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Gender and Psychological Variables as Key Factors in Mathematics Learning: A Study of Seventh Graders in Chile

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ABSTRACT

Chile is one of the countries with the largest gender gaps in high school mathematics achievement. Gender differences were studied examining the mathematics performance of 1,380 seventh grade students from 41 public schools, psychological variables related to achievement, and their perceptions of teachers' support and expectations. Students' self-reported attitudes and perceptions were assessed, as well as achievement at the beginning and end of the school year. Multivariate analysis of variance and co-variance, and multi-level regression analyses were performed. Significant differences were found favoring boys in mathematics achievement, motivation to learn mathematics, and math self-concept; and favoring girls regarding perceptions of teachers' instructional support. Controlling for prior achievement, math self-concept and students' perceptions of teacher expectations are significant predictors of mathematics achievement.

1. Introduction

In the strive for educational equality, gender differences are a recurring topic in discussions of the mathematics performance of students on international comparative tests, especially in higher grades (Organization for Economic Co-operation and Development (OECD), 2016, 2019). Chile is a country with a particularly large gender gap favoring boys, as shown by results of the Trends in International Mathematics and Science Study (TIMSS), where Chile showed the highest gender gap of all participating countries in 8th grade, in favor of boys (18 points) (Mullis et al., 2016). Along the same lines, results of the Programme for International Student Assessment (PISA) in 2015 and 2018 also showed a significant gender gap in favor of male students, which has been stable over the last decade. The only difference between 2015 and 2018 was that male achievement dropped significantly (Educational Quality Agency Agencia de Calidad de la Educación, 2019b).

The results of the 2013 and 2014 national mathematics achievement tests (Measurement System of Education Quality of Chile [*Sistema de Medición de la Calidad de la Educación de Chile, SIMCE]*) are consistent with international comparative test results in showing a statistically significant difference favoring boys in eighth and tenth grade, while showing no differences in 4th and 6th grade (Educational Quality Agency Agencia de Calidad de la Educación, 2015). Consistent with national and international test data, a research study conducted among 1,437 pre-school and elementary school students in Chile found no differences based on gender in basic math competence. This study evaluated the domains of relational and numeric competence of students using the Utrecht Early Mathematical Competence Test (Gamal et al., 2014).

Differences found in higher grades persist, however, as evidenced by the 2014 results of the Chilean University Entrance Exam

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(*Prueba de Selección Universitaria en Chile, PSU*). Results revealed that girls obtained average scores that are significantly lower than those of boys. Furthermore, the number of male students who are considered top performers is nearly four times greater than the number of female students with similar scores, despite the fact that the percentage of female students taking the test is slightly higher (Department of Evaluation, Measurement and Educational Registry (DEMRE), 2015). Likewise, in Chile as in other countries around the world, there are marked gender differences in the choice of field of study, professions and jobs. Men tend to choose programs of study related to Sciences, Technology, Engineering and Mathematics (STEM areas), whereas women choose those related to social sciences, caregiving, education, food and apparel (Charles & Bradley, 2002; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2012). This is manifested later as a gender salary gap (Ñopo, 2012; United Nations Development Programme (UNPD), 2010; World Bank, 2012).

According to the results of a meta-analysis based on TIMSS and PISA data with a sample of 493,495 students ages 14 to 16 from 69 countries around the world, on average, countries display similar levels of academic achievement in mathematics according to gender, although there is a large variation in the magnitude and direction of the effect sizes of the differences across countries (Else-Quest et al., 2010). However, the findings of this meta-analysis demonstrate that although boys and girls in several countries display similar levels of achievement, in all countries that were considered for the study boys presented more positive attitudes and feelings about mathematics (motivation, math self-concept, confidence, among others) than girls. According to the authors, this indicates the important role of socialization in the establishment of gender differences in math achievement (Else-Quest et al., 2010).

It is important to note that the gender gap in mathematics achievement in the United States and other Western developed countries has disappeared (Hyde et al., 2008), and that very recently this gap has also decreased in Chile (Educational Quality Agency Agencia de Calidad de la Educación, 2019a, 2019b). However, studies have demonstrated the prevalence of gender stereotypes with regard to mathematics as a domain, attributing females less ability, talent and interest in this discipline compared to males, and hence, mathematics is perceived as a symbolically masculine domain (Hyde et al., 1990; Hyde et al., 2008; Steffens & Jelenec, 2011). This stereotype has been found both in studies that utilize direct methods such as self-report questionnaires, and in studies that utilize automatic implicit associations, with both students and educators (Cvencek et al., 2015; Cvencek et al., 2011; Kessels, 2005; Nosek et al., 2002; Nosek & Smyth, 2011; Steffens et al., 2010). The findings based on implicit associations were replicated in Chile for early elementary school grades (Huepe et al., 2016). Likewise, the findings of a study performed with 180 Chilean kindergarteners and their parents from low and high SES background showed that 5-year-old children associated math with boys on implicit stereotype measures. In addition, their parents also believed that math was a masculine domain, on both implicit and explicit stereotype measures (del Río et al., 2018). The same was observed in their pre-school teachers (del Río, Strasser, & Susperreguy, 2016). In a previous study conducted with 81 Chilean kindergarteners Del Río and Strasser (2013) had found that 5-year old pre-school students presented explicit math gender stereotypes. These studies regarding math stereotypes are complemented by research that found that parents who have higher levels of expectations about math skills for their children's success in first grade, report a higher frequency of home numeracy practice, and that maternal practices at home predicted children's numeracy outcomes (del Río, Susperreguy, Strasser, & Salinas, 2017).

However, in Chile little empirical evidence exists regarding the factors that influence the marked differences between boys and girls with respect to mathematics learning *in higher grade levels*. One study filmed 40 seventh-grade math classes, where gender differences start manifesting themselves in terms of actual performance differences, in public elementary schools in Chile. The study was conducted in order to analyze the role of gender in the pedagogical interactions among students and teachers, and the relationship between teachers' self-reported beliefs and their teaching practices. The findings of the study demonstrated that teachers ask boys about twice as many questions requiring complex cognitive processes, give them more feedback, and that boys participate about three times as much in class than girls. This provides initial descriptive evidence that there are important gender-based differences in mathematics instruction in Chile in 7th grade (Espinoza & Taut, 2016a). However, there is missing evidence regarding the effects that these differential interactions might have on students' motivation, attitudes and achievement, and the study presented here addresses this void.

The following sections expand on some factors highlighted in the international literature that are related to gender-based individual differences in mathematics achievement. These include psychological variables such as students' math self-concept and motivation, as well as perceived teacher support and teacher expectations.

1.1. Students' math self-concept and motivation

Many studies have recognized the relationship between general levels of academic achievement by students and their intelligence (Gottfredson, 2002; Kuncel et al., 2004) or working memory (St. Clair-Thompson & Gathercole, 2006). For example, general intelligence accounts for about 25% of the variance in level of educational attainment among students (Kuncel, et al., 2004). Various studies have sought to determine which additional variables can explain the percentage of variance not attributable to intelligence, with motivation being one of the most widely studied. Based on a meta-analysis of numerous studies regarding the effects of different factors on educational attainment, Hattie (2009) found that among the psychological constructs studied (at student level), motivation is one of the variables with the strongest effect on educational attainment, once previous cognitive ability and learning progress have been accounted for.

While there are many theories on motivation (Gutman & Schoon, 2013), one of the most influential and widely used in the school context is the Expectancy-Value Theory (Eccles et al., 1983; Wigfield & Eccles, 2000). According to this theory, an individual's persistence and choice can be explained by their beliefs regarding how well they will perform a task in the future and the value they attribute to the task in question. Hence, commitment to an activity is the product of expectations about success and the value attributed to the task. Educational researchers evaluate these two constructs within a specific academic domain because empirical evidence demonstrates that ability self-concept and the value associated with a task can be distinguished within a specific domain by early school-aged children (Gottfried, 1985, 1990; Marsh, 1990; Möller et al., 2009; Wigfield et al., 1997). Domain-specific ability self-concept is often measured by asking students how well they believe they can succeed at a given task and how valuable it is, or by asking them how satisfied they will feel upon completing the task. Wigfield and Eccles (2000) suggest that the subjective value assigned to a task has three main components: its *importance*, which is related to how important it is for the individual to succeed at a given task in order to affirm their self-concept or need for power, achievement or prestige; *intrinsic task value*, which refers to the level of enjoyment the individual obtains based on their level of commitment to a specific task or activity; and *utility*, which implies how much the individual's level of commitment to the task helps them improve their studies or achieve other, more general objectives.

In this way, the variables known in the Expectancy-Value Theory as *ability self-concept*, *intrinsic value*, and *utility value* correspond to what in this study will be referred to as *math self-concept*, *intrinsic motivation*, and *extrinsic motivation*, respectively. In empirical studies, domain-specific self-concept is often used as an indicator of the expectancy component and domain-specific interest or motivation is used as the value component (Marsh et al., 2005). Although theoretically, expectancy beliefs and self-concept are two different constructs, they are not empirically separable (Eccles & Wigfield, 2002). For this reason, in many empirical studies the expectancy component is measured using a self-concept instrument (e.g., Guo et al., 2015; Meyer et al., 2019; Trautwein et al., 2012). Specifically, academic self-concept has been defined as students' assessment regarding their performance (doing well or poorly) in school in general (general academic self-concept) or in a particular domain, such as math (math self-concept), based on their previous performance as well as different socialization processes. Thus, math self-concept generally is measured by asking students their general judgments about their competencies in that domain (Skaalvik & Skaalvik, 2004b).

On the one hand, intrinsic task value refers to the subjective enjoyment that a student gains due to their engagement in a domain-specific task. Therefore, that construct can be viewed as similar to the *intrinsic motivation* component from self-determination theory (SDT, Deci & Ryan, 1985; Eccles & Wigfield, 2002). On the other hand, utility value refers to students' perceptions about how useful it is to be successful in a domain in terms of how that could impact their future lives. Since the most important aspect of this concept is extrinsic performance rewards, it can be understood as similar to the *extrinsic motivation* component of the SDT (Trautwein, et al., 2012). SDT posits that intrinsic and extrinsic motivation components are distinguished due to the different reasons that give rise to an action. Intrinsic motivation refers to completion of a task due to the fact that it is interesting or enjoyable in and of itself. Extrinsic motivation refers to completion of a task for instrumental reasons such as external pressures or rewards (Deci & Ryan, 1985).

The findings of various previous studies demonstrate the effect of motivation variables on students' math achievement, independent of cognitive factors such as intelligence (e.g. Köller et al., 2019; Steinmayr & Spinath, 2007; 2009), and their role for the Chilean seventh grade sample will be examined in this study.

Overall, various empirical studies have demonstrated a clear relationship between student motivation and math achievement (Elliot & Dweck, 2005; Murayama et al., 2013; Robbins et al., 2004). Specifically, both math self-concept and interest or values show correlations with math achievement (Gottfried, 1985, 1990; Lloyd & Barenblatt, 1984; Steinmayr & Spinath, 2007; 2009; Trautwein et al., 2012). However, at least with high school students, self-concept is a stronger predictor of math achievement than interests (e.g. Lotz et al., 2018). This is in accordance with the assumptions of the Expectancy-Value Theory (Eccles et al., 1983; Wigfield & Eccles, 2000), which suggest that values should be better predictors of academic choices, whereas domain-specific ability self-concept should have a greater correlation with current performance. More specifically, there is a large body of literature that demonstrates a positive relationship between math self-concept and math achievement in secondary school students (Lotz et al., 2018; Marsh, 1986; Tosto et al., 2016).

Furthermore, a large body of empirical evidence utilizing longitudinal data supports the Reciprocal Influence Model between math self-concept and academic achievement (Huang, 2011; Marsh & Craven, 2006; Marsh & Martin, 2011; Möller et al., 2014). According to this model, not only does previous academic achievement influence academic self-concept, but previous beliefs about one's abilities in a domain will also influence the subsequent level of academic self-concept. This model has been tested in different cultures and at different grade levels, and it has demonstrated gender invariance (Antunes & Fontaine, 2007; Marsh et al., 2005; Pinxten et al., 2014). Thus, for instance, the study of Skaalvik and Skaalvik (2006) shows that students' self-perceptions regarding math strongly predicted subsequent levels of math achievement, above and beyond the prediction that could be made from prior levels of math achievement.

Regarding gender differences, international studies show that there are differences in the average levels of academic self-concept between boys and girls that are in accordance with dominant gender stereotypes. That is, girls have higher self-concept in verbal domains (Heyder et al., 2017; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), and boys have higher math self-concept (Fredricks & Eccles, 2002; Jacobs et al., 2002; Marsh, 1989; Skaalvik & Skaalvik, 2004a; Wilgenbusch & Merrell, 1999). Previous international studies have also found that gender differences favor boys in terms of intrinsic and extrinsic motivation in math (Gaspard, Dicke, Flunger, Schreier, Häfner, Trautwein, & Nagengast, 2015; Skaalvik & Skaalvik 2004a; Steinmayr & Spinath, 2010). Related to intrinsic motivation, a study by Skaalvik and Skaalvik (2004a) that utilized a total of 907 Norwegian students in sixth, ninth and eleventh grade, and also the first year of "senior high", reported that male students demonstrate, controlling for grades, higher levels of intrinsic motivation and self-enhancing ego orientation in math compared to female students, whereas girls had higher levels of intrinsic motivation for learning languages than did male students. Similarly, based on a sample of 1,867 ninth-grade German students, Gaspard et al. (2015) found that girls reported lower intrinsic motivation and perceived math as less useful for both their general and their professional future than boys.

1.2. Student perceptions of teacher support and teacher expectations

Prior research demonstrated that student perceptions of the quality of teacher-student interactions in the classroom are related to learning outcomes (Bill and Melinda Gates Foundation, 2012; Pianta et al., 2007). Pianta and Hamre (2009) provide empirical evidence regarding a three-factor model of instructional quality in pre-school and elementary school classrooms, using confirmatory factor analysis, which have been replicated with observational data from secondary school classrooms (Hafen et al., 2014). They distinguish (a) classroom organization, (b) emotional support, and (c) instructional support. The three-factor model is consistent with the three dimensions of instructional quality proposed by Klieme et al. (2009) (also see Lipowsky et al., 2009). According to Pianta and Hamre (2009), emotional teacher support refers to aspects related to teachers-student relationships, teachers´ encouragement to enjoy learning, and regard for students´ perspectives. On the other hand, instructional support refers to the ways in which teachers support students' cognitive and academic development. These two teacher support dimensions are also congruent with the models proposed by other researchers (e.g., Johnson et al., 1983; Patrick et al., 2007).

It is important to notice that it is relevant how much emotional and instructional support students perceive their math teachers to provide to them because it has been shown to be related to math achievement (Ahmed et al., 2010; Bill and Melinda Gates Foundation, 2012; Gregory & Weinstein, 2004; Puklek Levpuscek & Zupancic, 2009; Roorda et al., 2011). Specifically, when students perceived their teacher to be emotionally supportive, they are likely to show higher achievement (e.g., Goodenow, 1993). Additionally, the level of instructional support by teachers has a significant effect on performance in math among adolescent students, particularly in competitive learning environments (e.g., Chen, 2005). Therefore, both the emotional and instructional support domains of instructional quality, as perceived by students in participating mathematics classrooms, have been included in this study, and their roles in predicting mathematics learning have been examined.

Regarding gender differences, studies to date are inconclusive, as some find no differences between male and female students in perceptions of classroom support (DeWit et al., 2010), whereas others find that girls perceive greater classroom support compared to boys (Oelsner et al., 2011), and still others find that boys report higher levels of approval, reinforcement, and corrective feedback by teachers compared to girls (Meece et al., 2006), especially in areas traditionally associated with the masculine gender such as mathematics (Eccles et al., 2011).

Last but not least, student perceptions of teachers' learning expectations have been examined in a large number of studies following the seminal work of Rosenthal and Jacobson (1968), which demonstrated the effects of a self-fulfilling prophecy reflecting teachers' educational expectations as important predictors of student achievement (Auwarter & Aruguete, 2008; Jussim & Eccles, 1992; Palardy, 1998; Palardy & Rumberger, 2008). Differential expectations have been shown to translate into differential teaching practices (Auwarter & Aruguete, 2008; Palardy, 1998; Palardy & Rumberger, 2008), and can in turn influence students' self-concepts and learning expectations (Kuklinski & Weinstein, 2001). From an early age, students perceive these differential learning expectations held by their teachers (Myhill & Jones, 2006). Other studies have shown that teachers possess differential expectations regarding girls and boys in mathematics, reflecting the predominant gender stereotype in society that girls tend to have a lower ability in mathematics compared to boys (Eccles, 1989; Jussim & Eccles, 1992; Li, 1999; Tiedemann, 2000, 2002). These findings have been replicated in Chile in a sample of 208 primary school teacher candidates (Mizala et al., 2015). Furthermore, international empirical studies have shown that teachers' expectations have an influence specifically in students' achievement in math in primary and secondary school (Friedrich et al., 2015; Szumski & Karwowski, 2019), and that students who are members of stigmatized groups, such as girls in mathematics, were indeed more susceptible to the influence of teachers' expectations on their achievement (Jamil et al., 2018; McKown & Weinstein, 2002).

The present study measures students' perceptions of their mathematics teachers' learning expectations and examines their role as one of the predictors of mathematics learning, since this relationship has not yet been explored in Chilean high school students.

2. Research questions and hypotheses

The purpose of this study was to examine gender differences in mathematics performance as well as relevant psychological variables related to mathematics achievement in seventh grade students attending public schools in Chile. The study also sought to determine whether the measured psychological variables predicted these students' mathematics learning. The questions that guided this study are as follows:

1) Do gender differences exist among male and female students in terms of their motivation to learn mathematics, math self-concept, as well as student perceptions of their math teacher's support and expectations regarding student learning?
2) Do gender differences exist among male and female students regarding mathematics performance and learning throughout one school year (7^{th} grade)?
3) Can mathematics learning be predicted by gender, motivation, math self-concept, and student perceptions of teacher support and teacher learning expectations?

The first hypothesis of this study was that boys present higher levels of motivation, a more positive math self-concept, a more favorable perception of the support as well as the level of expectations provided by their math teachers, compared to girls. Second, we expected that boys demonstrated higher levels of achievement in math than girls, at both the beginning and the end of the school year. Similarly, it was hypothesized that gender is a significant predictor of mathematics learning over the course of the school year, specifically that male students show stronger learning progress than girls by the end of the school year. Finally, we expected that students with higher levels of motivation, more positive math self-concept, and more favorable perceptions of mathematics teacher's support and expectations demonstrated greater mathematics learning progress.

3. Methods

3.1. Participants

The sample of 43 participating mathematics classrooms came from 41 public schools in the Metropolitan Region of Santiago de Chile. All 43 participating mathematics teachers gave their informed consent to participate; they were paid an economic incentive and received an invitation to a day of training based on the results of learning among their respective students. The directors of their schools also granted authorization. Each of the 43 mathematics teachers participated with a specific seventh grade math class during 2013 or 2014. The participating teachers were 51,16% women, with their ages ranging from 28 to 65 years ($Me = 46$; $SD = 9.82$).

Of the 41 public schools, five pertained to rural communities while 36 were in urban areas. The majority of the schools served students with middle-low socioeconomic status (SES) ($n = 30$), followed by middle ($n = 6$), low ($n = 4$), and middle-high SES ($n = 1$) (Educational Quality Agency Agencia de Calidad de la Educación, 2014). Regarding the results of the 2013 SIMCE test in mathematics among sixth graders, 63.4% of participating schools ($n = 26$) obtained significantly lower results than the national average among students of similar socio-economic status, whereas 24.4% ($n = 10$) had similar results and 12.2% ($n = 5$) had significantly higher scores (Educational Quality Agency Agencia de Calidad de la Educación, 2014).

A total of 1,380 students participated in the study, including 745 (54%) boys and 635 (46%) girls. All these students agreed to participate and signed an assent for minors, and also had parental permission to participate in the study. Their dates of birth ranged from 1997 to 2002, with 2001 being the most common. That is, the mode student age at the time of participation was 13 years.

3.2. Procedure

This study was part of a larger research project that aimed to study the instructional practices of Chilean public school teachers. In order to measure students' mathematics learning, we used standardized, curricular, vertically scaled mathematics achievement tests which were administered at the beginning and end of the school year (in April and November). The sixth-grade mathematics test was administered at the start of the year, and the seventh-grade test was administered at the end of the year. Therefore, longitudinal math achievement data was available for the students in the sample, allowing to determine the learning progress in students´ mathematics achievement during the school year. Furthermore, at the end of the school year, students also completed a questionnaire that gathered self-reported information about their intrinsic and extrinsic motivation, math self-concept, and perceptions regarding their mathematics teacher's attitudes and practices.

3.3. Data Collection Instruments

The first instrument consisted of a standardized mathematics test from the Learning Assessment System [*Sistema de Evaluación para el Aprendizaje, SEPA*] developed by the Measurement Center [*Centro de Medición MIDE U*C] at the Pontificia Universidad Católica de Chile. This test contains multiple choice items based on the Chilean national curriculum, which is organized in four thematic axes: i) Numbers, ii) Algebra, iii) Geometry and iv) Statistics and Probability. The sixth grade test contains 40 items, and the seventh grade test contains 50 items. Each item presents 4 response alternatives, with one correct answer and three distractors. The tests are vertically scaled, that is, their scores allow an analysis of the comparability of scores between grade levels and over time (equating). Thus, the tests capture learning progress over time when the same cohort of students is tested repeatedly, as occurred in this study.

The degree of difficulty of the items used in the SEPA tests is between 15% and 85%, and the discriminative capacity of each item is greater than 0.2. Results of each student were modeled within the framework of Item Response Theory, specifically, a one-parameter latent regression Rasch model.

The second instrument used in this study was a questionnaire developed to gather self-reported student-level data (see Supp. Table 1). It was constructed based on relevant literature (e.g. Jones & Smart, 1995; Rakoczy et al., 2005; Seegers & Boekaerts, 1996) as well as existing validated instruments (e.g. Fennema & Sherman, 1976; Leder & Forgasz, 2002; Tapia & Marsh, 2004; TERCE, 2013). The first four scales are related to relevant student-level variables: positive math self-concept, negative math self-concept, intrinsic motivation, and extrinsic motivation to learn mathematics. The other three scales are related to student perceptions regarding their teacher's attitudes and practices, in terms of instructional and emotional support, as well as their teacher's level of expectations for their students' learning. All scales had a four-point answer format: (1) Strongly disagree; (2) Disagree; (3) Agree; or (4) Strongly agree, except for the instructional support and emotional support scales that had a 5-point response format: (1) Never; (2) Almost never; (3) Sometimes; (4) Almost always; (5) or Always. We performed a pilot study with a sub-sample of 65 seventh grade students, in order to evaluate the psychometric properties of the scales.

3.4. Reliability Analysis

Mathematics achievement tests showed high internal consistency, as indicated by Cronbach's Alpha coefficient, with values of 0.88 for sixth grade and 0.89 for seventh grade tests. The items on the student questionnaire scales were analyzed using classical test theory, ensuring item-test correlations of at least 0.3, without a distribution among the response categories highly weighted toward

Table 1
Cronbach's alpha coefficient for scales from the Student Questionnaire.

Scales from student questionnaire	Cronbach's alfa coefficient
Positive math self-concept	.805
Negative math self-concept	.775
Intrinsic motivation for mathematics	.843
Extrinsic motivation for mathematics	.697
Teacher instructional support	.848
Teacher emotional support	.772
Teacher learning expectations	.897

the extremes and with an omission percentage of less than 10%. As demonstrated in Table 1, the questionnaire scales reached satisfactory internal consistency (Cronbach's Alpha) of more than 0.69 for all the scales utilized in the study.

3.5. Data Analysis

To answer the first research question, data analysis included descriptive statistics and group mean comparisons defined by student gender, utilizing multivariate analysis of variance (MANOVA) and corresponding post hoc analyses. Meanwhile, a multivariate analysis of covariance (MANCOVA) was performed in which students' pre-SEPA score was used as a co-variable to determine whether group differences were maintained in the psychological variables.

To answer the second research question, a multivariate analysis of variance (MANOVA) was performed to determine whether group differences exist according to gender in math learning (pre-SEPA score, post-SEPA score, and learning progress), along with corresponding post hoc analyses.

To answer the third research question, multi-level regression analyses were implemented, reflecting the nesting of students within classrooms and teachers (Raudenbush & Bryk, 2002). In the regression models we used the result of the post-SEPA test as a dependent variable (DV). Different models with fixed effects of level-1 and level-2 predictors were estimated. Predictors at the student level were gradually added: 1) pre-SEPA, 2) pre-SEPA and gender, and 3) the scores of the scales measuring psychological variables. The level-1 predictors were centered around the group mean in order to facilitate the interpretation of results. The models with level-1 predictors were estimated according to the following equations[2] :

Model 1:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEPAPre_{ij} + r_{ij} \tag{1}$$

Model 2:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * SEPAPre_{ij} + r_{ij} \tag{2}$$

Model 3:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * PosSC_{ij} + \beta_{3j} * NegSC_{ij} + \beta_{4j} * SEPAPre_{ij} + r_{ij} \tag{3}$$

Model 4:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * ExtrinMOT_{ij} + \beta_{3j} * PosSC_{ij} + \beta_{4j} * NegSC_{ij} + \beta_{5j} * SEPAPre_{ij} + r_{ij} \tag{4}$$

Model 5:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * IntrinMOT_{ij} + \beta_{3j} * PosSC_{ij} + \beta_{4j} * NegSC_{ij} + \beta_{5j} * SEPAPre_{ij} + r_{ij} \tag{5}$$

Model 6:

$$\begin{aligned} SEPAPost_{ij} = {} & \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * INSTSupp_{ij} + \beta_{3j} * EMOSupp_{ij} + \beta_{4j} * PosSC_{ij} + \beta_{5j} * NegSC_{ij} + \beta_{6j} * TeLEXP_{ij} \\ & + \beta_{7j} * SEPAPre_{ij} + r_{ij} \end{aligned} \tag{6}$$

Subsequently, a model with level-2 predictors was tested, including the average and standard deviation of the pre-SEPA scores for each classroom, the proportion of male students compared to female students in each classroom, and the teacher's gender. The level-2 predictors were centered around the grand mean. The model with only level 2 predictors is defined as follows:

Model 7:

Level-1:

[2] Equations 1 through 8 use the following variables: SEPAPre = Pre-SEPA Score; SEXStu = Student's gender; PosSC = Positive math Self-Concept; NegSC = Negative math Self-Concept; ExtrinMOT = Extrinsic motivation; IntrinMOT = Intrinsic motivation; INSTSupp = Instructional support; EMOSupp = Emotional support; TeLEXP = Teacher learning expectations; MeSEPAPre = Mean Pre-SEPA score for each classroom; SDSEPAPre = Standard deviation of the pre-SEPA score for each classroom; MFRatio = Proportion of male students compared to female students in each classroom; SEXTea = Teacher's gender.

$$SEPAPost_{ij} = \beta_{0j} + r_{ij}$$

Level-2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * MeSEPAPre_j + \gamma_{02} * SDSEPAPre_j + \gamma_{03} * MFRatio_j + \gamma_{04} * SEXTea_j + u_{0j} \tag{7}$$

The complete and final multi-level model with level-1 and level-2 predictors is determined through the following equation:
Model 8:
Level-1:

$$SEPAPost_{ij} = \beta_{0j} + \beta_{1j} * SEXStu_{ij} + \beta_{2j} * NegSC_{ij} + \beta_{3j} * TeLEXP_{ij} + \beta_{4j} * SEPAPre_{ij} + r_{ij}$$

Level-2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * MeSEPAPre_j + u_{0j}$$

$$\beta_{0j} = \gamma_{10} + u_{1j}$$

$$\beta_{0j} = \gamma_{20} + u_{2j}$$

$$\beta_{0j} = \gamma_{30} + u_{3j}$$

$$\beta_{0j} = \gamma_{40} + u_{4j} \tag{8}$$

Regarding the correlations between predictor variables included in the multi-level regression analyses, these are generally of low to moderate magnitude, while none is above 0.75 (see Supp. Table 3).

3.6. Missing data

Expected maximization (EM; Graham, 2012) was used to account for missing responses. Imputation of missing responses was performed at the level of scale scores for the seven psychological variables measured in this study, as well as the three SEPA results (pre, post, progress). For imputation, two criteria of inclusion were used: The first was that students counted with either SEPA-pre or SEPA-post, and at the same time, with any of the scale scores for the psychological variables measured in the questionnaire. The second was to include those students who counted with both SEPA-pre and SEPA-post, but with none of the psychological scales measured in the questionnaire. 72 students did not meet these criteria and were excluded from the analysis.

4. Results

4.1. Checking the assumptions

A lack of multivariate normality of the student's responses to the questionnaires was determined using Mardia's Test (skewness $g1p = 5.811$, $p < .001$; kurtosis $g2p = 86.924$, $p < .001$). However, because robust tests such as MANOVA and MANCOVA were used, this should not threaten the results. Levene's homogeneity of variance test was also applied, indicating that the variance error was the same across groups of male and female students, except for intrinsic motivation ($p = .033$; see Supp. Table 2).

The results of Maria's test for the SEPA test data reveal that there is also no multivariate normality of the data (skewness $g1p = 1.467$, $p < .001$; kurtosis $g2p = 29.157$, $p < .001$). Therefore, the results of the estimations with a robust standard error were utilized in the multi-level regression analysis, thus ensuring a correct interpretation of the results. The results of Levene's homogeneity of variance test indicate that the variance error is the same across groups of male and female students in SEPA learning progress ($p = .209$; see Supp. Table 2).

4.2. Gender differences in motivation, math self-concept, and teacher perceptions

The results demonstrate that gender differences exist in the set of psychological variables studied (*Wilks'* $\lambda = 0.952$, $F(7, 1372) = 9.945$, $p < .001$). Specifically, group comparisons reveal that boys present significantly higher average levels of both *intrinsic* motivation ($F(1, 1378) = 19.766$, $p < .001$, partial $\eta^2 = 0.014$) and *extrinsic* motivation ($F(1, 1378) = 4.724$, $p = .030$, partial $\eta^2 = 0.003$) in mathematics than girls.

Regarding math self-concept, the study found that boys had a significantly higher *positive math self-concept* than girls ($F(1, 1378) = 33.774$, $p < .001$, partial $\eta^2 = 0.024$). Accordingly, boys have a significantly lower *negative math self-concept* than girls ($F(1, 1378) = 18.921$, $p < .001$, partial $\eta^2 = 0.014$).

Regarding student perceptions of math teachers, the results suggest gender differences in favor of girls in perceptions of *instructional support* ($F(1, 1378) = 6.331$, $p = .012$ partial $\eta^2 = 0.005$). However, no gender differences were observed in *emotional support* ($F(1, 1378) = 2.664$, $p = .103$) nor *teacher learning expectations* ($F(1, 1378) = 0.339$, $p = .528$).

However, the results of the MANCOVA indicate that group differences found in levels of *intrinsic motivation* ($F(1, 1377) = 15.363$, $p < .001$, partial $\eta^2 = 0.011$), *positive math self-concept* ($F(1, 1377) = 20.118$, $p < .001$, partial $\eta^2 = 0.014$), *negative math self-concept* ($F(1, 1377) = 9.371$, $p = .002$, partial $\eta^2 = 0.007$), and perceptions of *instructional support* ($F(1, 1377) = 10.145$, $p = .001$, partial η^2

Table 2
Descriptive statistics of scales from the Student Questionnaire.

Scales		Gender		Total
		Male	Female	
Intrinsic motivation for mathematics	Mean (SD)	2.848 (0.767)	2.658 (0.817)	2.761(0.795)
Extrinsic motivation for mathematics	Mean (SD)	3.448 (0.540)	3.383 (0.570)	3.418 (0.555)
Positive math self-concept	Mean (SD)	2.826 (0.510)	2.664 (0.529)	2.751 (0.525)
Negative math self-concept	Mean (SD)	2.319 (0.542)	2.447 (0.551)	2.378 (0.550)
Teacher learning expectations	Mean (SD)	3.071 (0.529)	3.089 (0.532)	3.079 (0.530)
Teacher instructional support	Mean (SD)	4.108 (0.755)	4.207 (0.701)	4.153 (0.732)
Teacher emotional support	Mean (SD)	3.892 (0.848)	3.967 (0.857)	3.926 (0.853)

Note. SD = Standard Deviation.

= 0.007), are maintained when controlling for the effect of students' prior achievement (pre-SEPA scores). However, after controlling for prior achievement, the gender differences regarding *extrinsic motivation* turned marginally significant in favor of boys ($F(1, 1377) = 3.405$, $p = .065$, partial $\eta^2 = 0.002$).

The descriptive results for the complete sample and the sub-samples of boys and girls are found in Table 2.

4.3. Gender differences in mathematics learning

The results demonstrate the existence of gender-based differences in mathematics learning outcomes (*Wilks'* $\lambda = 0.984$, $F(2, 1377) = 10.972$, $p < .001$). Table 3 presents descriptive statistics regarding these results.

Specifically, the results of the group comparisons indicate that gender differences do exist in favor of boys in terms of prior (start-of-the-year) achievement in math ($F(1, 1378) = 20.450$, $p < .001$, partial $\eta^2 = 0.015$) as well as math achievement at the end of the school year ($F(1, 1378) = 12.511$, $p < .001$, partial $\eta^2 = 0.009$). No gender differences were found in terms of math learning progress across time ($F(1, 1378) = 3.137$, $p = 0.077$).

4.4. Variables predicting mathematics learning

Based on multi-level regression analysis, we find that between-school variation in end-of-year math achievement is statistically significant ($\chi^2(42) = 248.84$, $p < .001$). Specifically, 12.8% of the variance in this variable is attributable to differences at school level (intra-class correlation coefficient (ICC) = 0.128). This suggests that multi-level regression analysis is indicated (Raudenbush & Bryk, 2002).

Meanwhile, the model using prior achievement as the only level-1 predictor (Model 1) indicates that this is a significant predictor of the dependent variable ($t(42) = 20.029$, $\beta = 0.460$, $p < .001$) and that it explains 32.11% of the variance ($R^2 = 0.321$) (see Table 4).

Upon including gender as a second level-1 predictor (Model 2), this variable is not a statistically significant predictor ($t(42) = -0.316$, $\beta = -0.557$, $p = .754$) and hence, a significant increase in explained variance is not generated ($R^2 = 0.328$).

Model 3 included positive and negative math self-concept at the student level, together with prior achievement and gender. The results of this model demonstrate that both positive ($t(42) = 2.665$, $\beta = 5.349$, $p < .001$) and negative math self-concept ($t(42) = -4.398$, $\beta = -7.601$, $p < .001$) are significant predictors of math achievement (see Table 4). This model as a whole explains 35.89% of the variance ($R^2 = 0.359$) (see Table 4).

Subsequently, we added extrinsic motivation (Model 4) and intrinsic motivation (Model 5) as additional level-1 predictors. Neither of the two were statistically significant (intrinsic motivation: $t(42) = 0.150$, $\beta = 0.213$, $p = .881$; extrinsic motivation: $t(42)$

Table 3
Descriptive statistics of the SEPA scores.

Scales		Gender		Total
		Male	Female	
Pre-SEPA score	Mean (SD)	605.23 (44.93)	594.62 (41.59)	600.35 (43.73)
Post-SEPA score	Mean (SD)	621.78 (37.90)	614.82 (34.63)	618.57 (36.58)
Progress SEPA score	Mean (SD)	16.55 (39.09)	20.19 (36.94)	18.22 (38.15)

Note. SD = Standard Deviation; Progress SEPA Score = (Post-SEPA Score–Pre-SEPA score) arithmetic difference.

Table 4
Multilevel predictors of Post-SEPA Score.

Parameter	Model 0		Model 1		Model 2		Model 3		Model 4
	B (SE)	p	B (SE)	p	B (SE)	p	B (SE)	p	B (SE)
Intercept	**618.32(2.18)**	< .001	**618.37(2.19)**	< .001	**618.37(2.17)**	< .001	**618.37(2.17)**	< .001	**618.36(2.20)**
Individual (Level-1)									
Pre-SEPA Score			**0.46(0.02)**	< .001	**0.46(0.02)**	< .001	**0.40(0.02)**	< .001	**0.40(0.03)**
Student's gender*					−0.56(1.76)	.754	0.46(1.76)	.793	0.51(1.83)
Positive math self-concept							**5.35(2.01)**	.011	5.19(2.21)
Negative math self-concept							**−7.61(1.73)**	< .001	**−7.61(1.90)**
Extrinsic motivation									0.24(1.60)
Intrinsic motivation									
Teacher instructional support									
Teacher emotional support									
Teacher learning expectations									
Cluster (Level-2)									
Mean Pre-SEPA score*									
SD Pre-SEPA score									
Classroom composition*									
Teacher's gender*									
Level-1 R^2	-		.321		.328		.359		.366
Level-2 R^2	-		-		-		-		-
Deviance	13726.07		13219.26		13212.14		13150.02		13145.15
Free parameters	2		4		7		16		22

Parameter	Model 4	Model 5		Model 6		Model 7		Model 8	
	p	B (SE)	p	B (SE)	p	B (SE)	p	B (SE)	p
Intercept	< .001	**618.36(2.20)**	< .001	**618.37(2.17)**	< .001	**618.29(1.80)**	< .001	**618.34(1.84)**	< .001

(*continued on next page*)

Table 4 (*continued*)

Parameter	Model 4	Model 5		Model 6		Model 7		Model 8	
	p	B (SE)	p	B (SE)	p	B (SE)	p	B (SE)	p
Individual (Level-1)									
Pre-SEPA Score	< .001	**0.40(0.03)**	< .001	**0.40(0.02)**	< .001			**0.42(0.02)**	< .001
Student's gender*	.781	0.24(1.81)	.895	−0.11(1.77)	.952			−0.26(1.72)	.881
Positive math self-concept	.024	5.17(2.64)	.056	3.49(2.17)	.115				
Negative math self-concept	< .001	**−7.60(1.85)**	< .001	**−7.53(1.79)**	< .001			**−8.93(1.43)**	< .001
Extrinsic motivation	.822								
Intrinsic motivation		0.21(1.48)	.886						
Teacher instructional support				1.48(1.48)	.324				
Teacher emotional support				−1.03(1.34)	.447				
Teacher learning expectations				**4.00(1.50)**	.011			**5.16(1.26)**	< .001
Cluster (Level-2)									
Mean Pre-SEPA score*						**0.46(0.12)**	< .001	**0.37(0.09)**	< .001
SD Pre-SEPA score						−0.17(0.28)	.539		
Classroom composition*						3.28(2.42)	.182		
Teacher's gender*						−0.21(3.47)	.953		
Level-1 R^2		.372		.365		-		.356	
Level-2 R^2		-		-		.295		.251	
Deviance		13142.95		13135.78		13704.79		13143.46	
Free parameters		22		37		2		16	

Note. **SE** = Standard Error; **Student's gender**: 1 = male; 2 = female; **Mean Pre-SEPA score** = Mean Pre-SEPA score for each classroom; **SD Pre-SEPA score** = Standard deviation of the Pre-SEPA score for each classroom; **Classroom composition** = Proportion of male students compared to female students in each classroom; **Teacher's gender**: 1 = male; 2 = female.
Boldface values indicate significant coefficient.

$= 0.168$, $\beta = 0.238$, $p = .867$) (see Table 4).

When student perceptions of teacher support are included in the model (instructional and emotional support), neither of these two variables were significant level-1 predictors. However, student perceptions of teacher learning expectations were a significant predictor of math achievement. In this model (Model 6), positive math self-concept is not anymore a significant predictor. This model explains 36.50% of the variance of the dependent variable ($R^2 = 0.365$) (see Table 4).

Model 7 tested a number of level-2 predictors, namely, the average and standard deviation of prior achievement at classroom level, the proportion of male students compared to female students in each classroom, and teacher gender (Model 7). As shown in Table 4, the only level-2 predictor found to be significant was the pre-SEPA classroom average ($t(38) = 3.728$, $\beta = 0.458$, $p < .001$). This model explains 29.55% of the variance of math achievement (level-2 $R^2 = 0.295$).

The final model (Model 8) included all significant predictors at level-1 and the classroom average in prior achievement at level-2. The set of level-1 predictors included in this final model explain 35.56% of the variance in the dependent variable (level-1 $R^2 = 0.356$), while the level-2 predictor explains 25.09% of the variance (level-2 $R^2 = 0.251$).

A summary of all the results from the multi-level regression analyses (Models 1 to 8) is presented in Table 4.

4.5. Limitations of the study

It is important to consider the results of this study in light of its limitations. One limitation is that our sample was not probabilistic or representative. The participants were public school 7th grade students mainly pertaining to a mid-low SES. This study was part of a larger research project that aimed at examining instructional practices of public school teachers in Chile. The educational system in Chile is highly segregated, with public education containing students with mainly low to mid-low SES. It is plausible that secondary students from other SES in Chile portray different math motivational beliefs, perceptions towards their math teachers, as well as math achievement, and that gender differences might be less pronounced, or more pronounced, depending on the SES group studied (Eccles, 2007; Guo et al., 2015). For example, in a study with Chilean kindergarteners, del Río et al. (2018) found that implicit math self-concept of Kindergarten girls was explained by parents' math self-concept and SES. Specifically, girls from high SES have higher math self-concept than girls from low SES. Concordantly, Guo et al., (2015) found in a sample of Hong Kong 8th grade students that SES positively predicts achievement-related behaviors in math by promoting students' self-concept and subjective task values. Future studies with Chilean students from different grade levels could examine if math motivation and achievement vary according to SES and how different qualities of teaching practices, and students' perceptions of these teaching practices, influence their math motivation.

Another limitation of this study is that we only used one point of measurement of psychological variables at the end of the school year, and for this reason, we could not evaluate the reciprocal influence of psychological variables and math achievement during the school year. Further studies could contribute to exploring the Reciprocal Influence Model (Marsh & Craven, 2006) and their possible gender differences in Chilean secondary school students.

5. Discussion

The results of this study indicate that there are significant gender differences favoring male 7th grade students in Chilean public schools in terms of their motivation to learn mathematics as well as their math self-concept. More specifically, it was observed that males present a significantly higher level of intrinsic and extrinsic motivation toward mathematics, and they present a math self-concept that is significantly more positive than that of girls, which is in accordance with the findings of previous international studies in primary and secondary school (Fredricks & Eccles, 2002; Gaspard et al., 2015; Jacobs et al., 2002; Marsh, 1989; Skaalvik & Skaalvik, 2004a; Steinmayr & Spinath, 2010; Wilgenbusch & Merrell, 1999; Watt et al., 2012), and with pre-school Chilean students (del Río et al., 2018). It is important to note that after controlling for prior achievement, the gender differences in extrinsic motivation in favor of boys disappeared. Prior achievement seems to outperform gender as a predictor variable for extrinsic motivation to learn mathematics; high-performing students show higher levels of extrinsic motivation, independent of their gender.

However, contrary to what was hypothesized, gender differences in student perceptions of math teachers were detected only in terms of instructional support (i.e., not in terms of emotional support nor in terms of teacher learning expectations), which was perceived more strongly by females than males. We can speculate that girls might, on the one hand, perceive greater instructional support from their teachers because, according to the roles traditionally assigned to the feminine gender, female students have a greater inclination than male students to seek support from significant others, such as their teachers (Malecki & Demaray, 2003). On the other hand, this difference in favor of girls could be due to the fact that they perceive teacher instructional support to a larger extent than boys because they perceive their teachers trust less in their math-related abilities and because of this, dedicate more time to support them (Li, 1999). In this way, teachers may implicitly communicate these differential beliefs through gender-differential classroom practices (Kuklinski & Weinstein, 2001), which were in fact observed in a Chilean study using video evidence from math classrooms (Espinoza & Taut, 2016a). This would be consistent with the lower levels of math self-concept of girls in our study. What could thus be seen as well-meant instructional support by teachers toward their female students (and in combination with other differential classroom interactions) might actually reinforce these lower self-concepts and turn out detrimental to girls (Gunderson et al., 2012).

Considering the entire sample, levels of perceived instructional support were relatively high, whereas perceptions of emotional support were considerably lower. Studies have shown that positive perceptions of emotional support contribute to student learning (e.g., Goodenow, 1993). However, specifically in math classrooms, boys might be less dependent on emotional support compared to female students since they possess higher motivation and more positive self-concept in this discipline (Hyde et al., 1990, Hyde et al., 2008, Steffens & Jelenec, 2011). Female students may benefit, to a greater extent than male students, from perceiving higher emotional support from their math teacher because it may increase their interest and math self-concept (and may decrease their levels of anxiety related to the discipline).

Gender differences in attitudes toward mathematics, in favor of males, are not new and have been found in previous Chilean studies but at lower ages (del Río & Strasser, 2013; del Río, et al., 2018; Huepe et al., 2016). According to the Expectancy-Value Theory (Eccles et al., 1983; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000), this would imply that girls demonstrate lower commitment to activities related to mathematics, in both their level of expectations regarding how capable they are of learning the discipline, and the value they attribute to such activities. This is linked to the importance the activity acquires in relation to their self-concept, in addition to intrinsic interest and perceived utility, in both short and long-term goals. Thus, it would be plausible to assume that this view would influence the performance, persistence, and academic choices of female students in relation to mathematics and that it could limit their current and future possibilities for development in this area (Eccles et al., 2011).

With regard to the second research question, the results reveal that gender differences favoring male students also exist in mathematics achievement both at the beginning and end of the school year. This agrees with the results of national and international standardized tests in this area, which demonstrate that gender differences in learning achievement begin to emerge around seventh grade (Educational Quality Agency Agencia de Calidad de la Educación, 2012, 2015; Gelber et al., 2016; Organization for Economic Co-operation and Development (OECD), 2013). However, it is important to highlight the fact that gender differences were not found in learning progress itself, which indicates that boys and girls made equal learning progress in participating classrooms, and the gender gap favoring boys remained constant over the course of the school year.

In terms of the third research question, upon analyzing students' gender as a predictor of mathematics achievement at the end of the school year, while controlling for their initial math achievement, contrary to hypothesized, this variable was not a significant predictor, which is consistent with the results of the group comparisons. However, after controlling for students' initial math achievement, and in accordance with what was hypothesized here and with previous research (Skaalvik and Skaalvik, 2006; Steinmayr & Spinath, 2009), math self-concept, particularly negative math self-concept, is a predictor that explains a significant portion of the variance in mathematics learning outcomes. This finding indicates that students with lower math self-concept present lower mathematics learning outcomes. Regarding the other psychological variables that we studied, only the variable students´ perceptions of teacher learning expectations, was found to be a significant predictor in the multi-level regression model. That confirms that teacher expectations are perceived by students and have a significant effect on their achievement, as shown extensively in prior research in other countries (Auwarter & Aruguete, 2008; Friedrich, et al., 2015; Jamil, et al., 2018; Jussim & Eccles, 1992; McKown & Weinstein, 2002; Palardy, 1998; Palardy & Rumberger, 2008, Szumski & Karwowski, 2019), but not so far for the Chilean middle school context. Of the predictors included at level-2, it was confirmed that only classroom average prior achievement in math had a significant effect, which reveals the role of disciplinary knowledge by peers on learning in a specific domain, which is in accordance with previous research in this topic in Chile (e.g. Taut & Escobar, 2012).

At a more general level, the results of this study confirm the effect of variables other than intelligence or prior achievement -and particularly math self-concept, which may also be related to anxiety- on student achievement in a particular domain, in this case, mathematics. These findings can be understood in light of the Interests as Identity Regulation Model (Kessels & Hannover, 2004, Kessels & Hannover, 2007; Kessels et al., 2014). This theory explains the differences that exist in students' academic interests and achievements, based on the idea that individuals are more likely to become involved in domains that they perceive as fitting with their identities and tend to avoid those they consider different from themselves. In this way, the stereotypes that associate mathematics and more broadly the disciplines of Science, Technology, Engineering, and Mathematics (STEM) with a symbolically masculine domain, could generate an imbalance between girls' identity and their commitment and involvement in these domains.

In particular, the characteristics associated with a high achiever in mathematics would not fit with the characteristics traditionally associated with a "feminine woman". Likewise, the stereotype that girls' academic achievement is primarily due to their sustained effort also would not fit with the predominant stereotype that mathematics learning depends on ability and talent more than on effort (Kessels, 2015). Of course, the level of disjuncture between interest in mathematics and girls' identities would depend on the extent to which female students establish the link between math and a symbolically masculine domain, and also on the particular characteristics of their gender identity. This line of thinking should be further explored in future empirical studies in the Chilean cultural and educational context, using, for instance, measures of math gender stereotypes and students' gender identity.

Educational policies can contribute to overcoming the gender gap in mathematics. One line of action is strengthening girls' positive self-concepts in mathematics by providing successful female role models in the STEM area. Being able to identify with in-group role models is especially important for group members who are aware of negative stereotypes of their group, as some girls do regarding mathematics (Dasgupta, 2011). This could be achieved by preparing educational materials and text books with this objective and to sensitize the media regarding this issue. Furthermore, it is necessary to train teachers to become aware of and modify gender stereotypes they themselves might hold regarding specific domains, and for them to communicate positive achievement expectations for both girls and boys in mathematics (Organization for Economic Co-operation and Development (OECD), 2009). Attributions of success and failure in mathematics should be made based on effort and difficulty of a task, and not on the basis of personal attributes such as intelligence or gender (Wang & Degol, 2016).

Another suggestion to promote mathematical learning for both boys and girls is to encourage the analysis of pedagogical interactions with a focus on gender equality, for instance, through observing, videotaping, giving feedback and reflecting on mathematics instruction. An important focus could be instructional dialogues; for example, questions should reflect different levels of cognitive challenge and be directed equally towards girls and boys. This could be complemented with an analysis of learning outcomes differentiated by gender, and self-reports of girls and boys regarding their involvement and motivation in mathematics. These analyses and reflections can form part of the continuous self-evaluation at the school level or be the focus of teachers' professional development (Espinoza & Taut, 2016b). Schools and teachers should also work with families on their expectations about future studies and work alternatives to which students can aspire (Gelber et al., 2016). It is important that teachers and other social agents contribute to the development of more flexible and diverse gender role identities in students and society in general (Nollenberger et al., 2016).

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijer.2020.101611.

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