

RESEARCH REPORT

# Examining Science Achievement in Chile: A Multilevel Model Approach Using PISA 2015 Data

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**Abstract:** *This study employed data from the 2015 Chilean sample of the Programme for International Student Assessment to examine the factors that influence science achievement and factors that may reduce the gender gap in science achievement. Our research was guided by Eccles' Expectancy-Value Theory, which focused on motivational factors that influence gender differences in students' achievement choices and performance. Our results indicate that socioeconomic status (SES), motivation, enjoyment of science, expected occupational status, school SES, and class size are related to higher science achievement. Also, anxiety was negatively associated with science achievement. Implications for Chilean policymakers and school administrators to improve Chilean girls' science achievement are discussed.*

**Keywords:** *PISA, gender differences, science achievement*

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## Introduction

Chile is an emergent country in South America that has shown considerable economic growth over the last decades (The World Bank, 2018). Despite economic progress, gender inequalities remain prevalent (CONICYT, 2017). According to the United Nations, women in Chile have a 30 percent difference in labor force participation when compared to men (United Nations, 2017). Additionally, the Chilean National Statistics Center reports that women are paid about 30 percent less than men on average for the same type of job (Instituto Nacional de Estadística Chile, 2017). Despite this fact, women in Chile have the same level of educational attainment as men (Instituto Nacional de Estadística Chile, 2016). Conversely, of the total number of students who enrolled in a Science, Technology, Engineering, or Mathematics (STEM) college major in Chile, only 19% of those were females, and 81% were males (Comunidad Mujer, 2017). According to Wigfield and Eccles (2000), one reason women participate at lower rates in STEM fields has been linked to previous negative experiences with mathematics or science. Given the labor participation rates, salary disparities, and the participation gap in STEM college majors in Chile, it is important to study the factors that impact Chilean students' science achievement.

The Organization for Economic Co-operation and Development (OECD, 2018a) reported that Chile had one of the largest gender gaps in science achievement of all 72 participating countries based on data obtained from The Programme for International Student Assessment (PISA) administered in 2015. Males scored an average of 454 points compared to females who scored an average of 440 points, which is a gap of 14 points (OECD, 2018a). In comparison, across all OECD countries, males scored 4 points higher than females. These results seem to echo other international student evaluations. For instance, the 2015 *Trends in International Mathematics and Science Study* (TIMSS) reported that in Chile 8th-grade male students scored about 12 points higher in science achievement than female students, making it one of the largest gender gaps within their sample (Martin et al., 2016).

Lower science achievement in secondary education may lead females not to enroll in a STEM major in college (Eccles, 2011), which in turn could hinder women's future economic opportunities and social mobility that come along with a STEM career (Joensen & Nielsen, 2013). For example, Radovic-Sendra (2018) examined gender gaps in mathematics achievement for students in grades 4 through 8 from a national Chilean standardized test called SIMCE (Sistema de Medición de Calidad de la Educación). She found that girls consistently performed worse than boys did. Moreover, this gap was exacerbated when girls came from families with lower socioeconomic status (Radovic-Sendra, 2018). This link between poor achievement and low socioeconomic status was also apparent from PISA 2015 data, where students that came from

lower or disadvantaged socioeconomic backgrounds were “three times more likely than advantaged students not to attain the baseline level of proficiency in science” (OECD, 2016 p.18). According to the Chilean Department of Education, science education brings students the possibility of social mobility (Ministerio de Educación, 2019). Chileans graduating with engineering and medical degrees have higher average earnings than all other college degree students four years after graduating from college (Ministerio de Educacion, 2019). In principle, STEM education would afford women in Chile the opportunity to have social mobility, as such, it is vital to understand whether socioeconomic status can help explain the gap in science achievement.

Few studies have examined gender differences in student achievement in Chile, and fewer have considered students’ performance on international standardized tests. For instance, Bharadwaj and colleagues (2016) used PISA data from 2006 and 2009 in conjunction with data from a Chilean standardized test to examine gender differences in mathematics achievement and again found that male students had better mathematics performance than females and this difference became larger as students progressed through school (e.g., from 4th grade to 8th grade). While prior research has studied the mathematics achievement of Chilean students (e.g., Bharadwaj et al., 2016; Radovic-Sendra, 2018), there is insufficient research on gender differences in science achievement in Chile. Understanding the factors that influence gender disparities in science performance can contribute to improvements in policy to help close this gap and improve the upward economic mobility for Chilean women. At the same time, this type of research could prompt policy initiatives aimed at increasing Chilean girls’ engagement with STEM. Given the importance of science education and the low standardized test scores for Chilean girls, this study aims to expand our understanding of student performance in science. In particular, the purpose of this exploratory study was to examine the factors that related with the science achievement of Chilean students and explore factors that may contribute to the gender gap in science achievement.

## Literature Review

### *Eccles’ Expectancy-value Theory*

The guiding framework for this study relies on the expectancy-value theory proposed by Eccles and colleagues (Eccles, 1983; Wigfield & Eccles, 2000). This theory attributes children’s achievement motivation (i.e., achievement choices and performance) to the individual’s expectancies for success and subjective task-values (Wigfield & Eccles, 2000). The expectancies for success concept refers to the child’s belief of being able to be competent in forthcoming tasks (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). This is closely related to Bandura’s (1997) self-efficacy or self-concept of ability idea that the belief in one’s abilities to succeed in a particular

task will affect one's performance in that task. At the same time, self-concept is affected by the level of difficulty that the child attributes to that task, so for example, children will not choose subjects or courses that seem too hard for them (Eccles, 1983). Furthermore, Eccles (1983) asserts that expectations for success are influenced directly by the individual's cultural milieu. In other words, the environment in which an individual is socialized has a profound influence on the person's belief about individual capabilities of performing a task. More specifically, Eccles (2011) has connected the person's achievement beliefs, performance, and objectives to the child's socioeconomic status and the expectations of people such as parents, teachers, and peers.

Subjective task-values are comprised of four main elements: attainment value, intrinsic value, utility value, and cost (Eccles, 1983; Wigfield & Eccles, 2000). Attainment value is the personal value one attributes to doing well on a task, and it is linked to validating or dismissing aspects of one's self-schema (Wigfield & Eccles, 2000). Intrinsic value is defined as the innate enjoyment a person finds when performing a specific task, and it is related to the concept of intrinsic motivation formulated by Deci and Ryan (1985). Utility value is the usefulness of an activity to the individual's current and future objectives (Wigfield & Eccles, 2000). Costs are the negative aspects that an individual associates with performing a particular task, such as fear, anxiety, and effort (Wigfield & Eccles, 2000).

Eccles' expectancy-value theory attempts to explain what drives children's educational choices and academic achievement (Eccles & Wigfield, 2002; Eccles, 1983). In summary, Eccles (1983) has theorized that expectancy and value have a profound impact on behaviors related to achievement such as "choice of the activity, intensity of the effort expended, and actual performance" (p.81).

Eccles (1983) originally conceived this framework in the context of mathematics achievement and choice because she believed mathematics was essential for completing most STEM-related majors, in which women are less represented. However, this theoretical framework has also been used by researchers to explore gender differences in achievement and choice in both mathematics and other STEM fields (e.g., physics, engineering, technology) (Ball et al., 2016; Musu-Gillette et al., 2015; Rozek et al., 2015; Sáinz & Müller, 2018). This exploratory study applies Eccles' expectancy-value theory to science achievement to help explain gender differences in Chilean students' science achievement.

#### *Prior Research on Science Achievement*

Gender has been shown to be related with student achievement in several academic areas such as reading, mathematics, and science (McGraw et al., 2006; Samad, 2018; Stoet & Geary, 2013). Results from PISA 2015 showed that boys were the top performers in 33 of the 72 participating countries while girls were the top performers in only one of the participating countries in their sample (OECD, 2017a). Moreover, research (e.g., Else-Quest et al., 2013) has

shown that male students report higher levels of confidence in science and mathematics achievement and have higher expectations for success in these subjects than female students. For instance, Else-Quest et al. (2013) surveyed the attitudes of 364 high school students to examine the relationship between mathematics achievement, science achievement, and students' attitudes towards those subjects and found that these "attitudes helped to explain a great deal of variance in mathematics and science achievement" (p. 304). On the other hand, Gonzalez de San Ramon and De la Rica Goicelaya (2016) found that in countries where gender equality is promoted, girls performed better than boys.

Socioeconomic status (SES) has also been linked with higher student achievement in a number of studies (e.g., Caldas & Bankston, 1997; Chen et al., 1996; Delaney et al., 1997; Patton, 2012; Perry & McConney, 2010; Ritchie & Bates, 2013; Sirin, 2005; Tucker-Drob et al., 2014). According to Mueller and Parcel (1981), SES can be defined as a family or a person's position on a hierarchy which depends on social status, access to wealth, and possessions. Not surprisingly, studies have found that science achievement and students' SES are strongly and positively associated (e.g., Sun et al., 2012; Tucker-Drob et al., 2014). For example, Perry and McConney (2010) explored the influence of SES on science achievement in the results from the Australian sample of PISA 2003. They found that the difference in science achievement between students with low and high SES was 80 points with a standard deviation of .80. In a meta-analysis of the literature on SES and academic achievement that examined 74 independent samples, Sirin (2005) found that family SES and school SES had a medium to strong correlation with academic performance. This correlation was moderated by factors related to how SES was measured in each sample, and student characteristics such as grade level, minority group status, and location of their school. He found that a larger proportion of minority students in a specific sample would yield a negative association between SES and academic achievement.

There are several motivational constructs such as self-efficacy, motivation, and enjoyment which have been shown to be related with student achievement (Abdelfattah, 2010; Al-Qahtani, 2013; Deci & Ryan, 1985; Sawtelle et al., 2012). Sawtelle et al. (2012) found that self-efficacy was especially important when predicting achievement in Hispanic populations. In a multilevel model analysis, Sun et al. (2012) found that both self-efficacy and motivation were strong predictors of science achievement. Areepattamannil and Kaur (2013) investigated the factors that influence science achievement among a large sample of students in Canada, and they observed that enjoyment of science along with self-efficacy and motivation were good predictors of science achievement.

Not only are characteristics of the students essential to consider when studying achievement, but aspects of the schools that the students attend have also been linked with achievement. For instance, factors such as the number of teachers in a school, student-teacher ratio, and school resources have been associated with achievement (Areepattamannil & Kaur,

2013; Beese & Liang, 2010; Koc & Celik, 2015; Tucker-Drob et al., 2014). In a project related to Canadian students' science achievement, Areepattamannil and Kaur (2013) found that the shortage of science teachers affected, in particular, the performance of immigrant children.

There have also been many studies linking the type of school (e.g., private, public, voucher) to achievement (e.g., Braun et al., 2006; Gaspard et al., 2019; Wenglinsky, 2007; Witte, 1992). The differences in performance among the types of schools seem to be contextual and linked to specific countries and socioeconomic differences (OECD, 2012). For example, Beese and Liang (2010) conducted an analysis of the factors that affect science achievement between three countries: United States, Canada, and Finland, using data from PISA 2006. They found that school type (private versus public) was associated with higher science achievement scores for the United States and Canada sample, but not for Finland, even after controlling for other school and student characteristics.

#### *The Social and Educational Context of Chile*

Chile has shown a commitment to improving the quality of its educational system through the implementation of programs that target vulnerable students and plans that focus on teachers' professional development (Santiago et al., 2017). Despite the commitment, "about 20% of a cohort does not reach the final year of upper secondary education" (Santiago et al., 2017, p. 13). Chilean schools went through an educational reform in 1981, in which institutions were separated into three types of schools: public, private, and private-voucher (private-voucher schools receive a subsidy from the government for each student enrolled) (Santos & Elacqua, 2016). In 2015, more than half of the Chilean students (55.9%) were matriculated in private-voucher types of schools (Ministerio de Educación de Chile, 2015). Additionally, until 2015, the administration of public schools in Chile was dependent on local municipalities rather than a centralized (federal) government-run system (Santiago et al., 2017).

Today, Chile struggles with both socioeconomic inequalities and gender inequalities. For example, PISA 2015 results showed that Chile had one of the highest levels of socioeconomic inequalities in their sample (Santiago et al., 2017). Chile's Gini index in 2015 was 48%, which is a measure of inequality in a society where a higher percentage indicates greater inequality (The World Bank, 2015). Additionally, the OECD (2018b) reports that in Chile women earn on average 35% less than men even after graduating from college.

Given the inequalities in the educational system, the gender gap in performance in international science standardized tests, and the scarcity of women in STEM fields in Chile, it is pressing to understand science achievement in Chilean students. Therefore, the purpose of this study was to investigate what factors contribute to the science achievement of 15-year-old Chilean students using the data from the 2015 PISA assessment and what factors influence the gender gap in Chilean students' science achievement. Given the economic disparities in Chile and the fact

that SES has been linked with greater science achievement, SES may possibly explain some of the gender gaps in Chile. We also explore whether the facets of Eccles' Expectancy-value Theory (e.g., science self-efficacy, motivation, intrinsic value) and structural characteristics of students' high schools (e.g., class size, proportion of science teachers) reduce the gender gap. Specifically, the research questions guiding this study were:

1. Does controlling for Chilean students' SES reduce the gender gap in their science achievement?
2. Does controlling for factors related with Eccles' expectancy-value theory and high school characteristics reduce the gender gap in Chilean students' science achievement?
3. What factors at both the student and high-school levels are associated with Chilean students' science achievement?
4. Does socioeconomic status moderate the gender difference in Chilean students' science achievement?

## Methods

### *Data Source*

The data for this project came from the PISA test administered in 2015. PISA is an international assessment conducted every three years, which measures students' capabilities in reading, mathematics, and science (OECD, 2017a, p. 22). Every time this assessment is conducted, there is a stronger focus on one of the three main areas mentioned earlier. In 2015, the main focus was science, which meant that students, parents, teachers, and school principals had the chance to answer questionnaires regarding their perceptions on this topic (OECD, 2017a). The data set corresponding to Chile contained 7053 students from 227 schools. However, mainly due to missing school information (e.g., class size, and number of science teachers), the analytic sample for this study was reduced to 4806 students and 206 schools.

### *Variables*

The dependent variable for this analysis was the PISA 2015 science achievement score. Science achievement is defined by OECD (2016) as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (p. 50). Matrix sampling is used when administering the test; this means that during the assessment process, different students complete different smaller parts of a larger assessment. The final science achievement score is then provided in the form of ten plausible values that are estimates of the students' scores if they had completed the full test. Sampling is done this way due to time constraints when administering the PISA assessment (OECD, 2017a) and to obtain "unbiased estimates of population performance parameters" (OECD, 2009, p. 43). The psychometric properties for PISA's test scores including test design and development as well as validity and reliability evidence are reported in the PISA *Technical Report* (OECD, 2017a).

There are 16 independent variables in this study that were chosen based on Eccles' expectancy-value theory, which attempt to explain the psychological and social reasons for gender differences in achievement choices and performance (Eccles, 1983). Due to the hierarchical nature of the data, the independent variables were divided into student-level and school-level variables. The student-level variables for this analysis included: gender, socioeconomic status (SES), science self-efficacy, instrumental motivation, achieving motivation, enjoyment of science, school-related anxiety, emotional support, and students' expected occupational status. These variables reflect the inclusion of individual motivational constructs (e.g., intrinsic motivation, self-efficacy, anxiety) which are critical aspects of the expectancy-value theory, as well as student's expectations for their own future (e.g., expected occupational status) (Eccles, 1983; Eccles, 2014). The science self-efficacy, instrumental motivation, achieving motivation, enjoyment of science, school-related anxiety, and emotional support variables are item response theory scores created by PISA (OECD, 2017a). Students' expected occupational status is an index created by PISA where higher levels indicate higher expectations for future occupational status (OECD, 2017a).

Additionally, social factors such as students' SES and school environment are also essential components of Eccles expectancy-value theory (Eccles, 1983; Eccles, 2014; Wigfield & Eccles, 2000). At the school level, the variables included were class size, the proportion of science teachers, shortage of educational materials, science resources, average school SES, proportion of female students per school, and the type of school (public, private-voucher, and private). The type of school was dummy-coded with public schools serving as the reference group. Thus, the coefficients for private and private-voucher schools were interpreted based on comparisons to public schools.

Descriptive statistics for the independent variables are presented in Table 1. More details on how each of these variables was constructed along with the variables' PISA codes can be found in Tables 3 and 4 in the Appendix. Validity and reliability evidence for each of these PISA constructs are available in the *PISA Technical Report* (OECD, 2017a).

Table 1.

*Description of the independent variables*

Variable	<i>n</i>	<i>M</i>	<i>SD</i>
Student characteristics			
<sup>a</sup> Gender (female)	4806	0.51	0.50
Socio economic status (SES)	4806	-0.06	1.16
Science self-efficacy	4806	-0.02	1.15
Instrumental motivation	4806	0.39	1.04
Achieving motivation			
Enjoyment of science	4806	0.16	1.12
School related anxiety	4806	0.05	0.94
Emotional Support	4806	0.10	1.10
Students' expected occupational status (SEI)	4806	66.36	15.57
School characteristics			
Class size	206	31.45	8.43
Proportion of science teachers	206	0.09	0.05
Shortage of educational materials	206	-0.45	0.82
Science resources	206	4.26	2.50
School SES	206	-0.19	0.96
Proportion of females	206	0.48	0.22
<sup>a</sup> Private schools	206	0.32	0.47
<sup>a</sup> Private-voucher schools	206	0.37	0.48
<sup>a</sup> Public schools	206	0.31	0.46

a. Means represent the proportion of the dummy coded variable

*Analysis Techniques*

Multilevel linear modeling (MLM) procedures were used to construct a two-level model to investigate the factors that are related to 15-year-old Chilean students' science achievement and to investigate the gender gap in this sample. MLM is an appropriate method to examine these data because the data have a hierarchical structure (i.e., students are clustered or nested within their schools), and we are interested in variables at both levels of the hierarchy (i.e., students and schools). Given the multilevel structure, the observations are not independent. Not considering the clustered nature of the data could lead to bias coefficient estimates and standard errors (Hox et al., 2018). The software used for this analysis was HLM 7.03 (Raudenbush et al., 2013). This software is designed to work with clustered data and allows the use of plausible values in the analysis. To avoid problems with sampling and bias within the data, survey weights provided by PISA were included at both the student and high-school levels.

Prior to estimating our models, we assessed the adequacy of the assumptions underlying MLM following procedures outlined in Raudenbush and Bryk (2002) and Hox et al. (2018). Normal probability plots and residual plots indicated assumptions of linearity, normality, and homoscedasticity were satisfied. Residual plots were also checked for potential outliers and

influential data points. An examination of the variance inflation factors revealed that multicollinearity was not an issue in our models. Finally, we compared model-based standard errors and robust standard errors to identify possible misspecification of the distribution of random effects. All models were estimated using full maximum likelihood.

The multilevel models were constructed using a bottom-up approach. That is, we began with the simplest model possible then added the variables and tested their significance in the model (Hox et al., 2018). This process was accomplished in five steps. First, an unconditional model was calculated in which there were no predictors at either level. The purpose of this step was to decompose the variability in science achievement into variation among students within high schools and variation between high schools. Second, a model with only gender was estimated to investigate the gender gap in this sample of Chilean students. Next, SES was added to the model to examine the first research question (i.e., whether the gender gap is reduced once SES is taken into account). Fourth, our set of variables operationalizing Eccles' expectancy-value theory and structural characteristics of the high schools were added to the model to investigate whether these variables help explain the gender gap (i.e., Research Question 2) and to examine the relationship these variables have with science achievement (i.e., Research Question 3). Finally, an interaction effect between gender and SES was entered to answer the Research Question 4 (i.e., whether the relationship of gender on science achievement varies by SES).

As commonly done in multilevel analyses, variables were rescaled or centered before entering them into the model, according to the research questions. The student-level variables science self-efficacy, instrumental motivation, achieving motivation, enjoyment of science, school-related anxiety, emotional support, and students' expected occupational status (SEI) were grand mean-centered. Thus, the intercept modeled at level two represents the average school-level science achievement adjusted for differences on these level-1 variables. Gender and socioeconomic status (SES) were group mean-centered, as recommended by Enders and Tofighi (2007), to be able to test their interaction effect. Additionally, since group mean centering removes any between-group effects, the group means for gender (i.e., proportion of female students) and SES (i.e., average school SES) were included in the analysis in the school-level model. Moreover, all school-level variables were grand mean centered (Enders & Tofighi, 2007).

## Results

First, the null model was computed and the intraclass correlation was calculated to understand how much variation in science achievement was due to differences across high schools. Results indicate that 43.6% of the variance in science achievement was due to differences across high schools. The design effect, which quantifies the effect of the independence violations on the standard error estimates, for this study was 11.2. The large intraclass correlation and design

effect provide further support for conducting a multilevel analysis. Additionally, coefficient estimates from the null model indicated that the grand average science achievement for Chilean students was 434 points, which is below the average for science in the PISA 2015 international scale ( $M=493$ ,  $SD=100$ ).

The final full model is shown in the following equations:

*Level-1 Model:*

$$\begin{aligned} \text{Science Score} = & \beta_{0j} + \beta_{1j} (\text{Gender}_{ij}) + \beta_{2j} (\text{SES}_{ij}) + \beta_{3j} (\text{Emotional support}_{ij}) + \beta_{4j} (\text{Science-self efficacy}_{ij}) \\ & + \beta_{5j} (\text{Intrinsic motivation}_{ij}) + \beta_{6j} (\text{Achieving motivation}_{ij}) + \beta_{7j} (\text{Enjoyment of} \\ & \text{science}_{ij}) + \beta_{8j} (\text{School anxiety}_{ij}) + \beta_{9j} (\text{SEL}_{ij}) + r_{ij} \end{aligned}$$

*Level 2 Model:*

$$\begin{aligned} \beta_{0j} = & \gamma_{00} + \gamma_{01} (\text{Proportion of female students}_j) + \gamma_{02} (\text{Average school SES}_j) + \gamma_{03} (\text{Average class} \\ & \text{size}_j) + \gamma_{04} (\text{Proportion of science teachers}_j) + \gamma_{05} (\text{Educational shortages}_j) + \gamma_{06} \\ & (\text{Science resources}_j) + \gamma_{07} (\text{Private schools}_j) + \gamma_{08} (\text{Public-voucher schools}_j) + u_{0j} \end{aligned}$$

$$\beta_{qj} = \gamma_{q0}, \text{ for } q = 1, 2, \dots, 8, 9.$$

Results from each step of the model can be found in Table 2. In the full model (Model 3), the variance component representing within school variation decreased significantly from 4470.7 to 3873.3. This indicates that the student characteristics explain around 13.4% of the variation in science achievement that is due to differences among students within high schools. The final model explained a large portion of the school-to-school variation in mean science achievement. Specifically, around 76.8% of the variation in mean science achievement scores can be explained by the level-2 variables.

Using our model estimates in Table 2, we can begin answering our research questions:

1) *Does controlling for Chilean students' SES reduce the gender gap in their science achievement?*

When we initially measured the impact of gender on science achievement (Model 1), we found that females scored approximately 22 points lower when compared to males. When we controlled for SES, we found that this gap was reduced only by 1.3 points (Model 2). However, SES was significantly and positively related to science achievement. In this second model for each unit increase in SES students' scores in science, achievement increased by about 11 points.

2) *Does controlling for factors related with Eccles' expectancy-value theory and high school characteristics reduce gender gap in Chilean students' science achievement?*

When we examined our full model (Model 3), we concluded that the gender gap in science achievement for Chilean students while reduced was still statistically significant. Females on average scored 17.7 points less than males in science achievement scores even after accounting for factors within Eccles's expectancy-value theory and structural characteristics of the high school.

3) *What factors at both the student and high-school levels are associated with Chilean students' science achievement?*

At the student level, gender ( $\gamma = -17.69$ ), SES ( $\gamma = 8.20$ ), achieving motivation ( $\gamma = 3.78$ ), school anxiety ( $\gamma = -15.27$ ), enjoyment of science ( $\gamma = 9.15$ ), and students' expected occupational status ( $\gamma = 0.67$ ) were significantly related with science achievement. The effect of school anxiety was especially noteworthy because for each unit increase in school anxiety, students scored on average 15 points less in science achievement when controlling for the rest of the variables in the model. In addition, school anxiety, enjoyment of science, and SES had the three biggest effects on science achievement, as measured by the standardized coefficients. On the other hand, emotional support, science self-efficacy, and intrinsic motivation were not statistically related with science achievement when controlling for other variables in the model. At the high-school level besides average school SES ( $\gamma = 44.99$ ), only average class size ( $\gamma = 1.62$ ) was significantly related to school mean science achievement. This implies that for each unit increase in school-level SES, average science achievement scores would increase by 45 points, and for each unit increase in class size, average science scores would increase by 1.6 points.

4) *Does socioeconomic status moderate the gender difference in science achievement?*

An interaction effect between SES and gender was entered into the model to assess whether the relationship between gender and science achievement varies by SES. However, the interaction effect was not statistically significant ( $\gamma = -2.83$ ,  $p = .44$ ). This indicates that the impact of SES on science achievement was similar for both males and females.

Table 2.  
Multilevel model estimates: coefficients, standard errors, and variance components

Variables	Null Model	Model 1: Female	Model 2: Female + SES	Model 3: Full Model	Model 3: Standardized Coefficients
<b>Student level</b>					
Intercept $\gamma_{00}$	434.07 (6.32)***	433.89 (6.37)***	433.77 (6.39)***	461.07 (2.96)***	
Female		-22.32 (2.77)***	-21.03 (2.78)***	-17.69 (2.77)***	-0.10
SES			10.63 (1.60)***	8.20 (1.59)***	0.11
Emotional support				-2.83 (1.25)	-0.04
Science self-efficacy				-0.07 (1.29)	-0.001
Instrumental motivation				-3.86 (1.46)	-0.05
Achievement motivation				3.78 (1.50)**	0.04
Enjoyment of science				9.15 (1.37)***	0.12
School Anxiety				-15.27 (1.33)***	-0.17
Expected occupational status				0.67 (0.09)***	0.12
<b>School level</b>					
Proportion of females				20.92 (20.05)	0.05
School SES				44.99 (4.93)***	0.50
Class size				1.62 (0.44)**	0.16
Proportion of science teachers				29.72 (91.79)	0.02
Educational shortages				-5.32 (5.18)	-0.05
Science resources				1.06 (1.35)	0.03
Private schools				11.99 (12.80)	0.07
Private-voucher schools				11.02 (9.00)	0.06
<b>Variance components</b>					
Within school variability $\sigma^2$	4470.67	4364.36	4292.98	3873.30	
Between school variability $\tau_{\beta}$	3460.00	3494.81	3514.98	803.06	
<b>Pseudo <math>R^2</math></b>					
Variability explained at level 1				0.134	
Variability explained at level 2				0.768	

\*\* $p < .05$ , \*\*\* $p < .001$

## Discussion

This study examined the factors that contribute to the gender gap in Chilean students' science achievement and explored what other factors influence the science achievement of 15-year-old Chilean students using the data from the 2015 PISA assessment. Even after taking into account student and high-school characteristics, including aspects of Eccles' Expectancy Value Theory, we still found a statistically significant gap in science achievement scores between females and males, where females scored on average 18 points lower than males. This finding is not surprising and confirms other research that found a gender gap in STEM achievement in developing countries like Chile, where males tend to outperform females (Radovic-Sendra, 2018; Stoet & Geary, 2013).

We also found that students' SES had a positive impact on science achievement, meaning that students with higher SES have higher scores in science achievement, which is also not surprising given that a number of studies have found that the socioeconomic status of a student can have a profound influence on achievement (Radovic-Sendra, 2018; Sun et al., 2012). The relationship of SES and science achievement also aligns with Eccles' Expectancy Value Theory in that students' perceptions of their achievement abilities are influenced by their cultural milieu and SES, which in turn will affect their achievement choices and ultimately their performance (Eccles, 1983).

At the student level, achievement motivation, enjoyment of science, expected occupational status, and school anxiety had a significant relationship with science achievement. All of these constructs align with Eccles' Expectancy Value theory because they affect students' achievement behaviors, persistence, choice, and performance (Parsons Eccles et al., 1984). Also, anxiety had one of the largest effects on science achievement (as measured by standardized coefficients). Anxiety can be detrimental in the context of achievement for students, but it is worth noting that within STEM college majors, females tend to experience higher levels of anxiety than males (Udo et al., 2004). Therefore, this is a factor that Chilean policymakers should account for when trying to engage Chilean girls with science. Implementing policies or incentives aimed at reducing school-related anxiety may be a worthwhile initiative for improving student outcomes, particularly science achievement.

While we found support for Eccles' Expectancy Value Theory, there were some areas where the theory was not supported, specifically regarding the utility value and expectations for success aspects of the theory. For instance, Eccles claims that the perceived usefulness of a task to a person's future objectives (e.g., utility value) would influence students' motivation and achievement in science. However, in our study, instrumental motivation to learn science, emotional support, and science self-efficacy were not related to science achievement in Chile.

Perhaps the way these questions were structured was not appropriate for the Chilean context. In other words, there could be underlying cultural reasons as to why these constructs were not meaningful for the Chilean context. For example, thinking about the instrumental motivation construct, are students making the connection between what they are learning in science and how it can help them in their future careers? Is there something in the pedagogy that prevents them from understanding the practical use of what they are learning? For example, Cofré et al. (2010) note that much of the science curriculum in Chile focuses on memorization of facts rather than applying concepts to real-world problems.

At the high school level, only school SES and class size were related to science achievement. The standardized effect for school SES was quite substantial. Something similar was found by Troncoso et al. (2016) in another study done with Chilean students regarding mathematics achievement. They found that mathematics achievement scores were negatively associated with being a female and attending a low SES school. The fact that being female and attending a low SES school were associated with lower science achievement could suggest a compounding effect for girls at lower socioeconomic schools. School administrators should be made aware of the greater risk for girls from lower socioeconomic families and policymakers could implement policies aimed at this vulnerable population. For instance, the government could implement programs aimed at increasing girls' engagement in STEM activities such as the 'She Can' STEM Summer Camp, which is a program in the Washington D.C. area in the United States run by the Department of Education (U.S. Department of Education, 2018). In these summer camps, girls from 6<sup>th</sup> to 8<sup>th</sup> grade have the opportunity to engage in fun STEM activities for ten weeks (U.S. Department of Education, 2018).

The present work was also able to further shed light on possible reasons for the gender gap in science achievement in Chile. However, from examining our final model one could conclude that rather than individual motivational factors, or structural school circumstances preventing girls from succeeding in science achievement, there might be societal reasons for why there is a gender gap in science achievement in Chile. The fact that Chilean females are lagging in science achievement compared to males could be attributed to the educational choices related to STEM that have led them to become more or less competent in their performance (e.g., completing advanced physics course) (Eccles, 2014). In the context of our sample, these educational choices might be influenced by the patriarchal nature of Chilean society, in which there is a tendency to stereotype STEM subjects and professions as male-related and this could prevent girls in Chile from pursuing them (Comunidad Mujer, 2017). These societal and cultural aspects need to be examined further so that girls have equal opportunities and are equally supported as boys in order to be able to succeed in STEM. The Chilean government has tried to address the gender gap in science achievement, and equity issues in general, by creating the Ministerio de la Mujer y la Equidad de Género (Department of Women and Gender Equity) in

2015, (CONICYT, 2017). This government unit has attempted to promote gender equity in different aspects of Chilean life such as public policy, labor market, gender violence, and education. Despite these efforts, only 9% of Chilean female students are choosing to enroll in a STEM college major, which is relatively low when compared to 47% of the Chilean males students who decide to register in a STEM major (Comunidad Mujer, 2017).

Further research is needed to understand the cultural nuances and stereotypes regarding gender issues that are part of Chilean society which could be impeding girls to be as successful as boys in STEM. This research, for example, may include measurements regarding parents' attitudes. It may contain specific questions about the way parents interact with their children, their academic expectations for their children, and to what extent their stereotyped notions influence children's achievement behaviors. The contribution parents play in the achievement of their students is a critical part of Eccles Expectancy Value Theory, and it has shown to influence the way children perform in STEM subjects (Eccles, 1987; Šimunović et al., 2018).

### Limitations

As with any piece of research, ours is not without its limitations. One limitation of this study was related to the proxies used to operationalize Eccles' expectancy-value theory. For example, there were concepts within the expectancy-value theory that were not included in the model because we lacked the ability to measure them within the available data. Specifically, PISA does not include information regarding parents' and teachers' perceptions on their expectations of their students' performance, nor does it provide information about caretakers' opinions on gender roles, so this aspect of Eccles' theory was not included in this analysis. Our results should also be interpreted as correlational and not causal. As with all observational data, the possibility of the omitted variable bias prevents causal interpretation of the parameter estimates.

Another limitation of this study was that the proportion of schools sampled by PISA might not be entirely representative of the Chilean population. In 2015, the Chilean government reported that 36.5% of schools were public, 55.9 % were private-voucher schools, and 7.6% were private schools (Ministerio de Educación de Chile, 2015), but the 2015 Chilean PISA sample had 34% public schools, 40% private-voucher schools, and 26% private schools. Moreover, the PISA Chilean sample "excluded 0.04% of its students who live in Easter Island, Juan Fernandez Archipelago and Antarctica" (OECD, 2017b, p. 257).

With these limitations in mind, we believe that this study still provides valuable insights into the factors that influence science achievement in Chile and can offer beneficial information for Chilean policymakers.

## Conclusion

In this study, we explored the factors related with Chilean high school students' science achievement and the gender gap in science achievement using Eccles' Expectancy Value Theory. Our findings indicated that male students had an advantage in science performance over female students, and this gap still persisted when SES and other characteristics of Eccles' expectancy-value theory were factored in. However, more needs to be done to better understand and alleviate the gap in science achievement between males and females. Findings from this study suggest that SES, motivation, enjoyment of science, expected occupational status, school SES, and class size are related to higher science achievement. In addition, anxiety was negatively associated with achievement. However, other structural characteristics of the school (e.g., proportion of science teachers, science resources, and school type) did not seem to be linked to science achievement. This suggests that there might be cultural or societal reasons for why there is a gender gap in science achievement in Chile, which could be addressed with further research. This study was a first step in examining the factors that influence science achievement in Chile. We hope that administrators and policymakers can use these findings to further discuss how to improve science achievement of Chilean girls.

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### Appendix. Description of independent variables

Table 3. <sup>a</sup>Variables at the student level

Variable	Definition	PISA Code
Gender	Dummy coded variable measuring gender (female = 1, male =0)	ST004D01T
Socio economic Status (SES)	Variable created by PISA derived from several questions regarding parents' jobs and home possessions.	ESCS
Science self-efficacy	Item response theory (IRT) variable created by PISA derived from answers to question ST129: 'How easy do you think it would be for you to perform the following tasks on your own?'. E.g. 'Explain why earthquakes occur more frequently in some areas than in others.'	SCIEEFF
Instrumental motivation	IRT variable created by PISA derived from answers to question ST113: How much do you agree with the statements below. E.g. 'Many things I learn in my <school science> subject(s) will help me to get a job.'	INSTSCIE
Achieving motivation	IRT variable created by PISA derived from answers to question ST119: To what extent do you disagree or agree with the following statements about yourself? E.g. 'I want to be the best, whatever I do.'	MOTIVAT
Enjoyment of Science	IRT variable created by PISA derived from answers to question ST094: How much do you disagree or agree with the statements about yourself below? E.g. 'I generally have fun when I am learning <broad science> topics.'	JOYSCIE
School-related anxiety	IRT variable created by PISA derived from answers to question ST118: To what extent do you disagree or agree with the following statements about yourself? E.g. 'I often worry that it will be difficult for me taking a test.'	ANXTEST
Emotional Support	IRT variable created by PISA derived from answers to question ST123: Thinking about the <this academic year>: to what extent do you agree or disagree with the following statements? E.g. 'My parents are interested in my school activities.'	EMOSUPS
Students' expected occupational status	Index variable created by PISA from question ST114. Higher levels of this variable indicate that students reported higher expectations for their future occupational status.	BSMJ

a. For more information on these variables, consult the PISA 2015 Technical Report.

Table 4. <sup>a</sup>Variables at the school level

Variable	Definition	PISA Code
Class size	This variable indicated the average class size, and it was created by PISA from question SC003.	CLSIZE
Proportion of science teachers	Variable the indicated the proportion of science teachers, calculated by PISA from questions: SC018, SC019	PROSTAT
Shortage of educational materials	Index variable that describes the lack of school resources created by PISA from questions: SC017Q05NA, SC017Q06NA, SC017Q07NA, and SC017Q08NA.	EDUSHORT
Science Resources	Index variable that indicated the amount of school resources specific to science, created by PISA from question SC059.	SCIRES
Proportion of females	Variable computed by researchers that indicated the proportion of females in each school.	
School SES	Variable computed by researchers that indicated the average SES in each school.	
School type	Dummy coded variable (Public = 0, Public-voucher= 1, Private =2) derived from SCHLTYPE in PISA 2015 school data set.	SCHLTYPE

a. For more information on these variables consult PISA 2015 Technical Report