Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables

R. B. Toma*[a], I. M. Greca[a] and M. L. Orozco Gómez[b]

[a]Departamento de Didácticas Específicas, Área de Didácticas de las Ciencias Experimentales, Universidad de Burgos, Burgos, España;

[b]Departamento de Ciencias de la Educación, Área de Didáctica y Organización Escolar, Universidad de Burgos, Bugos, España

* corresponding author

ABSTRACT

Background: There is a growing interest in investigating attitudes towards science and views of Nature of Science among elementary grade students in terms of gender, cultural backgrounds, and grade level variables.

Purpose: The purpose of this study is to examine the attitudes toward science and views of Nature of Science among Spanish students, Spanish students of gypsy ethnicity and second-generation Spanish students with east-European heritage, and to determine if their attitudes are related to their views of Nature of
Science.

Sample: Data for this study was gathered from seven elementary schools in Spain, forming a convenience sample of 149 students enrolled from 2nd to 5th grade.

Design and Methods: The Nature of Science Instrument (NOSI) and an adaptation of the Test of Science Related Attitudes scale (TOSRA) were used. Follow-up structured interviews were performed with 15 participants.

Results: Regarding gender, boys had better attitudes toward Science than girls but more naïve views of the empirical Nature of Science. In relation to cultural background, second generation Spanish students with east-European heritage reported significantly better attitudes toward Science than Spanish students and Spanish students of gypsy ethnicity. No differences in Nature of Science views were found. Concerning grade level, third graders had more positive attitudes toward Science than fifth and sixth graders and more informed views of the tentative Nature of Science. Finally, no relation between Nature of Science views and attitudes towards Science were identified.

Conclusion: This study stress the need to address the steady decline in positive attitude toward Science and to improve students' views of Nature of Science from early elementary grades, and to use gender and culturally inclusive science teaching strategies.

KEYWORDS

Attitudes towards science; Nature of Science; elementary school; cultural backgrounds; TOSRA

Article published and to be cited as follows:

Toma, R. B., Greca, I. M., & Orozco Gómez, M. L. (2019). Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables. *Research in Science & Technological Education, 37*(4), 492–515. https://doi.org/10.1080/02635143.2018.1561433

1. Introduction

Many studies have investigated attitudes towards science and views of Nature of Science (NOS) at secondary school level (Abd-El-Khalick and Lederman 2000; Chai et al. 2010; Kalman 2010; Khishfe and ederman 2007; Vázquez-Alonso et al. 2014), although the same research questions at elementary grade levels are only approached in a few studies. Indeed, literature reviews by Osborne, Simon, and Collins (2003), in which the authors reviewed attitudes toward science studies, and Deng et al's. (2011) NOS literature review has identified few studies focusing on the elementary stage. For example, from among the 105 empirical studies examined by Deng et al. (2011), fewer than 13% included primary school students. Moreover, even more worrying is the exclusion of some social groups from these studies, especially in NOS-related research. In the case of the USA, after examining 112 NOS research studies, Walls (2016, 1557–1558) stated that '(. . .) white students and teachers emerged as the majority racial group under study' and that NOS research is '(. . .) operating completely oblivious to the narratives, voices, and stories of Black and other students and teachers of colour, instead relying on and valuing only the voices, narratives and stories provided by White participants'.

Hence, the aim of this study is to determine what attitudes towards science and views of NOS elementary students have, in the case of Spain. The aim is also to study how attitudes and NOS views may be different according to students' gender, cultural backgrounds and school levels. Finally, it is also intended to study whether the attitudes towards science among those students are related to their views of NOS. The results of this study can contribute to clarifying the effect of age, gender and cultural backgrounds on the development of attitudes toward science and NOS views in elementary school students. Additionally, this study can shed more light to the relationship between attitudes towards science and views of NOS, and may therefore be useful in guiding educational interventions focused on preventing the development of negative attitudes towards Science and naïve NOS views from early childhood. The improbability of changes in the aspirations of secondary school students is argued in a substantial corpus of recent studies. In fact, students aged between 10 and 14 years old are in a critical period when interventions can successfully focus on shaping student attitudes and aspirations towards science careers (Tai et al. 2006). Therefore, the elementary stage appears decisive for developing positive attitudes toward science and informed views on NOS. In the next section, the most relevant results from the literature related to elementary students' attitudes towards science and their views of NOS are presented. Information on the Spanish educational system and the cultural diversity of its students is also included.

2. Background

2.1. Studies on the attitudes towards science among elementary students

Research into the attitudes of students towards science points to different variables influencing their development during early childhood. These variables are mainly gender, age, and cultural backgrounds/nationality.

Regarding the first variable, most studies show that boys hold more positive attitudes and aspirations towards science than girls (Caleon and Subramaniam 2008; De Pro Bueno and Pérez Manzano 2014; Denessen et al. 2015; DeWitt and Archer 2015; George 2006; Hacıeminoğlu 2016; Vázquez and Manassero 2008). More specifically, girls appear to experience lower levels of enjoyment when learning science and technology (Denessen et al.

2015) and show greater indecision over their preferences for science-related careers (Caleon and Subramaniam 2008). In contrast, boys have stronger aspirations in science (DeWitt and Archer 2015). Nonetheless, despite boys having more positive attitudes towards science, George (2006) reported that the attitudes of boys in contrast to those of girls, diminishes as grade levels increase. Nevertheless, this gender effect remains a controversial question. Akpinar et al. (2009) found more interest in science among girl participants, and some studies had an absence of this gender effect in the attitudes of elementary students towards science (Khishfe and Boujaoude 2014; Said et al. 2016).

Some studies have revealed consistent data on age and grade level, showing a declining pattern in attitudes towards science as the age and grade level of the students increases (Akpinar et al. 2009; Ali et al. 2013; Denessen et al. 2015; DeWitt and Archer 2015; George 2006; Said et al. 2016; Vázquez Alonso and Manassero-Mas 2008). Students from upper elementary and middle school grades show negative attitudes towards the enjoyment of science lessons (Ali et al. 2013; DeWitt and Archer 2015), especially during 8th grade, when the sharpest decline in attitudes towards science takes place (Akpinar et al. 2009). Two studies reported that while attitudes towards the importance of science remained positive, attitudes towards school science decreased drastically over middle school and high school years (Akpinar et al. 2009; George 2006).

Several studies have explored attitudes toward science based on nationality and cultural background at secondary level (a comprehensive review can be found in Osborne, Simon, and Collins 2003), concluding that students belonging to different cultural groups hold differing perceptions on science, so ethnicity and cultural variables may appear to affect the formation of attitudes toward science. However, few studies have compared student attitudes towards science based on ethnicity or cultural background and existing results are contradictory. For example, DeWitt and Archer (2015) explored variables connected to science aspirations at elementary school level, finding that students from ethnic minority backgrounds appeared to show stronger aspirations for science careers. Khishfe and Boujaoude (2014) showed that students from developing countries appeared to have more positive attitudes towards science than those from developed countries, but Said et al. (2016) obtained opposite results with Qatari students. Although these results show some relation between student attitudes towards science and cultural backgrounds, it is not clear how ethnicity and cultural background variables may influence the development of student attitudes and further studies are needed to determine this relationship.

2.2. Studies on views of the nature of science among elementary students

At elementary level, most articles have focused on creative, tentative, empirical, and subjective constructs of NOS (i.e. Akerson et al. 2014; Cakici and Bayir 2012; Abd-El-Khalick, Masters and Akerson 2015; Quigley, Pongsanon, and Akerson 2010), reporting that, in general, students tend to hold naïve views about this NOS tenets (Cakici and Bayir 2012; Abd-El-Khalick et al. 2015; Khishfe 2008; Khishfe and Abd-El-Khalick 2002; Metin and Leblebicioğlu 2015), even at earlier stages of the educational system (Akerson and Donnely 2010; Akerson et al. 2014).

Few studies have explicitly examined NOS views based on gender, grade level and cultural backgrounds or nationality variables. Therefore, the little available evidence appears to indicate that there is no difference in the NOS views of boys and girls, who seem to both hold naïve views (Kang, Scharmann, and Noh 2005). The results are inconclusive when considering the grade levels. Some studies stated that at higher grade levels, students developed more

informed conceptions of NOS especially in the empirical and tentative constructs (Hacıeminoğlu et al. 2015; Yoon, Suh, and Park 2014) and in the subjective, observational and inferential constructs (Yoon, Suh, and Park 2014). But, other studies have shown that students from higher grades have more naïve views on the imaginative and creative aspects of NOS than students from lower grades (Hacıeminoğlu et al. 2015). Others studies reported no clear differences between 6th, 8th and 10th graders NOS views, with the majority of students holding absolutist/ empiricists views (Kang, Scharmann, and Noh 2005).

Finally, to the best of the authors' knowledge, there is no study at the elementary level that is directly focused on the impact of nationality and cultural background on the development of students' NOS views, particularly in the Spanish context. However, there are several NOS studies performed with students from different cultural backgrounds. Thus, Yoon, Suh, and Park (2014) explored the perceptions of five NOS constructs (empirical, tentative, observation, subjective, and creative NOS) among Korean students, reporting that as grade level increased, scores for empirical NOS decreased and more students perceived school science as passively listening to a lecture rather than performing lab activities. In addition, none of the 3rd graders held appropriate views on tentative, creative, and subjective aspects of the NOS, and only a few 7th and 10th grade students had more acceptable knowledge of the NOS. Kang, Scharmann, and Noh (2005) also studied Korean students' views of NOS, reporting that, in comparison with students from western countries, Korean students possessed a more pragmatic view of NOS. These results were explained by the characteristics of the Korean culture, which conceives science as '(. . .) one of the most effective means to be an internationally competitive country' (323–324). Finally, Walls (2012) reported that the 23 AfricanAmerican students in the 3rd grade of elementary schooling in his study have also naïve views about NOS, since they viewed experimentation as a way for preparing potions and 'mixing colourful liquids', following specific steps, procedures, and rituals. However, the reasons for these views were inconclusive and were not specific to AfricanAmericans students.

2.3. Cultural diversity in the Spanish educational system

Spain has experienced strong migratory flows over the past two decades. In 2016, a total of 4.618.581 immigrants were registered on the Spanish census, representing 9.92% of the total population (INE 2017). These results represent an increase of 8.32% of the foreign population compared to two decades ago. Thus, the Spanish education system has witnessed continuous growth in cultural diversity. Nowadays, 34.3% of the students enrolled in elementary education have an immigrant background (see Supplemental Figure 1), among who only 6.4% will continue on to study at middle and high school (MECD 2017). On the other hand, the gypsy population is estimated at around 725.000 to 750.000, all of whom are living in Spain, which correspond to approximately 1.6% of the total population (ERTF 2016).

In this study, cultural background refers to the sets of knowledge, beliefs and behavioural patterns shared by a social group that characterize them and that therefore differentiate them from other groups. We adopt the conceptualization of culture advanced by Bennet (1990, 64), in which culture is '(. . .) a system of shared knowledge and belief that shapes human perceptions'. Therefore, cultural backgrounds are a multidimensional system of ideas, public expressions, practices and behaviours of individuals from a particular group (Atran, Medin, and Ross 2005). The Royal Academy of the Spanish Language (RAE) uses the term 'Spanish' to refer to the people that are natives of Spain and the term 'gypsy' to refer to a '(. . .) person belonging to the people originating from India, spread over several countries, who is largely nomadic and has retained his own physical and cultural characteristics' (RAE 2014). On the

other hand, people born in Spain with both parents being not natives of Spain are known as 2nd generation Spanish people or Spanish people with immigrant heritage. Therefore, in this study the following terms are used: Spanish students, to refer to students' natives of Spain that represents the dominant culture; Spanish student of gypsy ethnicity to refer to Spanish gypsy students, and 2nd generation Spanish students to refer to students that were born in Spain and have Spanish nationality but whom parents are both from another country, thus having an immigrant heritage and also pertaining to minority cultures. In this study, we will focus on second-generation immigrants from Eastern European countries (i.e. Spanish students of Romanian, Russian and Bulgarian heritage), because the nationalities of 2nd generation immigrant students enrolled in Elementary Education in Spain are mainly Romanian, Ukrainian, and Russian (MECD 2017).

Second generation Spanish students and Spanish students of gypsy ethnicity have cultural backgrounds (i.e. traditions, habits, religious and moral values, ideas and practices) that all differ from those adopted by the dominant group in the Spanish contexts. Mainly, Spanish people of gypsy ethnicity belong to minority groups at risk of social and educational exclusion, and their culture differs greatly from non-gypsy-Spanish citizens, in particular due to the use of a different language (see ERTF 2016). At the age of 17, more than 58% of Spanish students of gypsy ethnicity drop out of school, and fewer than 1 out of every 10 Spanish students of gypsy ethnicity enroll in high school (see Supplemental Figure 2) (EDUCACNIIE 2014), a percentage that is below the average of other European Union Member states (FRA 2012).

In relation to students with immigrant heritage, longitudinal studies conducted in both the USA (Rumbaut and Portes 2011) and in Spain (Gómez-Quintero and Fernández-Romero 2014; Portes, Aparicio Gómez, and Haller 2013) have shown that while some 2nd generation immigrant students tend to integrate well into the mainstream culture of the new country, others have difficulties with their inclusion in the new dominant culture. So, many 2nd generation Spanish students face educational disadvantage, presenting higher dropout rates, lower educational performance, and greater difficulties accessing higher education in comparison with their Spanish peers (Portes, Aparicio Gómez, and Haller 2013; EC 2008). Although foreign, 2nd generation Spanish students and Spanish students of gypsy ethnicity are not segregated in different schools in the Spanish educational system, there is a tendency towards segregation given that parents from the dominant culture tend to withdraw their children from schools with high percentages of immigrants, Spanish students with immigrant heritage or Spanish students of gypsy ethnicity,1 generating disparities between schools and increasing social and educational inequalities among the population over time (EC 2008).

To the best of the authors' knowledge, there is an absence of studies in the Spanish context on how different cultural backgrounds may affect the attitudes towards science of elementary students and their views of NOS. This gap in the literature also appears to exist at an international level, as pointed out in previous sections.

2.4. Elementary school science education in the Spanish context

The Spanish legislation on Science Education has undergone several changes over recent decades. The LOGSE (1990, Ley Orgánica de Ordenación General del Sistema Educativo [Organic Law on General Regulation of the Educational System]) outlined a subject curriculum at elementary school level called 'Knowledge of the Natural, Social and Cultural Environment', designed to improve scientific literacy. Some years later, a new law called the LOE (2006, Ley Orgánica de Educación [Organic Law of Education]) emphasized the need to

provide science education based on the knowledge of children and using manipulative and reflective activities that foster child motivation for science-related issues. However, despite these demands from the educational system, in their description of the Spanish science education, Porlán et al. (2010) noted that teachers employ rote-learning as the predominant model for science education in Spain.

Recently, the urgent need for active teaching methodologies was highlighted in the new educational law called LOMCE (2013, Ley Orgánicapara la Mejora de la Calidad Educativa [Organic Law for the Improvement of Educational Quality]). This new law recognizes the importance of Science Education at an elementary stage, so it divides the subject of 'Knowledge of the Natural, Social and Cultural Environment' introduced in the LOGSE law into two different subjects called 'Social Sciences' and 'Natural Sciences', increasing the number of teaching hours assigned to science education, from one to two teaching hours per week. There is also specific content called 'Initiation in scientific inquiry' that demands teacher participation with students in inquiry-based activities in the school science syllabus of all Primary education grades. Nonetheless, there is still a lack of inquiry-based activities in science classrooms, as highlighted by Gil (2014), who reported that the most common practice during science classes was reading from textbooks and memorizing facts and laws, and that the activities for teaching science used least of all were planning and conducting experiments and research.

3. Design and methods

3.1. Purpose

As indicated earlier, the aims of this study are to determine, in the case of Spain, the attitudes of elementary students towards Science and to establish their views of NOS in relation to gender, cultural background, and school grade variables. Since most science education reform efforts have suggested the need to foster the development of informed conceptions of NOS to ensure the scientific literacy of students (McComas 2015; McComas and Olson 1998), the aim here is to find the relationship between attitudes towards science and views of NOS. These results would be of great interest in order to know which aspects educational interventions should focus in order to improve attitudes towards science. The research questions of this study are:

RQ 1. What effects do gender, cultural background and school grade have on elementary students' attitudes towards Science?

RQ 2. What effects do gender, cultural background, and elementary school grade level have on views of NOS among elementary students?

RQ 3. To what extent do attitudes towards science relate to views of NOS?

3.2. Sample and procedure

Participants in this study were drawn from six elementary schools in Burgos and one from Valladolid, Spain, by means of convenience sampling. Regarding cultural backgrounds, both Spanish, second-generation Spanish students and Spanish students of gypsy ethnicity were included in the sample of this study. Spanish students were recruited from five state schools located in the city of Burgos in middle to upper-class area, with a low percentage of second-generation immigrant students and immigrant students. 2nd generation Spanish students included in this study were born in Spain, but their parents were mostly from Eastern European

countries, with both parents born outside Spain. These students were attending a school in Burgos with a high presence of multicultural students (more than 50% of students enrolled were foreigners or 2nd generation Spanish students). The Spanish students of gypsy ethnicity from this sample were attending a segregated school specifically for that ethnicity (100% of students enrolled in this school were of gypsy ethnicity) located in a peripheral zone of Valladolid, a city near Burgos.

Two scales, an adapted version of the Test of Science Related Attitudes (TOSRA) and the Nature of Science Instrument (NOSI) were administered at the beginning of the second semester of the 2015–2016 school year. Students had 60 minutes to answer all the items individually. The first author of this study was present to ensure the questionnaires were administered in the same way in each school. Subsequently, some participants were randomly selected for interview, broadening the quantitative data (n = 15). Although all students included in this sample could write and speak fluently in Spanish (the language in which the questionnaires were administered), some data were missing: no 2nd grade student was capable of completing the scales used in this study, while three 3rd and two 4th graders failed to answer more than half of the items in both scales, leaving blank answers. After discarding these cases (found in all the different groups considered), a total sample was obtained of 118 valid questionnaires from 64 boys and 54 girls. Table 1 shows the gender and the school grade of valid participants and Table 2 displays the gender and the cultural background of the valid participants.

In order to gain richer insights and to elaborate further the quantitative findings by allowing students whose literacy was poor to express themselves more fully, structured interviews were carried out with several students. A qualitative sample was randomly selected from each sample subgroup for the interviews (Patton 2002). Initially, the aim was to select 20% of the total number of participants. However, interviews could only be conducted at the schools during school time, a fact which considerably reduced the available time and the potential advantages of using interviews. Therefore, the qualitative sample was lower, comprising a total of 15 students enrolled in 5th and 6th grades (12.7% of the total sample), of whose 5 were Spanish (three girls), 4 were 2nd generation Spanish students with Romanian heritage (2 girls), and 6 were Spanish students of gypsy ethnicity (2 girls). One Spanish girl and two Spanish boys of gypsy ethnicity that participated in the interview were 5th graders; the rest of the qualitative sample was formed by 6th graders. Interviews were performed from 5 to 7 days after the administration of the quantitative scales.

3.3. Measures

3.3.1. Test of science related attitudes (TOSRA)

The first scale to be administered was the adapted Test of Science related Attitudes (TOSRA) (Fraser 1978, 1981), used to assess seven attitudes towards science constructs. This scale was adapted from the original 70 items to only 14 items (2 for each construct), which was thought more suitable for elementary students. First, all negatively formulated items were discarded, in order to enhance the understanding of participants. Then, from the remaining original items, two authors of this paper independently selected four items for each attitude towards the science constructs under consideration that were considered to be the closest to student's maturational stage. For example, rather than 'Public money spent on science in the last few years has been used wisely' (Fraser 1981, 15), 'Money spent on science is well worth

Table 1. Participants' gender and school year.

Gender	3rd grade	4th grade	5th grade	6th grade	Total
Male	5	11	16	32	64
Female	5	4	16	29	54
Total	10	15	32	61	118

Table 2. Participants' gender and cultural background.

Gender	Spanish	Second generation immigrants	Gypsy Spanish	Total
Male	33	22	9	64
Female	34	8	12	54
Total	67	30	21	118

spending' was preferred, due to its shorter length and less complicated vocabulary, especially in Spanish language. Cohen's Kappa index was calculated, obtaining moderate inter-ratter agreement (k = .75) on the selected items (McHugh 2012). Finally, the items were translated into Spanish and a pilot test was performed (n = 24; 4th grade students). Preliminary results showed student fatigue and scale administration was time demanding, so low-reliability items (Cronbach's $\alpha < .65$) were removed, and a few items were re-phrased to form a final version of 14 total items (two per construct). The Cronbach's α of the final scale administered in this study was .80. This reduced version of the scale has already been used in the literature with Spanish speaking students, reporting reliable results (Toma and Greca 2018).

Attitudes towards science constructs included in the final scale were: (1) social implications of science (e.g. 'It is worth spending money on science so that scientists can make new discoveries'); (2) normality of scientists (e.g. 'Scientists are normal people who look like anyone else'); (3) attitude to scientific inquiry (e.g. 'It is better to discover the answer by experimentation rather than by asking the teacher'); (4) adoption of scientific attitudes (e.g. 'I am curious about the things around me and the world in which I live'); (5) enjoyment of science lessons (e.g. 'Science is the most interesting subject and I really like it'); (6) leisure interest in science (e.g. 'I would like to receive scientific materials to do experiments at home.'); and, (7) career interest in science (e.g. 'When I grow up, I want to study something related to science'). All items were measured on a five-point Likert scale, ranging from '1 = strongly disagree' to '5 = strongly agree'.

3.3.2. Nature of science instrument (NOSI)

The second scale was then administered, the Nature of Science instrument (NOSI), developed by Hacıeminoğlu, Yılmaz-Tüzün, and Ertepınar (2012) for use with elementary school students. This instrument measures students views related to the following NOS tenets: (1) Observation and inferences (e.g. 'Scientists believe that atoms exist from what they already know, but they cannot be certain'); (2) tentative NOS (e.g. 'Everything scientists say in books will never change'); (3) Empirical NOS (e.g. 'Scientists may reach different conclusions when looking at the same data'); and (4) Creative and imaginative NOS (e.g. 'Science could never involve imagination and creativity because this would result in incorrect or wrong findings'). All items were measured on a three-point Likert scale, where '1 = wrong', '2 = do not know', '3 = right'. The same group of 4th grade students (n = 24), as with the TORSA, participated in the pilot testing of the scale, after which four items were re-phrased. Cronbach's α was found to be .71, similar to the study by Hacıeminoğlu, Yılmaz-Tüzün, and Ertepınar (2012)

where Cronbach's α was .76. In both cases, this value can be considered acceptable for preliminary research (Nunnally 1978).

3.3.3. Structured interviews

For attitude toward science, the first part of the interview consisted of asking the qualitative sample to elaborate on their answers to both items that relate to the 'Enjoyment of science lessons', so as to examine their reasoning and to relate it to the results obtained for this construct on the quantitative scale. Specifically, students were asked to (1) rate and value science subjects in comparison to other school subjects, and to (2) explain their answer to the items 'Science is the most interesting subject and I really like it' and 'We should have more science classes each week' that examines enjoyment of science lessons.

The second part of the interview, again seeking to gain deeper insights into students views about the NOS, consisted of administering a questionnaire based on the Views of Nature of Science questionnaire (Lederman et al. 2002). The questionnaire was administered orally to overcome literacy barriers derived from poor writing abilities, especially in Spanish students of gypsy ethnicity. Only items measuring the same dimensions as the quantitative scale (i.e. NOSI) were selected: (1) observation and inferential NOS (i.e. 'How do scientists develop new ideas that explain our world?'); (2) tentative NOS (i.e. 'After scientists have developed a scientific theory, does that theory ever change?'); (3) empirical NOS (i.e. 'What, in your view, is science?'); and (4) creative and imaginative NOS (i.e. 'Do scientists use their creativity and imagination during their investigations?').

3.4. Data analysis

Two types of analyses were performed. Attitudes towards science and views of NOS scales were analyzed through descriptive and inferencial tests using the SPSS v.24 statistical software package, and the interviews were analyzed by means of conventional content analysis (Hsieh and Shannon 2005). More specifically, in relation to the interviews, the transcripts were edited to facilitate analysis at sentence level. The responses of each student were grouped, through a process of decomposition, by interview question and similarity of response. Once the answers had been grouped under each interview question, subgroups of answers sharing similar information among the participants were created.

Statistical analyses were completed in three steps. First, descriptive analyses with both scales (NOSI and TOSRA) provided simple summaries on participants and measures (i.e. mean scores and standard deviation). Second, significant differences in data between participants by cultural background, school grades levels, and gender variables were analyzed with inferential statistics. Kolmogorov-Smirnov with Lilliefors correction and Shapiro-Wilks tests were run on both scales and their dimensions to calculate whether the variables were adjusted to a normal probability distribution. The results for the variable 'gender' were significant ($p < .001$) in both tests, suggesting a violation of the assumption of normality distribution. Therefore, the gender variable was analyzed using non-parametric statistics, and cultural background ($p = .217$) and grade level ($p = .854$) variables using parametric statistics.

Third, Pearson correlation and multiple regressions tests were used to measure the inter-relations between the NOSI dimensions and the TOSRA constructs.

4. Findings

4.1. RQ 1. What effects do gender, cultural background and school grade have on elementary students' attitudes towards science?

Having considered a maximum score of 5 (positive attitude) and a minimum of 1 (negative attitude), the participants of this study reported a range of indifferent to somewhat negative attitudes towards science. Analyzing TOSRA by its constructs, the highest scores were reported in 'social implication of science' and the lowest scores in 'career interest in science' and 'enjoyment of science lessons'. However, the standard deviation was quite high in both dimensions, indicating that some students were highly interested in a scientific career and thoroughly enjoyed science lessons, while others showed no interest at all in science careers and the science lessons were not enjoyable for them. Table 3 reports the descriptive results from the TOSRA scale.

4.1.1. Gender

In a gender comparison, boys scored higher in attitudes towards science compared to girls. Girls had more negative attitudes than boys in both 'enjoyment of science lessons' and 'career interest in science' dimensions. Analyzing gender effects, the Mann-Whitney U Test indicated that boys and girls differed significantly in their attitudes towards science as measured on the TOSRA scale. On average, boys had better attitudes towards science than girls ($U = 1347.5$; $p = .04$; effect-size $r = .19$).

4.1.2. Cultural background

Comparing by cultural backgrounds, 2nd generation Spanish students reported slightly better attitudes towards science than Spanish students and those of gypsy ethnicity. Second generation Spanish students enjoyed science lessons more than any others and they were also the ones who reported positive attitudes towards a career in science. Spanish students of gypsy ethnicity were the ones that enjoyed science lessons the least, and Spanish students showed the least interest in following a scientific career.

A one-way ANOVA was conducted to compare the effect of cultural background on student attitudes towards Science. The results indicated that Spanish, 2nd generation Spanish students, and Spanish students of gypsy ethnicity differed significantly in their attitudes towards science, as measured with the TOSRA scale [$F(2, 115) = 8.763$; $p = .000$; $\eta_p^2 = .132$]. A Bonferroni post-hoc analysis indicated that the attitudes of 2nd generation Spanish students towards science were significantly more positive than the attitudes of both Spanish and Spanish students of gypsy ethnicity. However, no significant differences were found between the attitudes of these two groups towards science.

Table 3. TOSRA scale descriptive results.

	N	SI	NS	SI	SA	ES	LI	CI	TOT
All	118	3.40 (.66)[a]	2.83 (.89)	2.8 (.98)	3.26 (.76)	2.32 (1.10)	2.89 (.91)	2.3 (1.10)	2.84 (.47)
Girls	54	3.30 (.70)	2.74 (.82)	2.71 (1.00)	3.16 (.88)	2.21 (1.10)	2.83 (.91)	2.18 (1.10)	2.74 (.49)
Boys	64	3.45 (.63)	2.90 (.94)	2.90 (.95)	3.35 (.63)	2.41 (1.10)	2.94 (.92)	2.47 (1.00)	2.92 (.44)
3rd graders	10	3.10 (.69)	2.65 (.63)	3.50 (.85)	3.55 (.64)	3.6 (.46)	3.70 (.54)	3.20 (.79)	3.32 (.33)
4th graders	15	3.13 (.81)	2.17 (.75)	2.83 (.98)	3.33 (.59)	3.03 (.92)	3.33 (.90)	2.40 (1.24)	2.89 (.49)
5th graders	32	3.48 (.57)	2.88 (.90)	2.48 (1.01)	3.47 (.74)	2.10 (.87)	2.95 (.79)	2.30 (1.10)	2.81 (.44)
6th graders	61	3.48 (.65)	2.99 (.89)	2.87 (.93)	3.10 (.80)	2.10 (1.10)	2.61 (.92)	2.20 (1.01)	2.76 (.46)
Spanish	67	3.43 (.65)	3.07 (.87)	2.81 (.97)	3.28 (.78)	2.22 (1.10)	2.78 (.86)	2.11 (1.04)	2.81 (.45)
Foreign	30	3.33 (.71)	2.70 (.89)	3.10 (.82)	3.38 (.69)	2.87 (1.08)	3.25 (.93)	2.95 (1.00)	3.10 (.42)
Gypsy	21	3.38 (.67)	2.30 (.68)	2.43 (1.12)	3.05 (.80)	1.86 (.84)	2.74 (.96)	2.17 (.87)	2.66 (.45)

SI (social implication of science); NS (normality of scientists); SI (attitudes to scientific inquiry); SA (adoption of scientific attitudes); ES (enjoyment of science lessons); LI (leisure interest in science); CI (career interest in science); TOT (global results of TOSRA scale). [a]M (SD): Mean (Standard deviation).

An in-depth scale analysis reported significant differences in three attitudes towards science constructs: Spanish, 2nd generation Spanish students and Spanish students of gypsy ethnicity differed significantly in their attitudes towards 'normality of scientists' [$F(2, 115) = 7.574$; $p = .001$; $\eta_p 2 = .116$], 'enjoyment of science lessons' [$F(2, 115) = 6.574$; $p = .002$; $\eta_p^2 = .103$] and 'career interest in science' [$F(2, 115) = 7.588$; $p = .001$; $\eta_p^2 = .117$]. A Bonferroni post-hoc analysis indicated that the attitudes of Spanish students towards 'normality of scientists' was significantly more positive than the attitudes of students of gypsy ethnicity; that the attitudes of 2nd generation Spanish students towards 'enjoyment of science lessons' were significantly more positive than the attitudes of Spanish and Spanish students of gypsy ethnicity; and that the attitudes of 2nd generation Spanish students towards 'career interest in science' were significantly more positive than the attitudes of Spanish and Spanish students of gypsy ethnicity. The Bonferroni Post-hoc results are reported in Table 4.

4.1.3. School grade

A one-way ANOVA was conducted to compare the effect of grade level on student attitudes towards science. The results indicated that student attitudes towards science measured on the TOSRA scale differed significantly across different grade levels [$F(3, 114) = 4.62$; $p = .004$; $\eta_p^2 = .108$]. A Bonferroni post-hoc analysis indicated that the attitudes towards science of students in the 3rd grade were significantly more positive than the attitudes of students in 5th and 6th grades.

Table 4. Bonferroni post-hoc results for TOSRA scale according to participants cultural background.

Dependent variable	Cultural background (I)	Cultural background (J)	Mean Difference	Std. Error	p. value
TOT	Spanish	Foreign	−.27	1	.022
		Gypsy	.26	.11	.068
	Foreign	Spanish	.27	1	.022
		Gypsy	.52	.13	.000
	Gypsy	Spanish	−.26	.11	.068
		Foreign	−.52	.13	.000
NS	Spanish	Foreign	.40	.19	.098
		Gypsy	.78	.21	.001
	Foreign	Spanish	−.40	.19	.098
		Gypsy	.38	.24	.346
	Gypsy	Spanish	−.78	.21	.001
		Foreign	−.38	.24	.346
ES	Spanish	Foreign	−.64	.23	.017
		Gypsy	.37	.26	.478
	Foreign	Spanish	.64	.23	.017
		Gypsy	1	.29	.003
	Gypsy	Spanish	−.37	.26	.478
		Foreign	−1	.29	.003
CI	Spanish	Foreign	−.84	.22	.001
		Gypsy	−.05	.25	1
	Foreign	Spanish	.84	.22	.001
		Gypsy	.78	.29	.021
	Gypsy	Spanish	.05	.25	1
		Foreign	−.78	.29	.021

TOT (global results of TOSRA scale); NS (normality of scientists); ES (enjoyment of science lessons); CI (career interest in science)

Further analysis showed that, according to grade levels, student attitudes towards 'normality of scientists' [F (3, 114) = 3.879; p = .011; η_p^2 = .093], 'scientific inquiry' [F (3, 114) = 3.058; p = .031; η_p^2 = .074], 'enjoyment of science lessons' [F (3, 114) = 10.554; p =

.000; η_p^2 = .217], 'leisure interest in science' [F (3, 114) = 6.504; p = .000; η_p^2 = .146] and 'career interest in science' [F (3, 114) = 2.722; p = .048; η_p^2 = .067] differed significantly. A Bonferroni post-hoc analysis showed that the attitudes of 6th graders towards 'normality of scientists' was significantly more positive than the attitudes of 4th graders; that the attitudes of students in the 3rd grade towards 'scientific inquiry' was significantly more positive than the attitudes of 5th graders; that students in the 3rd grade enjoyed significantly more science lessons than 5th graders and 6th graders, and the same was true between 4th graders and 5th and 6th grade students; that the attitudes of 3rd graders towards 'leisure interest in science' were significantly more positive than the attitudes of 6th grade students, and the same held true between the attitudes of students in their 4th and in their 6th grade; and finally, that the attitudes of students in the 3rd grade towards 'career interest in science' were significantly more positive than the attitudes of students in their 6th grade. The Bonferroni Post-hoc results are reported in Table 5.

4.1.4. Summary of research question 1

In relation to the first research question, the results show that gender, age and cultural background variables have a significant impact on students' attitudes towards science, favouring students in lower grades of elementary education, 2nd generation Spanish students, and boys in general, who have shown more favourable attitudes towards science, especially in the 'enjoyment of science lesson' attitudinal construct.

Given the low number of students that were interviewed, the interview findings cannot be linked with any significance to gender, grade level or cultural background variables. However, they are presented in order to offer further insight into some aspects of the TOSRA scale. Thus, only the interview results related to the construct 'enjoyment of science lessons' are reported here, because attitudes towards the enjoyment of science lessons are far less positive as grade level increases, so much so that none of the participants interviewed (n = 15) confessed to enjoying their science lessons. Most students (n = 11) said that the science subject was their least favourite and that they were not on good terms with their science teachers. Arguments against science as a subject were: science lessons are boring (10 out of 15 students), a lot of homework (12 out of 15 students), and no experimentation or practical activities during lessons (12 out of 15 students). Three students reported that they usually carried out experiments at school. However, these experiments were either very simple, consisted of only watching the teacher performing the experiment, or involved 'things that I have already done at home when I was a child'. Finally, some students said that they would like to go to science laboratory instead of studying science in their conventional classroom setting. These further insights from the interview tend to support a view that science teaching at elementary level in this sample of schools in Spain is still very traditional and teacher-centred.

Table 5. Bonferroni Post-Hoc results for TOSRA scale according to participants grade level.

Dependent Variable	Grade (I)	Grade (J)	Mean Difference	Std. Error	p. value	Dependent Variable	Grade (I)	Grade (J)	Mean Difference	Std. Error	p. value
TOT	3rd	4th	.43	.18	.124	ES	3rd	4th	.57	.40	.933
		5th	.52	.16	.012			5th	1.52	.35	.000
		6th	.56	.15	.002			6th	1.53	.33	.000
	4th	3rd	−.43	.18	.124		4th	3rd	−.57	.40	.933
		5th	.08	.14	1			5th	.96	.30	.013
		6th	.13	.13	1			6th	.97	.28	.005
	5th	3rd	−.52	.16	.012		5th	3rd	−1.52	.35	.000
		4th	−.08	.14	1			4th	−.96	.30	.013
		6th	.05	1	1			6th	.01	.21	1
	6th	3rd	−.56	.15	.002		6th	3rd	−1.53	.33	.000
		4th	−.13	.13	1			4th	−.97	.28	.005
		5th	−.05	1	1			5th	−.01	.21	1
NS	3rd	4th	.48	.35	1	LI	3rd	4th	.37	.35	1
		5th	−.23	.31	1			5th	.75	.31	.105
		6th	−.34	.29	1			6th	1.09	.29	.002
	4th	3rd	−.48	.35	1		4th	3rd	−.37	.35	1
		5th	−.71	.27	.057			5th	.38	.27	.948
		6th	−.83	.25	.007			6th	.72	.25	.026
	5th	3rd	.23	.31	1		5th	3rd	−.75	.31	.105
		4th	.71	.27	.057			4th	−.38	.27	.948
		6th	−.12	.19	1			6th	.34	.19	.434
	6th	3rd	.34	.29	1		6th	3rd	−1.09	.29	.002
		4th	.83	.25	.007			4th	−.72	.25	.026
		5th	.12	.19	1			6th	−.34	.19	.434
SI	3rd	4th	.67	.39	.540	CI	3rd	4th	.80	.42	.366
		5th	1	.35	.024			5th	.90	.38	.106
		6th	.63	.33	.332			6th	1	.35	.032
	4th	3rd	−.67	.39	.540		4th	3rd	−.80	.42	.366
		5th	.35	.30	1			5th	.10	.32	1
		6th	−.04	.28	1			6th	.20	.30	1
	5th	3rd	−1	.35	.024		5th	3rd	−.90	.38	.106
		4th	−.35	.30	1			4th	−.10	.32	1
		6th	−.38	.21	.407			6th	.10	.23	1
	6th	3rd	−.63	.33	.332		6th	3rd	−1	.35	.032
		4th	.04	.28	1			4th	−.20	.30	1
		5th	.38	.21	.407			6th	−.10	.23	1

TOT (global results of TOSRA scale); NS (normality of scientists); SI (attitudes to scientific inquiry); ES (enjoyment of science lessons); LI (leisure interest in science); CI (career interest in science)

4.2. RQ 2. What effects do gender, cultural background, and elementary school grade level have on views of NOS among elementary students?

According to the NOSI scale, participants are poorly informed about NOS-related constructs. Regarding the NOSI-related dimensions, more informed views of NOS were obtained in the empirical NOS dimension and more naïve views in the tentative NOS construct. Table 6 reports the descriptive results from the NOSI scale.

4.2.1. Gender

Boys scored lower on NOS constructs compared to girls. The Mann-Whitney U test showed no significant differences in NOS views by student gender when measured on the NOSI scale (U = 1650; p = .671; effect-size r = −.03). However, analyzing each NOSI scale construct, the results showed that girls had significantly more informed views of empirical NOS than boys (U = 1336.5; p = .026; effect-size r = .19).

Table 6. NOSI scale descriptive results.

	N	Observation & inferences	Tentative	Empirical	Imagination & creativity	Total
All	118	2.22 (.48)[a]	1.99 (.63)	2.62 (.41)	2.10 (.29)	2.20 (.22)
Girls	54	2.14 (.49)	1.96 (.58)	2.70 (.39)	2.10 (.31)	2.21 (.22)
Boys	64	2.30 (.47)	2.01 (.65)	2.55 (.41)	2.10 (.27)	2.20 (.21)
3rd graders	10	2.15 (.53)	2.57 (.45)	2.20 (.55)	2.10 (.30)	2.23 (.22)
4th graders	15	1.97 (.35)	2.27 (.59)	2.29 (.47)	2.10 (.40)	2.16 (.23)
5th graders	32	2.22 (.46)	1.84 (.52)	2.73 (.30)	2.19 (.26)	2.24 (.22)
6th graders	61	2.30 (.50)	1.90 (.63)	2.72 (.33)	2.01 (.25)	2.19 (.21)
Spanish	67	2.28 (.44)	1.84 (.61)	2.73 (.34)	2.08 (.28)	2.21 (.20)
Foreign	30	2.27 (.54)	2.12 (.58)	2.40 (.50)	2.07 (.31)	2.19 (.26)
Gypsy	21	2.00 (.50)	2.25 (.59)	2.60 (.36)	2.07 (.30)	2.22 (.20)

[a]M (SD): Mean (Standard deviation).

4.2.2. Cultural background

NOS constructs were very similar between participants with different cultural backgrounds, with the Spanish students obtaining slightly higher scores. A one-way ANOVA was conducted to compare the effect of cultural background on students' views of NOS, obtaining that cultural background variables have not a significant impact on students NOS views, neither in the overall score nor in each NOSI dimensions [$F(2, 115) = .150$; $p = .861$; $\eta_p^2 = .003$].

4.2.3. School grade

Views on NOS remained very similar across grade levels, with a slight decrease in scores in the older grade levels. Interestingly, as the grade level increased, students gave lower ratings to the tentativeness of science and rated its empirical character more highly. Table 4 shows the descriptive results for the NOSI scale. A one-way ANOVA was conducted to compare the effect of grade level on student views of NOS. No effect of grade level on student views of NOS was found [$F (3, 114) = .570$; $p = .636$; $\eta_p^2 = .015$]. However, separate analysis of each NOSI dimension, by grade levels, showed that views of the tentative NOS construct differed significantly among students [$F (3, 114) = 5.615$; $p = .0001$; $\eta_p^2 = .129$). Thus, the Bonferroni post-hoc test reported that the tentative views of NOS among students in the 3rd grade were

significantly more informed than the views of students in the 5th and 6th grade. The Bonferroni Post-hoc results are reported in Table 7.

Table 7. Bonferroni post-hoc results for tentative NOS dimension according to participants grade level.

Grade (I)	Grade (J)	Mean Difference	Std. Error	p. value
3rd graders	4th graders	.30	.24	1
	5th graders	.73	.21	.004
	6th graders	.67	.20	.007
4th graders	3rd graders	−.30	.24	1
	5th graders	.43	.18	.116
	6th graders	.37	.17	.192
5th graders	3rd graders	−.73	.21	.004
	4th graders	−.43	.18	.116
	6th graders	−.07	.13	1
6th graders	3rd graders	−.67	.20	.007
	4th graders	−.37	.17	.192
	5th graders	.07	.13	1

4.2.4. Summary of research question 2

In relation to the second research question, the results show that gender and school year have a significant impact on student's views of NOS. Cultural backgrounds variables have found to not significantly impact students' NOS views. Thus, girls have more informed views about the empirical aspect of NOS and that students developed more naïve views about the tentative aspect of NOS as grade level increase. Content analysis of student responses during the interview supported the naïve views of NOS reflected on the NOSI scale. In relation to empirical NOS (i.e. 'What, in your view, is science?'), students held mixed views and considered science as a tool used by people to learn about the world and nature. Students' defined science as ways used to 'learn about nature, plants and trees', to 'make discoveries' or to 'investigate things that are very difficult for most people'. Student responses to observation and inferential NOS and to creative and imaginative NOS revealed naïve constructs. For example, the answers of respondents to the interview questions 'How do scientists develop new ideas that explain our world?', and 'Do scientists use their creativity and imagination during their investigations?', students consistently referred to experimentation as the basis of scientific knowledge and that experiments are performed following some specific steps and techniques that are unique to scientists and that must be learned before becoming a scientist. For example, one student said that scientists 'look at some cells of an animal to see if they can invent a medicine or something to cure diseases. They go to their laboratories; when they discover something, they call everybody'. Another participant argued that scientists 'use animals as guinea pigs to make medicines'. Finally, students consider scientific knowledge as 'discoveries never seen before' and that 'no one knows about', which suggest naïve

conceptions because it considers science as mysterious discovering or objective truths that are not influenced by social, cultural or personal aspects like creativity or imagination.

4.3. RQ 3. To what extent do attitudes towards science relate to views of NOS?

A Pearson correlation was performed to establish whether student attitudes towards science and their views of NOS were related: no significant relation [$r(118) = .225$, $p > .05$] was found. A multiple regression was conducted to see whether NOS constructs could predict students' attitudes towards science. Here, it was found that student views of NOS explained a non-significant amount of the variance in student attitudes towards science [$F = (4, 113) = 1.158$, $p = .333$; $R^2_{adjusted} = .005$). The analysis showed that none of the NOSI scale dimensions do significantly predict the values of student attitudes towards science: empirical NOS (Beta = −.076; t(−.811); p = .419); observation and inferential NOS (Beta = .128; t(1.375); p = .172); tentative NOS (Beta = .105; t(1.117); p = .266); and creative and imaginative NOS (Beta = .031; t(.335); p = .739).

5. Discussion

This study reports results related to students' attitudes towards Science and their views of Nature of Science according to gender, cultural background and grade level variables. Taken together, these results suggest that gender, cultural background, and school grade had an impact on student attitudes towards science. For example, boys from this sample had better attitudes towards science than girls; 2nd generation Spanish students reported more enjoyment of science lessons and more interest in science-related careers than Spanish and Spanish students of gypsy ethnicity; and at higher grade levels, student attitudes towards science decreased, especially after 3rd grade of elementary education. Specifically, students from higher grade level reported less enjoyment of science lessons, less interest in science-related activities during leisure time, and fewer aspirations to follow a scientific career. However, the effect size of the differences was small in all cases. This result suggests that in our sample, gender, cultural background and school grade variables do not have as much impact on student attitudes towards science as might be expected or reported in other studies (DeWitt and Archer 2015; Khishfe and Boujaoude 2014). However, gender results from this study are similar to previous results obtained in the literature showing better attitudes towards science in boys (Caleon and Subramaniam 2008; De Pro Bueno and Pérez Manzano 2014; Denessen et al. 2015; DeWitt and Archer 2015; George 2006; Hacıeminoğlu 2016; Vázquez Alonso and Manassero-Mas 2008). Nevertheless, the differences found in this study between students' attitudes are not as great as in the studies cited above. As for cultural background, the results reported in this study relating to 2nd generation Spanish students are similar to those previously reported in the literature showing that ethnic minority students have better attitudes towards scientific careers (DeWitt and Archer 2015). However, it must be highlighted that the cultural background and the nationality of the students included in this study differ from those students in the DeWitt and Archer (2015) study; therefore, this comparison should be made with caution until new research can further clarify these findings. Still, in this study, the attitudes of 2nd generation Spanish students towards scientific careers in this sample appear to confirm that students from developing countries have higher science-related aspirations (2nd generation Spanish students from our sample were mostly from east-European countries: e.g. Romania, Bulgaria), as stated previously by Khishfe and Boujaoude (2014).

The results of attitudes towards science according to grade level are similar to previous results in the literature, confirming the steady decline in positive attitudes towards Science as grade levels increase (Akpinar et al. 2009; Ali et al. 2013; Denessen et al. 2015; DeWitt and Archer 2015; George 2006; Said et al. 2016; Vázquez Alonso and Manassero-Mas 2008). Participants studying elementary grades in Spain appear not to enjoy science lessons, in a similar way to UK students (DeWitt and Archer 2015). The interview results showed dissatisfaction among elementary students in relation to science teaching methodology and the activities performed during science lessons. This finding is similar to Hacıeminoğlu's (2016) study where the author stated that rote-learning might lead to negative attitudes towards science. So, although children appeared to begin school with positive attitudes towards science, as they progressed in schooling, they began to lose interest, probably due to traditional science-teaching methodology that is teacher-centered and that relies mainly on textbooks and 'chalkand-talk' methods.

Regarding NOS, this study has shown that gender and cultural background have no effect on student views of NOS. In general, students included in this study showed naïve views of NOS, similar to those obtained by previous studies (e.g. Yoon, Suh, and Park 2014; Quigley, Pongsanon, and Akerson 2010). Comparing this results with other studies using the NOSI instrument (Hacıeminoğlu, Yılmaz-Tüzün, and Ertepınar 2012), sixth-grader Spanish students held views on NOS that were more informed than the views of Turkish students in terms of 'Empiricism' and 'Observation and Inference' and more naïve in terms of 'Tentativeness' and 'Imagination and Creativity'. An interesting result from our study is that, although no significant differences were found in students general NOS views based on grade level, students from upper grades had less informed views on 'tentative' NOS than students from lower grades, which may be a result of the use of traditional teaching strategies and teachers lack of NOS knowledge. As stated in previous studies that explored NOS instruction for improving student understanding of NOS (i.e. Akerson and Donnely 2010; Akerson et al. 2014; Abd-El-Khalick et al. 2015), NOS constructs are more likely to change when explicit-reflective NOS strategies are used during science lessons. However, in Spain, elementary teachers do not have specific training in science, and their knowledge of scientific issues and science-teaching strategies is very limited (García-Carmona and Acevedo Díaz 2016; Toma, Greca, and Meneses Villagrá 2017; Vázquez-Alonso et al. 2014). Given this lack of knowledge, teachers are unlikely to include more informed NOS views during their science lessons, which may contribute to no improvements in the naïve NOS views of students throughout elementary education.

According to the correlation analysis, there seems to be no relation between student views of Nature of Science and their attitudes towards Science. Although the results are inconclusive, it seems that both attitudes towards Science and NOS views develop independently throughout Elementary education grades. Further studies should explore this relationship including a more representative sample and also specific NOS and attitudes instruments developed and validated using Spanish-speaking students in order to obtain more valid and reliable results.

There are some limitations that may be found in this study. First, the sample was quite small and students' distribution by grade level and cultural background was irregular. A larger sample, with similar numbers of students at each grade level and from each cultural background would be preferable. The authors also acknowledge that grouping students according to cultural background may be limited, especially in the case of 2nd generation Spanish students. Future investigation is suggested to address this limitation. Second, the greater part of the data was collected from responses to self-administered scales, which may not be ideal for lower grade students. An attempt was made to overcome this limitation by

performing interviews with selected students. However, due to their availability and the time constraints imposed by school centres, the authors were unable to take maximum advantage of the interviews. Even so, the results from the interviews appear to support the results obtained from the self-administrated questionnaires.

6. Implications for science education

There are several implications for Science education that are linked to this study. Firstly, there is concern over the steady decline in positive attitudes towards science that elementary students experience as they become older and their grade-levels at school increase. In this regard, numerous studies have pointed to the need for more active teaching pedagogies. A meta-analysis revealed that problem-based learning is an effective teaching strategy for fostering positive attitudes towards school science among students (Demirel and Dağyar 2016). More recently, Hellgren and Lindberg (2017) concluded that authentic experiences that create opportunities for students to connect school science contexts to authentic science may improve the motivation of students towards learning science.

Secondly, gender inclusion strategies to reduce the gender gap (Scutt et al. 2013) should be included during science classes. Many studies argue that Science pedagogy and curricula need to be adapted in order to address the interests and learning methods of girls and to improve their self-efficacy in Science (Baker 2013). Jones et al. (2000) pointed out that girls are less competitive than boys, tend to follow the instructions of the teacher and classroom guidelines more than boys, and that girls may benefit more from cooperative-based learning activities. Additionally, gender discrepancies in science education are more likely to be reduced by offering similar experiences and opportunities to both girls and boys, and by engaging them in laboratory-type and hands-on activities (Cavallo and Laubach 2001). Also, gender-inclusive science curricula tend to include real-life context-based activities that foster collaboration and communication between peers in supportive environments, as pointed out by Brotman and Moore (2008) in their review of science education literature related to the inclusion of girls in science. Additionally, preventive educational measures should be adopted to assist girls from an early age in shaping their self-efficacy, academic performance and expectations of success in science, and in improving their scientific identity through mentoring programs and exposure to scientific role models (Cadaret et al. 2017).

Thirdly, teachers should plan science lessons acknowledging the differences that arise from cultural and gender variables between students, otherwise science reforms may not fit all student needs. For example, science teachers should foster inclusive participation of both boys and girls, ensuring that girls do not feel inhibited by boys and feel that they can participate in hand-on activities (Parker and Rennie 2002). In addition, teachers should not pass on unconscious messages about gender expectations in science achievement, as past research reported that teachers' expectations influence girls' performance (Elwood 2005) and they also should plan their classes attending to the possible existing differences in learning between boys and girls. For example, Chetcuti (2009) found that science teachers consider that boys tend to be more participative and engage more in hands-on activities, and that girls are less competitive and prefer to actively listen to explanations. In relation to culturally inclusive science teaching, Yoon, Kim, and Martin (2016) proposed a culturally inclusive science teaching model (CIST) that could be used in classes with culturally and linguistically diverse students as found in this study.

Finally, the results of this study have stressed the need to improve knowledge of the Nature of Science from early educational grades. In this regard, there is evidence on the effectiveness

of an explicit-reflective instruction approach for this matter (Akerson and Donnely 2010; Akerson et al. 2014; Cakici and Bayir 2012; Abd-El-Khalick et al. 2015; Khishfe 2008; Quigley, Pongsanon, and Akerson 2010).

7. Conclusions

The aim of this study was to contribute to the efforts in determining the influence of cultural background, gender, and grade-level on the attitudes of elementary students towards science and on their views of NOS. Identifying and understanding the relationship between these traits will be vital for attaining scientific literacy for all students.

Finally, the need to investigate the attitudes of elementary school students towards science in greater depth has also been stressed, especially attitudinal constructs related to the enjoyment of science lessons and leisure interests in science; two constructs that assist scientific and technological vocation and that may awaken science-related career aspirations.

Acknowledgments

This study was partially funded by the Spanish Ministry of Economy and Competitiveness through the research project MINECO EDU2017-89405-R.

We would like to acknowledge the reviewers for their comments and suggestions that have contributed substantially to improving this work.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Ministerio de Economía y Competitividad [EDU2017-89405-R].

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