The median was used to interpret the data obtained in each dimension, as it better indicates the central point of the distribution than the mean according to the Chi-square test analysis. The analysis showed that students' answers tended to be agreeable or unsure about some statements in each dimension, with the median score ranging from 2.0 to 3.5. The study found slight variations in the dimensions 'Relevance of Science' (DI.V) and 'Attitude to Inquiry' (D.II) based on the type of schools and SES. Additionally, other dimensions showed minor differences based on SES, gender, and age. For instance, male students had negative views towards the 'Relevance of Science' in dimension IV.

To thoroughly understand the adapted LSSr, each item was analysed using one-way ANOVA, considering the variables to identify those items that yielded statistically significant to understand better Chilean students' perception of biology in their last year of secondary education. Appendix B provides further analysis.

Concerning these variables, the type of school showed a highly significant difference when computing all Dimensions, and some items showed highly significant differences. To illustrate, item 35 (F (2, 611) = 6.76, $p = .001$) showed that state school students had more positive views about Charles Darwin's theory of evolution ($M = 2.42$, SD = 1.06) than private schools ($M = 2.09$, SD = .90) and voucher schools ($M = 2.15$, SD = 1.13). Likewise, item 9 showed a highly significant difference (F (2, 611) = 14.88, $p < .001$). Although, item 12 (F (2, 611) = 10.40, $p < .001$) showed that voucher schools students ($M = 3.51$, SD = 1.10) had more positive views towards scientists being less sociable due to their time in the lab compared to private schools ($M = 3.08$, SD = .96) and state school ($M = 3.13$ SD = .93). State school students have positive views of science and scientists, while voucher school students have stereotypical views of scientists as less sociable and wearing lab coats.

Item 27 (F (2, 611) = 3.76, $p = .024$) also showed that voucher school students ($M = 3.77$, SD = 2.21) tend to have more favourable opinions towards avoiding new ideas that may challenge their beliefs than private schools ($M = 3.47$, SD = 1.41) and State schools ($M = 3.49$, SD = 1.21). Items in dimension II, attitude towards scientific inquiry, showed significant differences across schools (F (2, 611) = 7.90, $p < .001$). Prevailing, students from private schools ($M = 2.67$, SD = .67) had more positive views than those from state schools ($M = 2.40$, SD = .71) and voucher schools ($M = 2.46$, SD = .75). An example is item 19 (F (2, 611) = 4.46, $p = .012$) that showed that private school students ($M = 2.73$, SD = 1.19) were more inclined to watch biology programs on T.V. than read books, compared to students from state schools ($M = 2.37$, SD = 1.26) and voucher school ($M = 2.50$, SD = 1.18). There were notable differences in the scientific attitudes toward voucher, private, and state schools.

Regarding Socioeconomic Status (SES), Relevance of Science (D.IV) showed that item 36 (F (2, 611) = 5.06, $p = .007$) was statistically significant. Working-class students ($M = 3.83$, SD = 1.08) felt bored when they must watch a science program on the television compared to upper-class ($M = 3.50$, SD = 1.06) and middle-class students ($M = 3.58$, SD = 1.05). In contrast, item 29 (F (2, 611) = 3.95, $p = .02$) within dimension VII, Social Implications of Science, was statistically significant. Upper-class students ($M = 3.13$, SD = 1.02) believed that scientific discoveries (such as atomic bomb) are doing more damage than good to the population than middle-class students ($M = 3.20$, SD = 1.04) and working-class students ($M = 2.92$, SD = 1.00). Here, upper-class students view science more positively than working or middle-class students.

The analysis revealed some slight variations, including a statistically significant difference between Q19 in Dimension II, Attitude to Scientific Inquiry, and gender (F (2, 611) = 4.89, $p = .017$). Female students ($M = 2.66$, SD = 1.91) provided more positive answers to biological topics and general science questions than male students ($M = 2.44$, SD = 1.23). Similarly, item 38 in Dimension V, Classroom and Teachers' Insight, showed a highly statistically significant difference (F (2, 611) = 6.36, $p = .002$). Female students ($M = 3.32$, SD = 1.19) had more positive opinions about science classrooms and teachers than male students ($M = 2.99$, SD = 1.15). Furthermore, no significant differences were found between the items and the age group variable. However, there was a significant difference between Dimension VII, Social Implications of Science, and age group (F (4, 611) = 2.65, $p = .33$). Older students (age 19 and 20) had more positive views about the importance of science in society than younger students (age 16, 17, and 18), indicating that age affects students' outlook on the social impact of science.

Table 2. Likert scale test, Chilean version: Median frequency table by SES, type of school and age.

	SES/Gender					
	Upper Class		Middle Class		Working Class	
	Female	Male	Female	Male	Female	Male
Median D1	2.5	2.5	3.0	2.5	2.5	2.5
Median D2	3.0	2.0	3.0	2.0	2.0	2.0
Median D3	3.0	3.0	3.0	3.0	3.0	3.5
Median D4	3.0	3.0	3.0	3.0	3.5	3.0
Median D5	2.5	2.5	2.5	2.0	2.0	2.5
Median D6	3.0	3.0	3.0	3.0	3.0	3.0
Median D7	2.0	2.0	2.5	2.0	2.0	2.0
Type of School/Gender						
	Private School		State School		Voucher School	
	Female	Male	Female	Male	Female	Male
Median D1	2.5	2.5	2.5	2.5	3.0	2.5
Median D2	3.0	3.0	2.0	2.0	3.0	2.0
Median D3	3.0	3.0	3.0	3.0	3.0	3.0
Median D4	3.0	3.0	3.5	3.0	3.0	3.0
Median D5	2.5	2.5	2.5	2.0	2.0	2.0
Median D6	3.0	3.0	3.0	3.0	3.0	3.0
Median D7	2.0	2.0	2.0	2.0	2.0	2.0

Age/Gender										
	16		17		18		19		20	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Median D1	2.3	2.5	2.5	2.5	2.5	2.5	3.0	2.5	2.0	2.8
Median D2	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
Median D3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5
Median D4	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5
Median D5	2.0	2.5	2.5	2.0	2.5	2.0	2.0	2.0	2.5	2.3
Median D6	3.0	3.3	3.0	3.0	3.3	3.0	3.0	3.0	3.0	3.8
Median D7	2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.0	2.0	2.5

3.2. *Aim 2: to evaluate the relationship between scientific literacy and attitudes toward science*

The correlation analysis conducted with Spearman's rho test showed a weak positive relationship between students' scores on the tests that measure scientific literacy in biology and their attitude towards science, although of moderate magnitude. An important finding was that even though these two adapted tests within dimensions, most tend to go up in response to one another, the value tends to be between 0 and 0.5, indicating a weak relationship or non-relationship, which implies that students' scores on measuring attitude towards science and their scores on the test for measuring their skills related to significant aspects of biological principles are almost independent.

3.2.1. Spearman's rho test analysis

An analysis was conducted using Spearman's rank-order correlation test to evaluate the adapted tests. The Spearman's rho values ranged between −1, 0, and 1 (Dancey and Reidy 2004), indicating weak positive and negative correlations, helping to determine the correlations between the computed dimensions on these two adapted test versions for the Chilean students, a complete analysis can be found in Appendix C.

In the adapted TOSLS version, Dimension one (D.I: *Understanding methods of inquiry that lead to scientific knowledge*) and Dimension III of the adjusted LSSr (*Adoption of Scientific Attitudes*) showed a weak positive correlation (Rho (612) = .107; $p < .05$). Additionally, Dimension two of the adapted TOSLS (D.II: *Organisation, analysis, and interpretation of quantitative data and scientific information*) showed a positive but weak correlation (Rho (612) = 0.108; $p < .05$) with Dimension V of the LSSR test (*Classroom & teachers' insights*) and Dimension II of the LSSr test (Attitude to Scientific Inquiry) has a weak positive correlation (Rho (612) = 0.115; $p < .05$) with Dimension two (D.II) of the adapted TOSLS. Furthermore, the two dimensions (D. I+ D.II) of the adapted TOSLS and Dimension II of the adapted LSSr test (*Attitude to Scientific Inquiry*) showed a weak positive correlation (Rho (612) = 0.095; $p < .05$).

The rest of the adapted Likert Scale Science-related (LSSr) dimensions presented very weak correlations and, in some cases, negative correlations between dimensions within adapted TOSLS, which indicated that these surveys were almost independent. The results suggest that while the scores of both adapted tests generally increase in some dimensions, the correlation between them is weak (less than 1%), which suggests that student's scores on the LSSr, which measures their attitudes towards science, and their scores on the adapted TOSLS that measures their skills on scientific principles can be considered independent of each other.

4. Discussion

In this study, the adapted TOSLS results showed no levels of biological illiteracy among Chilean students, which is consistent with the science education programs in the country (MINEDUC 2021). However, there are significant differences in educational outcomes depending on the socioeconomic background and the type of school attended. It was found that students attending private-voucher schools achieve better educational outcomes on biological principles and science than those from state schools linked with low SES. This finding is in line with international and national outcomes, which demonstrate a positive correlation between the socioeconomic and cultural index and the level of scientific literacy or performance in science achieved by students (Lyons & Quinn 2010; MINEDUC 2021; Navarro and Forster 2012; OECD 2020).

The literature stated that low levels of biological principles knowledge and high rates of science misconceptions are known to be present among secondary students (Kampourakis and Zogza 2007), seniors and the general public (Nehm and Ha 2011; Pazza, Penteado, and Kavalco 2010). The Chilean education system's institutional design showed that allowing the private voucher schools to choose students based on their criteria compared to state schools has promoted disparities, such as increasing test score gap between low- and high-SES students and disseminating 'cream skimming' practices based on student's performance and discipline, all of which negatively affected public schools (Carrasco and San Martín 2012; Contreras et al. 2011), which limited opportunities and experiences of acquiring knowledge and skills in science as a crucial aspect for their future roles as citizens.

The LSSr version showed that Chilean students' attitudes towards science varied; private school students showed the most positive attitude towards scientific inquiry and behaviours compared to voucher and state school students, with positive perceptions of science and iconic scientists. However, voucher students held more stereotypical views and needed more interest in new science topics, which may be because most voucher schools in Chile have religious or corporate affiliations. Indeed, studies showed that the type of school, science programs and quality of teachers' training could encourage more students to take up science and improve school experiences to be more engaging (Schoon, Ross, and Martin 2007; Smyth and Hannan 2006). Billingsley et al. (2018) consistently state that pedagogical and social barriers can prevent students from understanding how science and religion relate.

In the results of both adapted tests, a few gender differences were observed. In dimensions 2 and 5 of the adapted LSSr, females showed a slight edge over males. This indicates that females are more open to new ideas and more willing to modify their beliefs regarding science. This is because women view science as a social benefit. Even if they do not prefer specific scientific disciplines, they are more likely to change their judgments (Bybee and McCrae 2011; Navarro and Forster 2012). These results can be compared with those of the Smist (1994), which also found favourable differences for women in terms of scientific attitudes related to dimension 2 (Attitudes towards scientific inquiry) but also discovered more positive attitudes towards science and lifestyle, which were not investigated in this study. Thus, understanding biological principles and science helps apply evidence-based knowledge across various subjects that would impact and support society.

This study also found a weak positive relationship between students' scores on the tests that measure scientific literacy in biology and their attitude towards science, although of moderate magnitude. Chilean students' performance on the adapted TOSLS varied based on their SES and type of school. Their attitudes towards biological principles also showed differences based on these factors. The significance of these findings is rooted in the long-standing issue of school segregation in Chile, which has been exacerbated in recent years by a rise in private and voucher schools. Therefore, it is crucial to identify the factors that contribute to segregation to develop effective policies to reduce it. According to Valenzuela et al. (2014), the government should address this issue, as it could significantly impact Chilean society. Understanding students' interests and the impact of various factors on their prospects, learning preferences, and daily decision-making is critical (Fraser, Aldridge, and Adolphe 2010; Vegar, Prenszel, and Martin 2011).

5. Conclusions, recommendations and limitations

The current investigation provides one of the first pieces of information about levels of scientific literacy in biology, attitudes towards science and the influence of non-academic factors on students in the final year of secondary education. The implications of these results could be significant for the Chilean national curriculum to understand better how proficiency in answering a test that measures science knowledge could be deeply impacted by SES and type of school, as well as students' attitudes towards science.

The findings provide the opportunity to reassess the role of science programs in creating a more equitable education system that ensures each student has an equal chance to incorporate scientific knowledge and biological principles into their daily lives, helping to improve students' perception of science and achieve a multidimensional level of scientific literacy, meaning an enhanced understanding of science and its impact on society, making them better citizens. It could also provide an opportunity for Chilean education to prioritise funding and resources for state schools, which could focus on regulations intended to improve programs and training for science teachers, fundamental to the organisation of the educational system, stakeholder relationships, and resolving social-class disparities.

The education system in Chile currently suffers from increased social inequality and segregation among students, making it difficult to distinguish between market-driven policies and educational context. Therefore, it is imperative to critically assess the education system and examine the beliefs of teachers and students regarding the importance of scientific literacy and engagement with science. The existing science curriculum has resulted in evident tensions (Bellei 2000; García-Huidobro and Bellei 2003) and needs to be explored to understand further the perspectives of educators and learners, for example, using a more qualitative research approach (Dagher and Boujaoude 2005), which could contribute to improved scientific and technological developments in the country.

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Data availability statement

The data cannot be publicly shared because of privacy regulations on pupils' data. Participants were informed that only researchers have access to the data which will be treated as strictly confidential.

Ethical Approval statement

All procedures performed in this study involving human participants followed the Ethics Committee standards of the Education department at the University of York, which the committee approved. Moreover, informed consent was obtained from all individual participants involved in the study. Therefore, I declare that I have no conflicts of interest, and all research was carried out according to the regulations of this UK Institution.

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References

Alexander, N. A., and W. Choi. 2015. "Mirando mas alla de las paredes de la escuela." *Education Policy Analysis Archives* 23. https://doi.org/10.14507/epaa.v23.1492.

American Association for the Advancement of Science. AAAS. 1993. *Project 2061: Benchmarks for Science Literacy*. New York: Oxford University Press. http://www.project2061.org/publications/bsl/online/index.php.

Archer, L., J. DeWitt, J. Osborne, J. Dillon, B. Willis, and B. Wong. 2012. "Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification with Science'." *American Educational Research Journal* 49 (5): 881–908. https://doi.org/10.3102/0002831211433290.

Auguste, S., and J. P. Valenzuela. 2004. *Do students benefit from school competition? Evidence from Chile*. Ann Arbor, University of Michigan. unpublished.

Bayer, C. N., M. Luberda, and A. L. Roca. 2016. "Measure, Then Show: Grasping Human Evolution Through an Inquiry-Based, Data-Driven Hominin Skulls Lab." *Public Library of Science ONE* 11 (8): e0160054. https://doi.org/10.1371/journal.pone.0160054.

Bellei, C. 2000. "Middle Education and Youth in the 90s: Updating the Old Promise." *Ultima Decada* 8 (12): 45–88. https://doi.org/10.4067/S0718-22362000000100006.

Bellei C. 2009. "Does lengthening the school day increase students' academic achievement? Results from a natural experiment in Chile." *Economics of Education Review* 28 (5): 629–640. https://doi.org/10.1016/j.econedurev.2009.01.008.

Bellei, C. 2011. *The Failure of the Education Market*. La Tercera, A3.

Bennett, J. 2001. "The Development and Use of an Instrument to Assess students" Attitude to the Study of Chemistry." *International Journal of Science Education* 23 (8): 833–845. https://doi.org/10.1080/09500690010006554.

Billingsley, B., M. Nassji, S. Fraser, and F. Lawson. 2018. "A Framework for Epistemic Insight." *Research in Science Education* 48 (6): 1115–1131. https://doi.org/10.1007/s11165-018-9788-6.

Blasco, J. E., A. López, and S. Mengual. 2010. "Validación mediante método Delphi de un cuestionario." *The Agora* 12 (1): 75–79.

Borquez, E. 2014. *Análisis de la congruencia entre las habilidades incorporadas, por profesores de NM1, en planificaciones e instrumentos de evaluación en una unidad didáctica y las habilidades del nivel 5 de los Mapas de Progreso de Ciencias Naturales en Liceos municipales de la comuna de Talcahuano, región del Bio Bio*, 24–47. Vol. 14. N 2. Chile: Revista Investigaciones en, Educacion Universidad de la Frontera (UFRO). https://revistas.ufro.cl/ojs/index.php/educacion/article/view/1266.

Bravo González, P., and M. J. Reiss. 2021. "Science teachers' Views of Creating and Teaching Big Ideas of Science Education: Experiences from Chile." *Research in Science & Technological Education* 41 (2): 523–543. https://doi.org/10.1080/02635143.2021.1919868.

Bybee, R., and B. McCrae. 2011. "Scientific Literacy and Student Attitudes: Perspectives from PISA 2006 Science." *International Journal of Science Education* 33 (1): 7–26. https://doi.org/10.1080/09500693.2010.518644.

Camus, P. 2009. “Science Education and Evolution Education in Chile. Functional Problems and Conflicts Between Teaching and Learning.” *Gayana* 73 (Suplement): 19–31. https://doi.org/10.4067/S0717-65382009000300003.

Carrasco, A., and E. San Martín. 2012. “Voucher System and School Effectiveness: Reassessing School Performance Difference and Parental Choice Decision-Making.” *Estudios de Economía* 39 (2): 123–141. https://doi.org/10.4067/S0718-52862012000200002.

Caspi, A., P. Gorsky, R. Nitzani-Hendel, Z. Zacharia, S. Rosenfeld, S. Berman, and B. Shildhouse. 2020. “Children’s Perceptions of the Factors That Led to Their Enrolment in Advanced, Middle-School Science Programmes.” *International Journal of Science Education* 42 (11): 1915–1939. https://doi.org/10.1080/09500693.2020.1802083.

Cofre, H., J. Camacho, A. Galaz, J. Jimenez, D. Santiban, and C. Vergara. 2010. “Science Education in Chile: Teaching Weaknesses and Future Challenges of Science Teacher Education.” *Estudios Pedagogicos* 35 (2): 279–293.

Cofre, H., C. Vergara, D. Santibanez, and J. P. Jimenez. 2013. “Una primera aproximación a la comprensión que tienen estudiantes universitarios en Chile de la Teoría de la Evolución.” *Estudios pedagógicos (Valdivia)* 39 (2): 67–83. https://doi.org/10.4067/S0718-07052013000200005.

Contreras, D., D. Hojman, C. Hunneus, and O. Landerretche. 2011. *Profit in School Education. Evidence and Regulatory Challenges. Department of Economics*. Santiago, Chile: Universidad de Chile.

Contreras, D., P. Sepulveda, and S. Bustos. 2010. ”When Schools are the ones that choose: The effects of screening in Chile N.” *Social Science Quarterly* 91 (5): 1349–1368. https://doi.org/10.1111/j.1540-6237.2010.00735.x.

Dagher, Z. R., and S. Boujaoude. 2005. “Students’ Perceptions of the Nature of Evolutionary Theory.” *Science Education* 89 (3): 378–391. https://doi.org/10.1002/sce.20054.

Dalgety, J., R. Coll, and A. Jones. 2003. “Development of Chemistry Attitudes and Experiences Questionnaire (CAEQ).” *Journal of Research in Science Teaching* 40 (7): 649–668. https://doi.org/10.1002/tea.10103.

Dancey, C., and J. Reidy. 2004. *Statistics without Maths for Psychology: Using SPSS for Windows*. London: Prentice Hall.

Dorfner, Christian Förtsch, and Birgit J. Neuhaus. 2020. “Use of Technical Terms in German Biology Lessons and Its Effects on students’ Conceptual Learning.” *Research in Science & Technological Education* 38 (2): 227–251. https://doi.org/10.1080/02635143.2019.1609436.

Drago, J. L., and R. Paredes. 2011. “La brecha de calidad en la educación chilena.” *Revista de la Cepal* 104:167–180. https://doi.org/10.18356/7b1f89f6-es.

Duncan, G. R., and J. D. Boerwinkel. 2018. “Molecular biology.” In *Teaching Biology in School: Global Research, Issues, and Trends*, edited by K. Kampourakis and M. J. Reiss, 35–47. Routledge. https://doi.org/10.4324/9781315110158.

Elacqua, G. June 5 2009. The Impact of School Choice and Public Policy on Segregation. *Journal of Policy Analysis and Management* 5 (7): 17–26.

Fan, X., and D. Geelan. 2013. “Enhancing students’ Scientific Literacy in Science Education Using Interactive Simulations.” *Journal of Computers in Mathematics and Science Teaching* 32 (2): 125–171.

Fraser, B. J. 1981. *Test of Science-Related Attitude (TOSRA)*. Melbourne: Australian Council for Educational Research.

Fraser, B. J., J. M. Aldridge, and F. S. G. Adolphe. 2010. “A Cross-National Study of Secondary Science Classroom Environments in Australia and Indonesia.” *Journal of Research in Science Teaching* 40 (4): 551–575. https://doi.org/10.1007/s11165-009-9133-1.

García-Huidobro, J., and C. Bellei. 2003. *Educational Inequality in Chile*. Santiago, Chile: Universidad Alberto Hurtado.

Gormally, C., P. Brickman, and M. Lutz. 2012. “Developing a Test of Scientific Literacy Skills (TOSLS): Measuring undergraduates’ Evaluation of Scientific Information and Arguments.” *CBE – Life Sciences Education* 11 (4): 364–377. https://doi.org/10.1187/cbe.12-03-0026.

Guerrero, Gonzalo, and Betzabe. Torres-Olave. 2021. “Scientific Literacy and Agency within the Chilean Science Curriculum: A Critical Discourse Analysis.” *Curriculum Journal* 33 (3): 00–17. https://doi.org/10.1002/curj.141.

Gutierrez, A. 2009. *Biologia. La Teoria de la Evolucion En la Escuela [Biology. The Theory of Evolution in the School]*. Buenos Aires: Editorial Biblos.

Hanson, L. M., J. F. Westerlund, and P. W. Vaughan. 2020. “Gender Differences in Student Attitudes Towards Science in Secondary School Classrooms with and without NSF GK-12 Resident Scientists.” *The Electronic Journal for Research in Science & Mathematics Education* 24 (4): 50–68.

Harlen, W. 2010. “Principles and Big Ideas of Science Education.” ASE Accessed May 10, 2013. https://www.ase.org.uk.

International Council for Science [ICSU] (2011). Report of the ICSU Ad- Hoc reviews panel on science education, 10–23. Paris. https://council.science/publications/report-of-the-icsu-ad-hoc-review-panel-on-science-education-2011/.

Jenkins, E., and N. Nelson. 2005. “Important but Not for Me: Students’ Attitudes To- Wards Secondary School Science in England.” *Research in Science and Technological Education* 23 (1): 41–57. https://doi.org/10.1080/02635140500068435.

Johnston, J. 1997. *Measuring Attitudes in Science: What Exactly are We Measuring and Why?*. Department of Primary Education: The Nottingham Trent University Press. B.E.R.A.

Kampourakis, K., and V. Zogza. 2007. “Students’ Preconceptions About Evolution: How Accurate is the Characterization as ‘Lamarckian’ When Considering the History of Evolutionary Thought?” *Science & Education* 16 (3–5): 393–422. https://doi.org/10.1007/s11191-006-9019-9.

Keeney, S., F. Hasson, and H. McKenna. 2006. “Consulting the Oracle: Ten Lessons from Using the Delphi Technique in Nursing Research.” *Journal of Advanced Nursing* 53 (2): 205–212. https://doi.org/10.1111/j.1365-2648.2006.03716.x.

Kim, S. Y., and R. H. Nehm. 2011. “A Cross-Cultural Comparison of Korean and American Science Teachers’ Views of Evolution and the Nature of Science.” *International Journal of Science Education* 10:1–31. https://doi.org/10.1080/09500690903563819.

Kitchen, E., S. Reeve, J. Bell, R. Sudweeks, and W. Bradshaw. 2007. “The Development and Application of Affective Assessment in an Upper-Level Cell Biology Course.” *Journal of Research in Science Teaching* 44 (8): 1057–1087. https://doi.org/10.1002/tea.20188.

Lau, K. C., E. S. C. Ho, and T. Y. P. Lam. 2015. “Effective Classroom Pedagogy and Beyond for Promoting Scientific Literacy.” In *Science Education in East Asia*, edited by M. S. Khine, 13–40. Springer International Publishing. https://doi.org/10.1007/978-3-319-16390-1_2.

Lyons, T., and F. Quinn. 2010. *Choosing Science: Understanding the Declines in Senior High School Science Enrolments. National Centre of Science, ICT and Mathematics Education for Rural and Regional Australia (SiMERR Australia)*. Australia: National Centre of Science, SiMERR Australia. http://www.une.edu.au/simerr/pages/projects/131choosingscience.pdf.

Mansfield, J., and M. J. Reiss. 2020. “The Place of Values in the Aims of School Science Education.” *Values in Science Education*. https://doi.org/10.1007/978-3-030-42172-4_12.

Mhladza, G., M. Durana, and A. Doan. 2011. “Examining Primary School students’ Attitudes Towards Science in Terms of Gender, Class Level and Income Level.” *Procedia Social and Behavioral Sciences* 15:2582–2588. https://doi.org/10.1016/j.sbspro.2011.04.150.

Microsoft, and S. Kesar 2018. “Closing the STEM Gap: Why STEM Classes and Careers Still Lack Girls and What We Can Do About It.” https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE1UMWz.

Millar, R. 2008. Taking Scientific Literacy Seriously as a Curriculum Aim. In *Asia- Pacific Forum on Science Learning and Teaching*, Forward, 1. Vol 9. 2. The Education University of Hong Kong: FOREWORD, HKIED. https://www.eduhk.hk/apfslt/download/v9_issue2_files/foreword.pdf.

Miller, J. D., E. C. Scott, and S. Okamoto. 2006. “Public Acceptance of Evolution.” *Science* 321 (5890): 755–755. https://doi.org/10.1126/science.321.5890.755.

MINEDUC (Ministerio de Educación de Chile). 2019. *Bases curriculares 3° y 4° medio*. Santiago: Unidad Curriculum y Evaluación.

MINEDUC (Ministerio de Educación de Chile). 2021. Marco para la Buena Enseñanza. Centro de Perfeccionamiento, Experimentación e Investigaciones Pedagógicas CPEIP. Available online at: https://estandaresdocentes.mineduc.cl/wp-content/uploads/2021/08/MBE-2.pdf.

Montes, L. H., R. A. Ferreira, and C. Rodríguez. 2022. “The Attitude to Learning Chemistry Instrument (AlchI): Linking Gender, Achievement, and Attitudes.” *Chemistry Education Research and Practice* 23 (3): 686–697. https://doi.org/10.1039/D2RP00038E.

Mourshed, M., C. Chijioke, and M. Barber. 2010. *How the world’s Most Improved School Systems Keep Getting Better (Media&design)*. London: McKinsey & Company. https://www.mckinsey.com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/how%20the%20worlds%20most%20improved%20school%20systems%20keep%20getting%20better/how_the_worlds_most_improved_school_systems_keep_getting_better.pdf.

Mundy, K. 2005. ”Globalization and educational change: New policy worlds.” In International handbook of educational policy, 3–17. Vol. 1. Springer. https://doi.org/10.1007/1-4020-3201-3_1.

Narguizian, P. 2019. “Seven Pillars of Biology Literacy: A Proposal for What Secondary School Teachers Might Teach & What College Instructors Should Reinforce.” *The American Biology Teacher* 81 (3): 145. https://doi.org/10.1525/abt.2019.81.3.145.

National Research Council [NRC]. 1996. National Science Education Standards. Washington, DC: National Academy Press. National Academy Press. https://nap.nationalacademies.org/catalog/4962/national-science-education-standards.

Navarro, M. B., and C. E. Forster. 2012. “Nivel de alfabetizacion cientifica y actitudes hacia la ciencia en estudiantes de secundaria.” *Pensam Education Revista Internacional Education Latinoam* 49 (1): 1–17. https://doi.org/10.7764/PEL.49.1.2012.1.

Nehm, R. H., and M. Ha. 2011. “Item Feature Effects in Evolution Assessment.” *Journal of Research in Science Teaching* 48 (3): 237–256. https://doi.org/10.1002/tea.20400.

Norambuena-Meléndez, M., G. R. Guerrero, and C. González-Weil. 2023. “What is Meant by Scientific Literacy in the Curriculum? A Comparative Analysis Between Bolivia and Chile.” *Cultural Studies of Science Education* 18 (3): 937–958. (In press). https://doi.org/10.1007/s11422-023-10190-3.

OECD. 2020. “Results from TALIS 2018, Volume II, Country Note: Chile.” http://www.oecd.org/education/talis/TALIS2018_CN_CHL_Vol_II.pdf. [Google Scholar]

OECD [Organisation for Economic Cooperation and Development]. 2003. The PISA 2003 assessment frame- work. Accessed November. http://www.pisa.oecd.org/dataoecd/46/14/33694881.pdf.

Ogawa, M., and S. Shimode. 2004. “Three Distinctive Groups Among Japanese Students in Terms of Their School Science Preference.” *Journal of Science Education in Japan* 28 (4): 279–291. https://doi.org/10.14935/jssej.28.279.

Oppenheim, A. 1992. *Questionnaire Design, Interviewing and Attitude Measurement*. London: Pinter Publishers.

Osborne, J., S. Simon, and S. Collins. 2003. “Attitudes Towards Science: A Review of the Literature and Its Implications.” *International Journal of Science Education* 25 (9): 1049–1079. https://doi.org/10.1080/0950069032000032199.

Pazza, R., P. R. Penteado, and K. F. Kavalco. 2010. “Misconceptions About Evolution in Brazilian Fresh-Men Students.” *Evolution: Education and Outreach* 3 (1): 107–113. https://doi.org/10.1007/s12052-009-0187-3.

Peeraer, J., and P. Van Petegem. 2015. “Integration or Transformation? Looking in the Future of Information and Communication Technology in Education in Vietnam.” *Evaluation and Program Planning* 48:47–56. https://doi.org/10.1016/j.evalprogplan.2014.09.005.

Reiss, M. J. 2007. “What Should Be the Aim(s) of School Science Education?” In *The Re-Emergence of Values in Science Education*, edited by D. Corrigan, J. Dillon, and R. Gunstone, 13–28. Rotterdam: Sense. https://doi.org/10.1163/9789087901677_004.

Reiss, M. J. 2017. “Education and Sexualities: The Next Generation.” In *Education and Sexualities*, edited by P. Aggleton, 195–210. Vol IV. London: Routledge.

Reiss, M. J., and J. White. 2013. *An Aims-Based Curriculum: The Significance of Human Flourishing for Schools*. London: IOE Press.

Roberts, D. A. 2007. “Scientific Literacy/Science Literacy.” In *Handbook of Research on Science Education*, edited by S. K. Abell and N. G. Lederman, 729–779. Mahwah, NJ: Lawrence Erlbaum Associates.

Schoon, I., A. Ross, and P. Martin. 2007. "Science Related Careers: Aspirations and Outcomes in Two British Cohort Studies." *Equal Opportunities International* 26 (2): 129–143. https://doi.org/10.1108/02610150710732203.

Semilarski, H., and A. Laius. 2021. "Exploring biological literacy: a systematic literature review of biological literacy." *European Journal Education Research* 10 (3): 1181–1197. https://doi.org/10.12973/eu-jer.10.3.1181.

Simpson, R., and J. Oliver. 1990. "A Summary of Major Influences on Attitude Towards and Achievement in Science Among Adolescent Students." *Science Education* 74 (1): 1–18. https://doi.org/10.1002/sce.3730740102.

Smist, J. 1994. *Gender Differences in Attitudes Toward Science*. Annual Meeting of the American Educational Research Association (AERA). New Orleans, USA.

Smyth, E., and C. Hannan. 2006. "School Effects and Subject Choice: The Uptake of Scientific Subjects in Ireland." *School Effectiveness and School Improvement* 17 (3): 303–327. https://doi.org/10.1080/09243450600616168.

Tavakol, M., and R. Dennick. 2011. "Post-Examination Analysis of Objective Tests." *Medical Teacher* 33 (6): 447–458. https://doi.org/10.3109/0142159X.2011.564682.

Tuchman, Gaye. 2011. *Wannabe U: Inside the Corporate University*. Bibliovault OAI Repository, the University of Chicago Press. https://doi.org/10.7208/chicago/9780226815282.001.0001.

Uno, G., and R. Bybee. 1994. "Understanding the Dimensions of Scientific Literacy in Biology." *BioScience* 44 (8): 553–557. https://doi.org/10.2307/1312283.

Valenzuela, J. P., C. Bellei, and D. Ríos. 2014. "Socioeconomic School Segregation in a Market-Oriented Educational System. The Case of Chile." *Journal of Education Policy* 29 (2): 217–241. https://doi.org/10.1080/02680939.2013.806995.

Vegar, R., M. Prenszel, and R. Martin. 2011. "Interest in Science: A Many Faceted Pictures Painted by Data from the OECD PISA Study." *International Journal of Science Education* 33 (1): 1–6. https://doi.org/10.1080/09500693.2010.518639.

Yeh, D. Y., and C. H. Cheng. 2015. Recommendation system for popular tourist attractions in Taiwan using Delphi panel and repertory grid techniques. Tourism Management 46:164–176. https://doi.org/10.1016/j.tourman.2014.07.002.