Zamalloa, T., & Sanz, J. (2020). *Attitudes of secondary school students towards geology in Spain*. **Research in Science & Technological Education**, 41(1), 123–146. This is an Accepted Manuscript of an article published by Taylor & Francis in **Research in Science & Technological Education** on 07 Dec 2020, available at: https://doi.org/10.1080/02635143.2020.1845641.

Attitudes of secondary school students towards Geology in Spain

T. Zamalloa and J. Sanz

Department of Didactics of Mathematics and Experimental Sciences, University of the Basque Country, Spain

Corresponding author: Teresa Zamalloa. Faculty of Education. UPV/EHU. Bº Sarriena s/n, 48940 Leioa, Bizkaia. Spain. teresa.zamalloa@ehu.eus. https://orcid.org/0000-0001-8050-496X

Attitudes of secondary school students towards Geology in Spain

Background: The importance of attitudes in learning is gaining relevance among researchers and teachers and yet little research has examined students' attitudes specifically in relation to geology.

Purpose: The aim of this study was to examine students' attitudes towards geology and with respect to other sciences, as well as to determine the key factors that influence these attitudes.

Sample: A sample of 1.641 students in their 4th year of secondary education from five autonomous communities in Spain participated in this study.

Design and Methods: The research was conducted using a previously validated survey, specifically designed to answer the research questions of the study.

Results: The findings revealed that participants generally demonstrate more negative attitudes towards geology than with respect to other sciences. Although they do not consider it a difficult subject, they find it boring and of little interest. Demographic factors, school type or gender do not explain these attitudes: academic aspects seem to be the key to reversing this situation.

Conclusions: The findings of the present study provide some insights for the teaching of geology. For instance, geology programmes need to focus on topics in which students are interested in, and also on establishing connections between geological contents taught in the classroom and real life.

KEYWORDS: geology, secondary education, attitudes.

Introduction

The importance of attitudes in the educational context

The emotional engagement of the student in a science topic or course may increase their desire to learn or to deepen their knowledge of the subject content (Roemmele 2017). Therefore, the importance of the affective domain of learning, which includes emotions, values or attitudes is gaining relevance among researchers and teachers (van der Hoeven Kraft et al. 2011).

An attitude may be defined as a predisposition to respond in a favourable or unfavourable manner with respect to a given object, subject or domain. There are

generally three classes of attitudinal responses: affective, cognitive, and behavioural (Koballa and Crawley 1985; Oskamp and Schultz 2005). Affective response refers to feelings or emotions, for example, the fact of finding geology enjoyable; cognitive response refers to beliefs or thoughts, such as expressing the belief that geology is useful; and behavioural response refers to past behaviours or behavioural intentions, for example, a student that may visit an interpretation centre or museum.

Therefore, attitude is a complex and multidimensional construct that is influenced by a myriad of variables, is developed throughout the course of a person's life and tends to change with cognitive states (Germann 1988; Jach and Cervato 2004). Individual's attitudes towards science are mainly formed within the school context, when students have the opportunity to achieve most of their scientific literacy. Individuals are not inclined -and especially students in their learning practices are not encouraged- to examine, reflect on or review their attitudes, so they tend to become more resistant to change and persistent with age (Bybee and McCrae 2011; Oon and Fan 2017). Responses to scientific issues, for example, become consistent with age (Oon and Fan 2017). Until recent decades, the affective components of learning have been undervalued, which has sometimes resulted in an evident disconnection between the cognitive and emotional dimensions in the learning processes and in certain pedagogical approaches (Borrachero et al. 2014). In this regard, an even some methodological approaches and instructional methods have been proven to be effective to improve student's achievement, sometimes these have failed to make science more attractive or to develop positive attitudes towards a specific subject. As argued by Shulman and Tamir (1973), the affective outcomes of science instruction should be at least as important as the cognitive outcomes.

Given the accepted idea of a global declining interest in science and technology, and the implications of this for science-based career choices as well as for the

achievement of a STEM-empowered citizenship, students' attitudes towards science are currently a major concern and a focus of growing attention (Osborne, Simon, and Collins 2003). This importance is also reflected as international assessments (TIMSS, PISA) have been gradually reporting a global devaluation of attitudes towards science (Oon and Fan 2017).

Geosciences face a more difficult challenge than many other STEM disciplines due to students´ scant exposure to the geosciences early in their academic life (Adentuji 2018). This gradual decrease in favourable attitudes towards science, especially in the most developed countries (Potvin and Hasni 2014), is leading to an inevitable fall in students enrolled in careers related to sciences, among which geology is included (Meléndez, Fermeli, and Koutsouveli 2006, 2007).

For these reasons, the study of students' attitudes towards science has become an area of interest in science education in recent decades, giving rise to a body of knowledge that includes the development of instruments to evaluate student attitudes (Palmer, Burke, and Aubusson 2017; Potvin and Hasni 2014; Tytler and Osborne 2012).

One of the most important findings is that primary students' positive attitudes towards science become less so with age. Attitudes towards school science, but not science in general, are typically positive (Osborne and Dillon 2008), although these decline through adolescence (Palmer, Burke, and Aubusson 2017), the stage of development at which emotions become more selective (Borrachero et al. 2014). As they advance from primary to secondary education, students lose their interest in science (Ali et al. 2013) and cease to see it as a viable option for their future (Christidou 2011). Moreover, subject-related differences are often detected in secondary education, as students are more interested in nature sciences (biology and geology), and less attracted towards physics and chemistry (Vázquez and Manassero 2008).

Different studies have identified some major influencing factors in students' attitudes such as gender, year of study, ethnicity, or the socio-economic and cultural context (Regan and DeWitt 2015; Sherman-Morris 2013; Simpson et al. 1994). But above all, classroom experiences are a vital component in attitude formation (Roemmele 2017). In this regard, some authors maintain that the quality and type of instruction could exert a major constraint in shifting towards more positive attitudes (Bryan, Glynn, and Kittleson 2011; Kirikkaya 2011; Ornstein 2006; Pickens and Eick 2009). As remarked by Osborne (2007), most science curricula and practices are "foundationalist", conceived to "educate future scientists versus educating future citizens" (Bybee and McCrae 2011, 8). Moreover, science in secondary education is fragmented into isolated disciplines that are unable to contextualize students' interest in a coherent, understandable and holistic science practice, and this may potentially result in negative attitudes towards school science (Christidou 2011). Other factors, such as teachers' background knowledge and skills, content-led instruction, absence of practical activities or excessive orientation of class activities towards achievement tests could also be negatively influencing the attitudes that students develop towards school science (Vázquez and Manassero 1999).

Key aspects affecting attitudes towards geology

As mentioned before, if students have potentially negative attitudes towards school science, these are more significant in the case of geology (Betzner and Marek 2014; Young and Shepardson 2018).

The lack of exposure to the discipline in primary school is one of the factors that results in negative feelings towards geology (Schmidt 2013). This situation is also applicable to middle school, where, as determined by Gonzales (2010), only 11% - 15% of students took a specific geology course in the US in the decades 1990-2010. In Spain, geology in compulsory education has been losing presence in the curriculum in favour of

other sciences. This is especially significant in secondary education where geology is taught as a joint subject with biology, resulting in a subordination of the first with respect to the second. Likewise, in other countries such as the UK, Czech Republic or Slovakia, geology is included with geography and it is located on the border of science and social sciences (Department for Education 2013, Kubiatko, Janko, and Mrazkova 2012; Čipková, Karolčík, and Scholzová 2020).

Furthermore, a high number of university students have never experienced a geology or earth science course, compared to the number entering college having taken biology, chemistry or physics (Egger 2019). Generally, these subjects are not taught at the final years of secondary school, with merely 7% of secondary school students taking geology or earth science training (Betzner and Marek 2014; Lewis and Baker 2010).

In addition, the perception of the teachers also exerts a major influence on students' attitudes. In general, primary and pre-service teachers have minimal training in and very low practical content knowledge of geology (Ford 2018). Relatively few teachers have a geology degree or background knowledge in earth sciences (Houser, García, and Torres 2015); for example, less than 5% of secondary school science teachers had a specific degree (Betzner and Marek 2014; Gonzales 2011). As argued by Prokop et al. (2011), most secondary school science teachers have a biology background and "do not like" teaching geology. Therefore, they are "not interested" in geology, and are not comfortable or feel insecure with its teaching. Teachers' lack of interest and the low educational value that they give to geology seem to be passed on to their students, giving rise to poor attitudes towards the subject in school (Betzner and Marek 2014; King 2001).

In addition, teaching methodology is the major influence in shifting students' attitudes. The study conducted by Chang and Mao (1999) found that in secondary education, inquiry-oriented instruction significantly improved students' attitudes towards

earth sciences in comparison to the traditional teaching method. It is also worth noting that geology becomes more relevant in the outdoor setting. In this regard, fieldwork and field trips significantly improve attitudes towards geology (Boyle et al. 2007). Furthermore, extracurricular activities, such as summer courses designed to introduce students to career choices in geology or earth sciences show evidence of positive changes in students' attitudes (Carrick et al. 2016).

Complementary to instructional factors, the apparent disinterest and negative attitudes found among secondary students could possibly respond to the particular nature and idiosyncrasy of geology. Due to the practical and theoretical limitations of earth sciences, students have difficulties understanding and interpreting abstract geological concepts and processes, which in most cases they cannot submit to experimental verification as in other scientific disciplines (Dodick and Orion 2003). Students also hold persistent alternative ideas in key concepts such as rock formation and classification (Frøyland, Remmen, and Sørvik 2016) or plate tectonics (Dolphin and Benoit 2016; Mills et al. 2017). In addition, they struggle to comprehend the vast temporal and spatial scales inherent to geology, resulting in a limited capacity to visualize and construct mental models (Ault 1998; Johnson et al. 2006; King 2008). Students should therefore be trained in the additional set of skills required by geoscience education, and which are not commonly found in other areas. For example, conceptualization of very large-scale phenomena through time and across space, retrospective scientific thinking ("prediction" of the past), the need for visual representation and spatial reasoning, and the development of system thinking to identify the complex systems acting upon the Earth (King 2008; Orion and Ault 2007).

In conclusion, it seems necessary to identify and understand which factors are important in developing a favourable student attitude towards geology. For any

significant learning to take place, it is essential to pinpoint the problematic aspects of the subject and its teaching and propose solutions to these. For that purpose, the present work presents the results of an analysis of the attitudes towards geology and its teaching among students in their 4th year of secondary education, in a study carried out on a wide sample in Spain. Specifically, this article addresses the following research questions:

(1) What are students' attitudes towards geology, and how do these compare with their attitudes towards the other sciences?

(2) What are the key factors that influence these attitudes?

Materials and Methods

Design and validation of the questionnaire

As mentioned before, the research field of students' attitudes towards science is known for the diversity of instruments that have been developed to measure these. Studies have been carried out in different contexts and focused on specific disciplines, resulting in a wide variety of quantitative or semi-quantitative questionnaires and tests (Oon and Subramaniam 2018). As stated by certain authors, broadening the body of knowledge of studies and evaluation instruments is always positive, as long as some considerations are taken into account (Blalock et al. 2008). On the one hand, the construct being investigated must be (clearly) defined, including the relevant variables upon the objectives of research, and, on the other hand, reliability and validity data of the instrument should be provided (Germann 1988).

In the case of geology, few studies have investigated students' attitudes towards the geosciences. Most instruments are developed by modifying existing science attitude questionnaires, or are focused on specific instructional methods, such as field courses or the use of models (Esteves et al. 2013; Gray et al. 2011). Furthermore, few instruments

measure the attitudes towards science in Spanish-speaking school students. In this sense, Navarro et al. (2016) highlighted the limited availability of validated instruments to measure the attitudes towards science in languages other than English, such as Spanish. Moreover, this study can also be relevant as Spanish has the second largest number of native speakers in the world, and Spanish-heritage speakers are the fastest growing ethnic group in the US (Greenberg 2012; Zuniga, Olson, and Winter 2005).

Taking into account that students' attitudes towards school science is a multifaceted construct, the design of the present survey included an initial analysis of the most significant existing instruments and the identification of the items most relevant in the formation of attitudes, such as out-of-class experiences, classroom practices and activities, perceived enjoyment, difficulty and usefulness of school science or environmental challenge, among others (DeWitt and Archer 2015; Kennedy, Quinn, and Taylor 2016).

In the present study, the research team chose a survey as the appropriate methodology to be used in a quantitative study. The survey included 24 items and was written in Spanish and translated into English for reader information (available at https://ehubox.ehu.eus/s/y4YpYJAiKTiEBqF). It was divided into 5 blocks named (1) students' profile (for demographic data), (2) personal interest and curiosity in geology, (3) perception of geology and other sciences (related to research question number 1), (4) academic factors and (5) linkage with outdoor activities (related to research question number 2). Two types of instruments have been commonly used in attitude research in science education: semantic differential scales (Reid and Skryabina 2002; Shannon, Sleet, and Stern 1982) and Likert scales (Menis 1983). Previous studies have shown that both techniques provide comparable results when evaluating attitudes (Espinosa García and Román Galan 1998; McCallon and Braun 1971).

In our case, students responded to most of the items on a 6-point rating scale with labels according to the scale of 1 to 6, where 1 means 'I do not agree at all' and 6 'I totally agree'. In addition, they also responded to one open question. For the questions related to perception of geology and other sciences, semantic differential scales were formulated to evaluate the positive and negative aspects: boring/enjoyable, difficult/easy, uninteresting/interesting, useless/useful, of low/high professional future value of geology.

Concerning item selection, some of those included are commonly used in standard instruments (Barmby, Kind, and Jones 2008; Kennedy, Quinn, and Taylor 2016; Pérez and Pro 2005; Sjøberg and Schreiner 2010); other questions were adapted to the geology discipline, but most of the items of the questionnaire were specifically developed by the authors with the collaboration of 4 experts in geology and education. The questionnaire was first validated in a sample of 533 students in the 4th year of secondary education (age 15-16) from five autonomous regions in Spain and then expanded to 1641 students with the same profile.

For the validation of the questionnaire, five dimensions relating to attitudes were established in order to address the research questions (Table 1). These dimensions were related to the three types of attitudinal response: affective, cognitive and behavioural. Related to the first question "What are students' attitudes towards geology? And with respect to other sciences?", 3 dimensions were defined: (1) curiosity about geology, that included items such as "I would like to know how rocks and fossils help us to know the history of life on Earth", (2) perception of geology and biology, that included items such as "geology is boring/enjoyable", and (3) perception of physics and chemistry, that included items such as "chemistry is difficult/easy". Related to the second question "What are the key factors that influence these attitudes?", the following dimensions were defined: (4) learning geology in and outside the classroom that included items such as "I

like exercises with minerals and rocks"; and (5) evaluative belief about professional future that included items such as "Chemistry has a low/high professional future".

In Table 2 we present the component matrix where the effect of the items in each dimension can be observed (items with highest load for each dimension where chosen, using .400 as threshold). Cronbach's alpha reliability coefficients for all five dimensions of attitudes were determined (Table 3). The coefficients ranged from .882 to .911. All were above .80, which was the suggested criterion (Fink 2015). Therefore, the validation of the questionnaire presents the minimum guarantees of validity and reliability required by international standards for the creation and adaptation of tests (AERA, APA and NCME 2014).

Data collection

As mentioned, the study was conducted with 1641 students in 4th year of secondary education (age 15-16) from five autonomous regions in Spain (Andalusia, Aragon, the Basque Country, the Canary Islands and Galicia) from a total of 20 different provinces. In Spain, biology and geology is a combined subject that is compulsory only in 1st and 3rd year (ages 12-13 and 14-15 respectively), and optional in 4th year (MECD 2015). In particular, the topics studied in geology during the compulsory years are the history of the universe, the solar system, the geosphere, geological agents and the evolution of the landscape. The curriculum in the studied regions include the same conceptual contents (as defined by national legislation), although the educational approach taken might vary slightly. The regions were selected based on two criteria: the presence of points of rich geodiversity and the presence of at least 10 schools in the area. More than 60 secondary education teachers from the different autonomous communities carried out the application of the questionnaire through an online survey instrument during school hours. The teachers emphasized that the answers were anonymous. 62% of the schools were

state schools and 38% private or partially state-subsidised schools. According to gender, 50.2% of the students were female and 49.8% male.

Due to the ordinal and asymmetric nature of the variables, non-parametric statistical analyses were done, as follows: the Friedman test to check whether there were differences in the analysis of the aspects related to geology; Spearmen correlations to estimate the associations between marks given to enjoyment, easiness, interest, usefulness and professional future (Items 13.2); the nonparametric Mann-Whitney U-test and its associated effect to compare the means taking into account gender, type of school and whether geology is being studied as an option in 4th year; and finally the Kruskal-Wallis test and Man-Whitney U-test to compare the autonomous regions, as well as student preferences for activities related to geology. The software used was SPSS 22.0.

Results

What are students' attitudes towards geology? And with respect to other sciences?

The mean scores of secondary students for the five attitudinal components (enjoyment, difficulty, interest, usefulness, perception of relevance for students´ professional future) are around 3.0 on a scale from 1 to 6. Thus, the less appreciated aspects of geology are enjoyment and interest (2.87±1.43 and 3.16±1.50, respectively) and the most appreciated are its usefulness and relevance for students´ professional future (3.69±1.50 and 3.45±1.43, respectively) (Table 4). This suggests that students find geology boring and not very interesting, although, in general, they think that it is useful and of relevance for their future professional prospects.

As could be expected, students who think that geology is interesting and useful also feel it is enjoyable (r=0.73 and r=0.51, respectively) (Table 4). Moreover, the lowest relation found is between difficulty and professional future (r=0.20) or usefulness

(r=0.31). This indicates that even the students that consider geology to be more difficult, value its utility and future professional relevance.

According to the "curiosity about geology" dimension, when asking *When I go to the mountain or to the beach I ask myself how the landscape was formed* (Item 5), 45.6% of student responses score between 1 and 2. Only 3.6% of students asked themselves about geological phenomena that have caused the surrounding landscape (Item 8). However, more than half of the surveyed participants (50.6%) affirmed that they usually watch documentaries related to geology (Item 23), and, when asked *I would like to know how the Earth will change in the future* (Item 6), 73.1% of the student answers range from 4 to 6. These answers seem to indicate that students present more positive attitudes towards phenomena that might occur in the future than towards those that have already occurred and caused the current landscape

Regarding attitudinal aspects of the discipline and compared to other sciences, on average, attitudes towards geology are more negative than towards other science subjects of 4th year Secondary Education (Table 5). Geology is perceived to be significantly less interesting, less useful, with less professional future and more boring than the rest of the subjects ($p<0.005$), although it is not considered as difficult as physics or chemistry. Therefore, the difficulty of geology does not seem to be a factor that may affect the negative attitudes towards geology when compared to other science subjects (Table 6).

Furthermore, these results agree with the data obtained when asking students to name famous researchers related to physics, chemistry, biology and geology (Item 14). In general, they know few scientists and in their answers, they cite their own teachers´ names. It is striking that geology has a lower number of responses compared with the

other science subjects. This is in accordance with the fact that 87.6% of the students affirm that they do not know any geologist in their family or surrounding personal context (Item 24).

What are the key factors that influence these attitudes?

Different factors that could influence these attitudes towards geology including gender, type of school, choosing or not geology as optional subject and other academic aspects have been analysed.

Gender (data not shown) and type of school (state-owned, private…) have no influence in the perception of the usefulness or in the interest components of attitudes towards geology. Yet, a slight difference in difficulty, enjoyment and perception of professional relevance of geology depending on the type of school (that will not be taken into account due to the effect size) is observed (Table 6). As expected, the very fact of choosing geology, which is an optional subject in Spain in 4^{th} year of secondary education, has a positive effect on the students´ opinions of it; they perceive it to be more interesting and useful, as well as having a better professional future. In particular, they also find it more enjoyable and easier than those who do not choose the subject as an option (Table 6).

But, as for attitudes towards science, academic factors are also the major determinants in the case of students' attitudes regarding earth sciences. Consequently, and taking into account the overall results in Table 6, students that positively valued taking part in geology field trips (Item 17), exercises with minerals and rocks (Item 18), laboratory practices related to geology (Item 12) or geological dynamic models (Item 20), had better attitudes towards geology than those students who valued these activities less

or hadn't participated in them. Curiously, there is a difference between the attitudes towards indoor and outdoor activities. In this case, although we expected better attitudes towards field trips compared to classroom activities with minerals and rocks, geology laboratory practices or geological dynamic models, the results indicate that the students present better attitudes towards the indoor class activities.

On the other hand, it is worth mentioning that almost half of the surveyed students (41%) said that in previous years of secondary education they hadn´t had time enough to work on geology topics (Item 16). As mentioned previously, in Spain, 'biology and geology' is a compulsory subject in 1st and 3rd year, which includes contents like the history of the universe, the solar system, the geosphere, geological agents and the evolution of the landscape (MECD, 2015). In the light of the findings of our study we can deduce that teachers tend to focus on topics related to biology and they either do not have sufficient time to teach those related to geology, or presumably, consciously skip geology contents.

Finally, and concerning the social activities outside school, such as visiting science museums or caves with their family or friends (Item 21), nearly 48.9% of the students affirm that they have visited an interpretation centre with their family, 19.9% with a free-time group and almost 43.4% during a summer camp. In this sense, students that have visited interpretation centres with their families, even if they are not related to geology, perceive geology as more enjoyable, easier and more interesting (Table 7).

In any case, there seems to be a social interest and concern among students towards geology, as more than half of the surveyed participants (50.6%) affirmed that they usually watch documentaries related to geology, on topics such as mountain formation and movement of the plates (Item 23).

Discussion

The present research analyses the attitudes towards geology and with respect to other sciences taught in secondary school, identifying the key factors modulating these attitudes. Understanding these factors could assist the effort to reverse the current situation and to elaborate educational practices that highlight the values of the geosciences among students. For that purpose, a specifically designed survey has been validated and conducted with 1641 students (ages 15-17, in 4th year of secondary education) from five different regions in Spain.

Enjoyment, interest, success, value and prior school experience of the sciences are the most important influences on their decision to choose or reject a subject (Osborne, Simon, and Collins 2003; Palmer, Burke, and Aubusson 2017). The results of this study show that, although geology is not considered a difficult subject, it is not attractive for secondary students who admit that they do not enjoy it. Not considering geology attractive coincides with the scientific literature reporting a decline in students' attachment to science (Osborne, Simon, and Collins 2003; Potvin and Hasni 2014) and to earth sciences (Bezzi, 1999; Bybee and McCrae 2011; Young and Shepardson 2018). These results may be due to the fact that learning geology does not seem to fit the interests and needs of students (Hodson 2003), and also that, traditionally, the way geology has been taught is excessively theoretical with few practical activities (Teasdale, Selkin, and Goodell 2017). In fact, our results indeed indicate that students that have done practical hands-on activities consider geology more attractive than students that have not. It is also noteworthy that students in this study, in contrast with their lack of enjoyment in learning geology, nevertheless admit that it could be useful in the future both generally and from a professional point of view. These results are in accordance with those of Betzner and Marek (2014) where most students considered the learning of earth sciences throughout

secondary school to be important both for their general understanding of science and for their future university education. These results may evidence a gradual but significant evolution in students´ perceptions compared to older studies where undergraduate students perceived geology to be low in prestige, low in difficulty and low-paying relative to biology, chemistry and physics (Hoisch and Bowie 2010).

In addition, the results of the present work also indicate that students who find learning geology enjoyable also consider it to be easy, interesting, useful and offering a good professional future. This correlation is understandable, as the affective domain and the emotional part of students' attitudes towards science (comprising how a student feels about certain topics) is closely related to the relevance given to that science topic (Holbrook and Rannikmae 2009).

On the other hand, of the four major scientific disciplines (biology, geology, physics and chemistry) our results indicate that students present the most positive attitudes towards biology and the most negative attitudes towards geology. This is in line with the studies reporting the stereotypical view that students hold earth sciences to be less 'scientific', with a lack of experimental control and rigour than the other disciplines (Betzner and Marek 2014; Lewis and Baker 2010). This geologic "blindness" (Roemmele, 2017) portrays geology as a "derivative" science, giving students the idea that geology is not as important as other sciences, and negatively influencing their attitude towards earth sciences.

Egger (2019) explains that the negative attitude towards earth sciences could be attributed to the lack of exposure to geosciences in school. This earlier exposure in their school careers, especially in primary school, is one of the factors that results in positive feelings towards earth sciences in students (Schmidt 2013). The significant absence of

earth science education all throughout secondary school is a major problem, evidenced by the fact that, for example, in the US only 22% of graduating high-school students in 2005 had taken a geoscience course, compared with 92% who had taken a biology course (Gonzales and Keane 2010). In this regard, it is also interesting to note that in the European countries the teaching of geology as a separate discipline in secondary school curricula has been progressively reduced in the last two decades, so gradually students are getting fewer basic geologic contents (Fermeli et al. 2015).

Nevertheless, and as mentioned before, we have to admit that the practical and theoretical limitations of geology can also give rise to negative attitudes towards geological sciences among students. Sometimes students have difficulties attempting to comprehend the vast temporal and spatial scales inherent to geology, making it difficult for them to visualize and modelise the so-called *hidden geology* (Ault 1998; King 2008). Therefore, all these aspects should be addressed when designing any earth science educational intervention.

Concerning the key factors that moderate student's attitudes towards geology, the results of the present study indicate that gender does not exert a significantly influence. This finding is interesting as relevant studies have suggested gender-based attitudes towards some science disciplines, which could explain the underrepresentation of women in certain STEM careers and academic positions (Ceci and Williams 2007; Gokhale et al. 2015). As mentioned, some studies show that boys are more interested and have more positive attitudes than girls towards physical- and earth-sciences (Chang, Yeung, and Cheng 2009; Francis and Greer 1999; Toma, Greca, and Orozco Gómez 2019). In any case, even though the presence of stereotypes is especially strong in some regions, and although in some disciplines women still remain underrepresented at certain levels, recent reports indicate that gender balance in STEM, including geology, is

improving, albeit at a slow pace (She Figures 2018). This normalization could explain our results where no gender differences are detected in attitudes towards geology. Likewise, when analysing the gender balance in geography (which includes the study of geology in many countries), there has not been found differences in perception between genders either (Kubiatko, Janko, and Mrazkova, 2012).

We also studied the effect of classroom methodology, focusing on the attitudes towards the activities most commonly carried out by schools such as field trips or exercises with minerals and rocks. Our results show that students with positive attitudes towards these activities also had better attitudes towards the subject. Surprisingly, students present more positive attitudes towards indoor activities such as hand-on activities with rocks, laboratory practices or geological dynamic models than towards field trips.

This finding is in contrast with the broad consensus regarding the benefits of outdoor educational activities for the acquisition of scientific competence, including both contents and attitudes (Clary and Wandersee 2014; Orion and Hofstein1991). Specifically in geology, where field-trips are considered as the genuine practical work, students can improve skills such as causal reasoning or dynamic thinking (Batzri et al. 2015), they can also learn about locally-relevant geosites, and potentially be introduced to environmental and social aspects such as soil usage, landscape formation and preservation of cultural heritage. For these reasons, most studies have demonstrated the positive effect of field-work on students' values, interest, and attitudes (Boyle et al. 2007). Also, pre-service and in-service teacher training courses based on outdoor geology improve their cognitive and affective domains, 'carrying-over' those positive feelings to the classroom (Kern and Carpenter 1984; Weekes and Carpenter 1993). In any case, our results identifying students' better attitudes towards indoor activities and those less positive towards outdoor

geology, share similarities with those obtained by certain authors that have shown evidence that some students were less positive about specific tasks related to outdoor geology (Stokes and Boyle 2009; Young and Shepardson 2018). This could be explained by the fact that to be significant, geology fieldwork may require some prior basic knowledge (i.e. the main geological concepts and principles, rock identification and sampling, map reading…), and a minimal training in navigation and 3D visualization skills. Students and teachers that are not properly trained in such skills can feel uncomfortable, and subsequently develop negative attitudes towards geology field activities.

On the other hand, the fact that students in our study showed positive attitudes towards practical geology class activities is encouraging and reinforces the idea that active-learning and learner-centred pedagogies positively influence students' attitude formation, especially in the case of those who have little or no first-hand experience of the topic (Sharpe and Abrahams 2019). Sometimes, hands-on activities that have proven to be attitude-beneficial can be as simple and cost-effective as 3D geological models (Gray et al. 2011) or a geology resource-room (Boyd and Carpenter 1980). Nevertheless, some authors claim that, although first-hand experience of scientific phenomena have demonstrated to improve students' earth science achievements and attitudes, these activities must be oriented towards a student-centred and inquiry approach, in the framework of scientific practices (Mao and Chang 1998; Wysession 2012). So, even if many classrooms still rely almost exclusively on traditional lecture or confirmatory laboratory experiences (Kortz, Smay, and Murray 2008), and although geosciences have been slow to adapt to these research-based strategies (Egger, 2019), the use of active learning pedagogies and the transformation of the curriculum of subjects to include authentic inquiry activities is becoming more prevalent in geology (Apedoe 2008; Moss

and Cervato 2016). Moreover, and regarding to the attitudinal benefits, some studies have revealed that secondary education inquiry-oriented constructivist instruction significantly improved students' attitudes towards geology in comparison to the traditional teaching method (Aguilera 2019; Chang and Mao 1999; McConell, Steer, and Owens 2003; Shepardson and Pizzini 1993). Students exposed to inquiry-driven pedagogies are able to plan their own investigations, gather and interpret data, analyse results, and share findings with their classmates. In this way, students become engaged in their own learning process. These activities may not only be potentially beneficial to students, but also to teachers´ performance. As determined by Martin, Ryan, and Carpenter (1992), involving teachers in hands-on inquiry-oriented courses improves their attitudes towards geology, in addition to reinforcing their conceptual and pedagogical earth science knowledge.

On the other hand, when asked about geological concepts that are more attractive, our results indicate that students present more positive attitudes towards events that may occur in the future, such as the evolution of the Earth, than towards those geological phenomena from the past, for example, those that have concurred in the formation of the current landscape. Interestingly, and as determined by Trend (2009), primary age children (8- to 12-years) start having an interest in Earth-related subjects. This is evidenced by the fact that some of the most popular science topics in that age range lie within the discipline of geoscience: volcanoes, earthquakes, weather or the formation of planet Earth. Children are attracted by the spectacular and impressive nature of geology, its outstanding capacity to arouse curiosity and its narrative potential. However, as children advance in adolescence, this interest and positive attitude decreases. It may be because school science in secondary education is more fragmented into individual disciplines that prevent students from perceiving a holistic view of science or the relevance of theoretically-presented topics to their own lives. All of which may finally

result in negative attitudinal behaviours (Christidou 2011). Furthermore, and this can be in accordance with the results obtained in our study, often school science offers a backward-looking view, when students expect it to be "less retrospective and more prospective" (Osborne, Simon, and Collins 2003). Hence, there is a need to revise earth science education, from a focus on the past towards a focus on the future, with an emphasis on aspects that affect society and help students to perceive geoscience content to be more relevant and related to everyday facts (Bralower, Feiss, and Manduca 2008; Pelch and McConnell 2017).

Some studies have evidenced that a stronger connection between educational geoscience practice and students' day-to-day context, in some cases with explicit approaches to socio-scientific issues, can make a positive change to students' attitudes towards geology (Carpenter 1983; Holley 2017; Pelch and McConnell 2017; Young and Shepardson 2018). These educational approaches can expand public knowledge and awareness of locally-relevant issues, for example by emphasizing how geology can be used as a tool to solve community-based environmental problems (Murray et al. 2012) or by connecting topics like soil to the effect of climate change on global agriculture (Ford, 2018). As the commitment towards ecological problems and the sense of self-criticism appears in adolescence, students' environmental concerns and engagement could be capitalized on geology teaching activities that encourage them to connect geological science with their daily lives, personal interests and expectations.

To conclude the discussion of the instructional factors it is also important to consider that students' attitudes are significantly affected by teachers' performance, commitment and attitudes (Kessels and Taconis, 2012). Pre-college teachers hold negative attitudes towards teaching geology, which stem from their own previous educational experiences (Betzner and Marek 2014; Zembylas and Barker 2002). In

addition, a minimal exposure to earth content within teacher education and professional development programmes greatly affects the ways in which teachers embrace or avoid teaching geoscience in the classroom (Ford 2018).

As previously mentioned, it is striking to discover that almost half of the students in our study confirmed that in previous courses they did not study geology contents because of a lack of time. Therefore, it can be deduced that most teachers are not comfortable or feel insecure with teaching earth science topics, and thus less geology than that originally contemplated is taught. As mentioned, there is a significant absence of earth-science training in pre-service education, as for example in England where over 80% of earth science teachers affirmed that they learned very little to no earth science as student teachers (King 2001). The lack of further training after entering the school system is also a major weakness. In fact, as identified by Banilower et al. (2013), in the US 64% of middle school teachers and 42% of high school earth science teachers did not attend any earth science courses beyond an introductory level. Also in Spain, merely a 10% of the secondary education science teachers have a geology degree whereas a 60% have a biology background (Zamalloa et al 2014). Improving teachers' basic earth science literacy and pedagogical content knowledge would presumably increase their self-perceived ability and confidence to teach earth science. But increasing knowledge does not automatically improve teacher attitude, so effective science courses for teachers must also address the affective domain (Slater, Carpenter, and Safko 1996). In this regard, constructivist pedagogy, particularly within courses that emphasize inquiry (Mulholland and Wallace 1996) or NGSS scientific practices (Gray 2017; Lambert and Bleicher 2017), has demonstrated to improve the attitudes of pre-service teachers towards earth science (Gray 2017; Luera and Otto 2005).

Finally, and regarding the social domain and personal factors of students' attitudes, it is remarkable that a large part of the students in our study have occasionally visited informal education facilities related to geology such as interpretation centres, science museums or caves. Students who have visited these centres with their families have developed more positive attitudes towards geology. This perceived curiosity is corroborated by the fact that half of the surveyed students also enjoy watching documentaries and are interested in being informed about geology.

These results are in line with the increasing social interest in geology and geodiversity. This is also reflected in a growing promotion of participatory activities around local geology-sites and the socialization of geo-tourism, with a promising educational potential for different audiences such as schools or families (Carcavilla et al. 2009; Dunlop, Larwood, and Burek 2018). This rediscovering of the cultural and natural geoheritage by families and local communities is encouraging, not only for the promotion of non-formal educational initiatives, but also for potentially increasing the awareness of the local geological resources. Families provide a constant and enduring context for learning, and parents have a major influence in transmitting cultural values and practices to their children, and thus potentially encouraging them towards STEM. Studies in family learning have confirmed the significant role of parents in engaging with young children in informal science education institutions (Luce, Goldman, and Vea 2016; Zimmerman and McClain 2016). Therefore, and in relation to the results of our study, the involvement in these kind of informal out-of-school scientific activities by students may indicate a positive perception of the relevance of science (Bulunuz and Jarrett 2010; Christidou 2011; Gil-Flores 2012).

In addition to informal education activities, many students with interest in geology frequently get involved in short-term geoscience programmes promoted by

educational institutions, in most cases by universities. It has been demonstrated that students participating in activities such as summer courses designed to introduce middle school and high school students to earth sciences (Carrick et al. 2016; Houser, García, and Torres 2015; Miller et al. 2007), undergraduate geological field camps (Dykas and Valentino 2016) or community-based geoscience workshops (Murray et al 2012), have shown positive changes in their attitudes towards geosciences.

Conclusions

In this study we have attempted to identify the determining factors that affect attitudes towards geology and its teaching in secondary education students. It was also our aim to contribute to the research field of the affective domain of learning, especially in an underexplored area of attitudes towards geology, by providing a validated survey instrument.

Our results have corroborated some of the findings in the literature. For example, students do not consider geology a difficult subject, but they find it boring and not very interesting. Thus, students present more negative attitudes towards it than towards biology, chemistry or physics. Our study has also offered some insights into the factors affecting these attitudes, which mainly rely on instructional methods and academic aspects, noticeably in relation to teachers' geology competence. We were also able to identify a connection between more positive attitudes towards geology with the participation of students in hands-on geology activities in class and with their involvement in family-trips to informal education sites. These findings highlight the importance of developing educative proposals oriented to geology topics and practices that stimulate students' attitudes. We should keep in mind that attitudes play an important role in shaping individual's actions and behaviours. As a result, students´ attitudes

towards geosciences will influence their decision to enrol on undergraduate geoscience courses, to pursue a degree or career in geosciences, and above all, to become informed future citizens.

Finally, and based on the results obtained in our study, we would like to propose further contributions to the educational research area of attitudes towards geology. On the one hand, and as classroom strategies are one of the major moderating factors in students' attitudes, we may examine whether specific didactic interventions effectively improve these attitudes. We would direct our attention to newly-developed curricular methods, and also towards the geology training courses for science teachers. On the other hand, and considering the special nature and characteristics of earth sciences compared to other sciences, it would also be challenging to analyse the generating mechanisms of the origins of students' attitudes towards geology. In this case, the most suitable methods are based in qualitative research approaches, which could be combined with the survey instrument developed in the present study.

Acknowledgements

The authors thank Isabel Echevarría, Gurutze Maguregi, Lola Fernández and Nerea Casas for their assistance in the definition of the survey and the analysis of data. We would like to acknowledge the reviewers for their comments and suggestions that have contributed substantially to improving this work. This work was supported by the University of the Basque Country under Grant EHUA14/27.

References

Adetunji, O.O., J.M. Ba, W. Ghebreab, J.F. Joseph, L.P. Mayer, and R. Levine. 2012. "Geosciences Awareness Program: A Program for Broadening Participation of Students in Geosciences." *Journal of Geosciences Education* 60: 234–240.

AERA (American Educational Research Association), APA (American Psychological Association), and NCME (National Council on Measurement in Education). 2014. *Standards for Educational and Psychological Testing*. Washington DC: American Educational Research Association.

Aguilera, D., and F.J. Perales-Palacios. 2019. "Learning biology and geology through a participative teaching approach: the effect on student attitudes towards science and academic performance." *Journal of Biological Education* 54(3): 245–261. doi:10.1080/00219266.2019.1569084

Ali, M.M., R.E. Yager, E. Hacieminoglu, and I. Caliskan. 2013. "Changes in Student Attitudes regarding Science when Taught by Teachers without Experiences with a Model Professional Development Program." *School Science and Mathematics* 113(3): 109–119. doi:10.1111/ssm.2013.113.issue-3.

Apedoe, X.S. 2008. "Engaging Students in Inquiry: Tales from an Undergraduate Geology Laboratory-Based Course." *Science Education* 92: 631–663. doi: 10.1002/sce.20254

Ault, C.R. 1998. "Criteria of Excellence for Geological Inquiry: The Necessity of Ambiguity." *Journal of Research in Science Teaching* 35(2): 189–212. doi: https://doi.org/10.1002/(SICI)1098-2736(199802)35:2<189::AID-TEA8>3.0.CO;2-O

Baird, J. R., and C. Penna. 1992. "Shared Adventure: A View of Quality Teaching and Learning" In Second Report of the Teaching and Learning Science in Schools Project. Survey Research. Edited by Baird 185–274. Victoria: Monash University

Banilower, E.R., P.S. Smith, I.R. Weiss, K.A. Malzahn, K.M. Campbell, and A.M. Weis. 2013. *Report of the 2012 national survey of science and mathematics education.*

http://horizon-research.com/NSSME/2012-nssme/research-products/reports/technical-report (last accessed 27 July 2020).

Barmby, P., P.M. Kind, and K. Jones. 2008. “Examining Changing Attitudes in Secondary School Science.” *International Journal of Science Education* 30 (8): 1075–1093. doi: 10.1080/09500690701344966

Batzri, O., O. Assaraf, C. Cohen, and, N. Orion. 2015. “Understanding the Earth Systems: Expressions of Dynamic and Cyclic Thinking among University Students.” *Journal of Science Education and Technology* 24(6): 761–775. www.jstor.org/stable/43867743

Betzner, J.P., and E.A Marek. 2014. “Teacher and Student Perceptions of Earth Science and Its Educational Value in Secondary Schools.” *Creative Education* 5: 1019–1031. doi: 10.4236/ce.2014.511116

Bezzi, A. 1999. “What Is This Thing Called Geoscience? Epistemological Dimensions Elicited with the Repertory Grid and their Implications for Scientific Literacy.” *Science Education* 83(6): 675–700. doi: 10.1002/(sici)1098-237x(199911)83:6<675::aid-sce3>3.0.co;2-q

Blalock, C.L., M.J. Lichtenstein, S. Owen, L. Pruski, C. Marshall, and, M. Toepperwein. 2008. “In Pursuit of Validity: A comprehensive review of science attitude instruments 1935–2005.” *International Journal of Science Education* 30(7): 961–977. doi: 10.1080/09500690701344578

Borrachero, A.B., M. Brígido, L. Mellado, E. Costillo, and, V. Mellado. 2014. “Emotions in prospective secondary teachers when teaching science content, distinguishing by gender.” *Research in Science & Technological Education* 32 (2): 182–215. doi:10.1080/02635143.2014.909800

Boyd, H.W., and J.R. Carpenter. 1980. “Attitudinal Changes Associated with a Remedial Resource Room in Introductory Geology.” *Journal of Geological Education* 28(5): 238–243. doi: 10.5408/0022-1368-28.5.238

Boyle, A., S. Maguire, A. Martin, C. Milsom, R. Nash, S. Rawlinson, A. Turner, S. Wurthmann, and S. Conchie. 2007. “Fieldwork is good: The student perception and the affective domain.” *Journal of Geography in Higher Education* 31: 299–317. doi: 10.1080/03098260601063628

Bulunuz, N., and O.S. Jarret. 2010. “The effects of hands-on learning stations on building American elementary teachers’ understanding about earth and space science concepts.” *Eurasia Journal of Mathematics, Science & Technology Education* 6(2): 85–99. doi: 10.12973/ejmste/75230

Bralower, T.J., P.G. Feiss, and C.A. Manduca. 2008. “Preparing a New Generation of Citizens and Scientists to Face Earth's Future.” *Liberal Education* 94(2): 20–23.

Bryan, R.R., S.M. Glynn, and J.M. Kittleson. 2011. “Motivation, Achievement, and Advanced Placement Intent of High School Students Learning Science.” *Science Education* 95: 1049–1065. doi: 10.1002/sce.20462

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

Carcavilla, L., J.J. Durán, A. García-Cortés, and J. López-Martínez. 2009. “Geological heritage and geoconservation in Spain: Past, Present, and Future.” *Geoheritage* 1: 75–91. doi: 10.1007/s12371-009-0006-9

Carpenter, J.R. 1983. “A comparison of student attitudes, values and interests toward two contrasting introductory earth science courses.” *Journal of College Science Teaching* 12: 441–445.

Carrick, T.L., K.C. Miller, E.A. Hagedorn, B.R. Smith-Konter, and A.A Velasco. 2016. "Pathways to the Geosciences Summer High School Program: A Ten-Year Evaluation." *Journal of Geoscience Education* 64(1): 87–97. doi: 10.5408/15-088.1

Ceci, S.J., and W.M. Williams. 2007. *Why aren't More Women in Science. Top Researchers Debate the Evidence.* Washington, DC: American Psychological Association.

Chang, C.Y., and S.L. Mao. 1999. "Comparison of Taiwan Science Students' Outcomes with Inquiry-Group versus Traditional Instruction." *The Journal of Educational Research* 92(6): 340–346. doi: 10.1080/00220679909597617

Chang, S., Y. Yeung, and M.H. Cheng. 2009. "Ninth Graders' Learning Interests, Life Experiences and Attitudes towards Science & Technology." *Journal of Science Education and Technology* 18: 447–457. doi: 10.1007/s10956-009-9162-6

Christidou, V. 2011. "Interest, attitudes and images related to science: Combining students' voices with the voices of school Science, teachers, and popular science." *International Journal of Environmental & Science Education* 6 (2): 141–159.

Čipková, E., Š. Karolčík, and L. Scholzová. 2020. "Are secondary school graduates prepared for the studies of natural sciences? – evaluation and analysis of the result of scientific literacy levels achieved by secondary school graduates." *Research in Science & Technological Education* 38 (2): 146–167. doi: 10.1080/02635143.2019.1599846

Clary, R.M., and J.H. Wandersee. 2014. "Lessons from US fossil parks for effective informal science education." *Geoheritage* 6: 241–256. doi: 10.1007/s12371-014-0116-x

Department for Education. 2013. The statutory programmes of study and attainment targets for geography at key stages 1 to 3. Available at:

https://www.gov.uk/government/publications/national-curriculum-in-england-geography-programmes-of-study

DeWitt, J., and L. Archer. 2015. "Who Aspires to A Science Career? A Comparison of Survey Responses from Primary and Secondary School Students." *International Journal of Science Education* 37(13): 2170–2192. doi:10.1080/09500693.2015.1071899

Dodick, J., and N. Orion. 2003. "Geology as a Historical Science: Its Perception within Science and the Education System." *Science and Education* 12: 197–211. doi: 10.1023/A:1023096001250

Dolphin, G., and W. Benoit. 2016. "Students' mental model development during historically contextualized inquiry: How the 'tectonic plate' metaphor impeded the process." *International Journal of Science Education* 38(2): 2–22. doi:10.1080/09500693.2016. 1140247

Dunlop, L., J.G. Larwood, and C.V. Burek. 2018. "Geodiversity Action Plans – A Method to Facilitate, Structure, Inform and Record Action for Geodiversity." In *Geoheritage. Assessment, protection, and management* edited by E. Reynard and J. Brilha, 53–65. Elsevier, Amsterdam.

Dykas, M.J., and D.W. Valentino. 2016. "Predicting Performance in an Advanced Undergraduate Geological Field Camp Experience." *Journal of Geoscience Education* 64: 314–322. doi: 10.5408/15-128.1

Egger, A. 2019. "The Role of Introductory Geoscience Courses in Preparing Teachers—and all Students— For the Future: Are We Making the Grade?" *GSA Today* 29(10): 1–8. doi: 10.1130/GSATG393A.1

Espinosa García, J., and T. Román Galán. 1998. “La Medida de las Actitudes Usando las Técnicas de Likert y de Diferencial Semántico.” *Enseñanza de las Ciencias* 16(3): 477–484. https://www.raco.cat/index.php/Ensenanza/article/view/21551

Esteves, H., P. Ferreira, C. Vasconcelos, and I. Fernandes. 2013. “Geological Fieldwork: A Study Carried Out with Portuguese Secondary School Students.” *Journal of Geoscience Education* 61(3): 318–325. doi: 10.5408/12-394.1

Fermeli, G., G. Meléndez, A. Koutsouveli, M. Dermitzakis, A. Calonge, F. Steininger, C. D’Arpa, and C. Di Patti. 2015. “Geoscience Teaching and Student Interest in Secondary Schools-Preliminary Results from an Interest Research in Greece, Spain and Italy.” Geoheritage 7: 13–24. doi: 10.1007/s12371-013-0094-4

Fink, A. 2015. *How to conduct surveys: A step-by-step guide.* London: Sage Publications

Ford, D.F. 2018. “Preservice teachers’ conceptions of Earth and environmental topics appropriate for K–5 learners.” *Journal of Geoscience Education* 66 (2): 121–130. doi:10.1080/10899995.2018.1432194

Francis, L.J., and J.E. Greer. 1999. “Measuring attitude towards science among secondary school students: the affective domain.” *Research in Science & Technological Education* 17(2): 219–226. doi:10.1080/0263514990170207

Frøyland, M., K.B. Remmen, G.O. Sørvik. 2016. “Name-Dropping or Understanding?: Teaching to Observe Geologically” *Science Education* 100(5): 923-951.

Germann P.J. 1988. “Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school.” *Journal of Research in Science Teaching* 25 (8), 689–703. doi:10.1002/tea.3660250807

Gil-Flores, J. 2012. “Actitudes del Alumnado Español Hacia las Ciencias en la Evaluación PISA 2006.” *Enseñanza De Las Ciencias* 30(2): 131–152.

Gokhale, A.A., C. Rabe-Hemp, L. Woeste, and K. Machina. 2015. “Gender Differences in Attitudes towards Science and Technology among Majors.” *Journal of Science Education in Technology* 24: 509–516. https://www.learntechlib.org/p/162037/.

Gonzales, L.M., and C.M. Keane. 2010. Who will fill the Geoscience Workforce Supply Gap? *Environmental Science and Technology* 44: 550–555. doi: 10.1021/es902234g

Gonzales, L. 2011. *Status of the Geoscience Workforce*. American Geosciences Institute, Alexandria.

Gray, K. 2017. “Assessing Gains in Science Teaching Self-Efficacy After Completing an Inquiry-Based Earth Science Course.” *Journal of Geoscience Education* 65: 60–71. doi: 10.5408/14-022.1

Gray, K.R., K.D. Owens, D.N. Steer, D.A. McConnell, and C.C. Knight. 2011. “An exploratory study using hands-on physical models in a large introductory, Earth science classroom: Student attitudes and lessons learned.” *Electronic Journal of Science Education* 12(2):1–23. http://ejse.southwestern.edu/article/view/7391/6904.

Greenberg, J. 2012. “Educational engagement practices of urban immigrant Latina mothers.” *Journal of Ethnic and Cultural Diversity in Social Work* 21(3): 231–248. doi:10.1080/15313204.2012.700495

Hodson, D. 2003. “Time for Action: Science Education for an Alternative Future.” *International Journal of Science Education* 25(6): 645–670. doi: 10.1080/09500690305021

Hoisch, T.D., and J.I. Bowie. 2010. “Assessing Factors that Influence the Recruitment of Majors from Introductory Geology Classes at Northern Arizona.” *University Journal of Geoscience Education* 58(3): 166–176, doi: 10.5408/1.3544297

Holbrook, J., and M. Rannikmae. 2009. “The meaning of scientific literacy.” *Journal of Environmental and Science Education* 4(3): 275–288.

Holley, E.A. 2017. “Engaging Engineering Students in Geoscience through Case Studies and Active Learning.” *Journal of Geoscience Education* 65(3): 240–249. doi: 10.5408/16-145.1

Houser, C., S. Garcia, and J. Torres. 2015. “Effectiveness of Geosciences Exploration Summer Program (GeoX) for Increasing Awareness and Knowledge of Geosciences.” *Journal of Geoscience Education* 63: 116–126. doi: 10.5408/14-016.1

Jach, J.Y., and C. Cervato. 2004. “Attitude toward learning science of students in introductory geology courses.” *Geological and Atmospheric Sciences Publications* 13. Retrieved from https://lib.dr.iastate.edu/ge_at_pubs/13/

Johnson, A., J. Leigh, P. Morin, P. van Keken. 2006. “GeoWall: Stereoscopic visualization for geoscience research and education.” *IEEE Computer Graphics and Applications* 26(6): 10–14. doi: http://doi.ieeecomputersociety.org/10.1109/MCG.2006.127

Kennedy, J.P., F. Quinn, and N. Taylor. 2016. “The School Science Attitude Survey: A New Instrument for Measuring Attitudes towards School Science.” *International Journal of Research & Method in Education* 39(4): 422–445. doi: 10.1080/1743727X.2016.1160046

Kern, E.L., and J.R. Carpenter. 1984. “Enhancement of Student Values, Interests and Attitudes in Earth Science through a Field-Oriented Approach.” *Journal of Geological Education* 32 (5): 299–305. doi: 10.5408/0022-1368-32.5.299

Kessels, U., and R. Taconis. 2012. “Alien or alike? How the Perceived Similarity between the Typical Science Teacher and a Student’s Self-Image Correlates with Choosing

Science at School." *Research in Science Education* 42(6): 1049–1071. doi: 10.1007/s11165-011-9230-9

King, C. 2001. "The Response of Teachers to New Subject Areas in a National Science Curriculum: The Case of the Earth Science Component". *Science Education* 85: 636–664. doi:10.1002/sce.1030

King, C. 2008. "Geoscience Education: an Overview." *Studies in Science Education* 44(2): 187–222. doi: 10.1080/03057260802264289

Kirikkaya, E. 2011. "Grade 4 to 8 Primary School Students' Attitudes towards Science: Science Enthusiasm." *Educational Research and Reviews* 6: 374–382. https://www.researchgate.net/publication/265211842_Grade_4_to_8_primary_school_students'_attitudes_towards_science_Science_enthusiasm

Koballa, T. R., and F.E.Crawley. 1985. "The Influence of Attitude on Science Teaching and Learning." *School Science and Mathematics* 85(3): 222–232. doi: 10.1111/j.1949-8594.1985.tb09615.x

Kortz, K.M., J.J. Smay, and D.P. Murray. 2008. "Increasing Learning in Introductory Geoscience Courses Using Lecture Tutorials." *Journal of Geoscience Education* 56(3): 280–290. doi: 10.5408/1089-9995-56.3.280

Kubiatko, M., T. Janko, and K. Mrazkova. 2012. "The influence of gender, grade level and favourite subject on Czech lower secondary school pupils' perception of geography." *International Research in Geographical and Environmental Education* 21(2): 109–122. doi: 10.1080/10382046.2012.672675

Lambert, J.L., and R.E. Bleicher. 2017. "Argumentation as a strategy for increasing preservice teachers' understanding of climate change, a key global socioscientific issue." *International Journal of Education in Mathematics, Science and Technology* 5: 101–112. doi:10.18404/ijemst.21523

Lewis, E., and D. Baker. 2010. “A Call for a New Geoscience Education Research Agenda.” *Journal of Research in Science Teaching* 47: 121–129. https://digitalcommons.unl.edu/teachlearnfacpub/122

Luce, M.R., S. Goldman, and T. Vea. 2016. “Designing for family science explorations anytime, anywhere.” *Science Education* 101(2): 251–277. doi:10.1002/sce.21259

Luera, G.R., and C.A. Otto, 2005. “Development and evaluation of an inquiry-based elementary science teacher education program reflecting current reform movements.” *Journal of Science Teacher Education* 16(3): 241–258. doi: 10.1007/s10972-005-4585-2

Mao, S.L., and C. Chang. 1998. “Impacts of an Inquiry Teaching Method on Earth Science Students’ Learning Outcomes and Attitudes at the Secondary School Level.” *Proceedings of the National Science Council Part D: Mathematics, Science, and Technology Education* 8(3): 93–101.

Martin, L.E., J.M. Ryan, and J.R. Carpenter. 1992. “Improving Teacher Attitude Toward Science and increasing their knowledge of Earth Science.” *Journal of Geological Education* 40: 216–221.

McCallon, E.L., and J.D. Brown. 1971. “A Semantic Differential Instrument for Measuring Attitude Toward Mathematics.” *Journal of Experimental Education* 39: 69–72. doi: 10.1080/00220973.1971.11011288

McConnell, D.A., D.N. Steer, and K.D. Owens. 2003. “Assessment and active learning strategies for introductory geology courses.” *Journal of Geoscience Education* 51: 205–216.

MECD. 2015. Real Decreto 1105/2014, por el que se establece el currículo básico de la Educación Secundaria Obligatoria y del Bachillerato [Royal decree 1105/2014

establishing the minimum teaching corresponding to compulsory secondary education and high school]. Madrid.

Meléndez, G., G. Fermeli, and A. Koutsouveli. 2006. “Teaching Geology and Geological Heritage in Secondary Schools: Similar Approaches in Spanish and Greek Schools.” *ProGeo symposium: Safeguarding our Geological Heritage*: 11–12.

Meléndez, G., G. Fermeli, and A. Koutsouveli. 2007. “Analyzing Geology Textbooks for Secondary School Curricula in Greece and Spain: Educational Use of Geological Heritage.” *Bulletin of the Geological Society of Greece*, XXXVII, 1819–1832.

Menis, J. 1983. “Attitudes towards chemistry as compared with those towards mathematics, among tenth grade pupils (aged 15) in high level secondary schools in Israel.” *Research in Science & Technological Education* 1(2): 185–191. doi: 10.1080/0263514830010206

Miller, K.C., T. Carrick, C. Martinez-Sussmann, R. Levine, C.L. Andronicos, and R.P. Langford. 2007. “Effectiveness of a Summer Experience for Inspiring Interest in Geoscience among Hispanic-American High School Students.” *Journal of Geoscience Education* 55(6): 596–603. doi //doi.org/10.5408/1089-9995-55.6.596

Mills, R., L. Tomas, C. Whiteford, and B. Lewthwaite. 2020. “Developing Middle School Students’ Interest in Learning Science and Geology through Slowmation.” *Research in Science Education* 50: 1501–1520. doi:10.1007/s11165-018-9741

Moss, E., and C. Cervato. 2016. “Quantifying the Level of Inquiry in a Reformed Introductory Geology Lab Course.” *Journal of Geoscience Education*, 64(2): 125-137.

Mulholland, J., and J. Wallace. 1996. “Breaking the cycle: Preparing elementary teachers to teach science.” *Journal of Elementary Science Education* 8: 17–38. doi: 10.1007/BF03173739

Murray, K.S., J. Napieralski, G. Luera, K. Thomas-Brown, and L. Reynolds-Keefer. 2012. “Broadening Diversity in the Geosciences through Teacher–Student Workshops that Emphasize Community-Based Research Projects.” *Journal of Geoscience Education* 60: 179–188. doi: 10.5408/10-215.1

Navarro, M., C. Förster, C. González, and P. González-Pose. 2016. “Attitudes toward science: measurement and psychometric properties of the Test of Science-Related Attitudes for its use in Spanish-speaking classrooms.” *International Journal of Science Education* 38(9): 1459–1482. doi: 10.1080/09500693.2016.1195521

Oon, P.T. and X. Fan. 2017. “Rasch analysis for psychometric improvement of science attitudes rating scales.” *International Journal of Science Education* 39(6): 683–700. doi: 10.1080/09500693.2017.1299951

Oon, P.T., and R. Subramaniam. 2018. “Comparative study of middle school students’ attitudes towards science: Rasch analysis of entire TIMSS 2011 attitudinal data for England, Singapore and the U.S.A. as well as psychometric properties of attitudes scale2.” *International Journal of Science Education* 40(3): 268–290. doi:10.1080/09500693.2017.1413717

Orion, N., and C. Ault. 2007. “Learning earth sciences”. In *Handbook of research on science education*, edited by S. K. Abell and N. G. Lederman, 653–688. Mahwah, New Jersey: Lawrence Erlbaum Associates Inc.

Orion, N., and A. Hofstein. 1991. “The Measurement of Students’ Attitudes towards Scientific Field Trips.” *Science Education* 75: 513–523. doi: 10.1002/sce.3730750503

Ornstein, A. 2006. “The Frequency of Hands-On Experimentation and Student Attitudes toward Science: A Statistically Significant Relation (2005-51-Ornstein).” *Journal*

of Science Education and Technology 15: 285–297. doi: 10.1007/s10956-006-9015-5

Osborne, J. 2007. “Science Education for the Twenty First Century.” *Eurasia Journal of Mathematics, Science & Technology Education* 3(3): 173–184. doi: 10.12973/ejmste/75396

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

Osborne, J., and J. Dillon. 2008. *Science Education in Europe: Critical Reflections.* London (GB): Nuffield Fundation.

Oskamp, S., and P.W. Schultz. (2005). *Attitudes and opinions* (3rd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Palmer, T.A., P.F. Burke, and P. Aubusson. 2017. “Why School Students Choose and Reject Science: A Study of the Factors that Students Consider When Selecting Subjects.” *International Journal of Science Education* 39(6): 645–662. doi: 10.1080/09500693.2017.1299949

Pelch, M.A., and D.A. McConnell. 2017. “How Does Adding an Emphasis on Socioscientific Issues Influence Student Attitudes About Science, Its Relevance, and Their Interpretations of Sustainability?” *Journal of Geoscience Education* 65(2): 203–214. doi: 10.5408/16-173.1

Pérez, A., and A. Pro. 2005. *Evaluación nacional de actitudes y valores hacia la ciencia en entornos educativos* [National assessment of attitudes and values towards science in educational settings]. Madrid: FECYT

Pickens, M., and C. Eick. 2009. “Studying Motivational Strategies Used by Two Teachers in Differently Tracked Science Courses.” *Journal of Educational Research* 102: 349–362. doi: 10.3200/JOER.102.5.349-362

Potvin, P., and A. Hasni. 2014. “Interest, Motivation and Attitude towards Science and Technology at K-12 Levels: A Systematic Review of 12 Years of Educational Research.” *Studies in Science Education* 50(1): 85–129. doi: 10.1080/03057267.2014.881626

Prokop, P., S.D. Tunnicliffe, M. Kubiatko, A. Hornackova, and M. Usak. 2011. “The Role of Teacher in Students’ Attitudes to and Achievement in Paleontology.” *Energy Education Science and Technology PartB: Social and Educational Studies* 3(1): 29–45. https://www.researchgate.net/publication/209658987_The_role_of_teacher_in_students'_attitudes_to_and_achievement_in_palaeontology

Regan, E., and J. DeWitt. 2015. “Attitude, interest and factors influencing STEM enrolment behavior: A review of relevant literature.” In *Understanding student participation and choice in science and technology education,* edited by E. K. Henriksen, J. Dillon and J. Ryder, 63–88. Dordrecht: Springer.

Reid, N., and E.A. Skryabina. (2002). “Attitudes towards physics.” *Research in Science & Technological Education* 20(1): 67–81. doi: 10.1080/02635140220130939

Roemmele, C. 2017. “Unearthing geologic blindness: undergraduate students’ attitude and conceptual understanding of geology.” Theses and Dissertations Available from ProQuest. Purdue University.

Schmidt, R.W. 2013. “Bridging the geoscientist workforce gap: Advanced high school geoscience programs.” PhD. Diss., Drexel University

Shannon, A. G., R.J. Sleet, and W. Stern. 1982. “School students’ attitudes to science subjects.” *Australian Science Teachers Journal* 28(1): 77–82.

Sharpe, R., and I. Abrahams. 2019. “Secondary school students’ attitudes to practical work in biology, chemistry and physics in England.” *Research in Science & Technological Education* 38(1): 84–104. doi: 10.1080/02635143.2019.1597696

She Figures Report 2018. European Comission. doi: 10.2777/936

Shepardson, D.P., and E.L. Pizzini. 1993. “A Comparison of Student Perceptions of Science Activities within Three Instructional Approaches.” *School Science and Mathematics* 93(3): 127–131. doi: 10.1111/j.1949-8594.1993.tb12209.x

Sherman-Morris, K., M.E. Brown, J.L. Dyer, K.S. McNeal, and J.C. Rodgers III. 2013. “Teachers' Geoscience Career Knowledge and Implications for Enhancing Diversity in the Geosciences.” *Journal of Geoscience Education* 61(3): 326–333. doi: 10.5408/11-282.1

Shulman, R., and P. Tamir. 1973. “Research on teaching in the national science”. In *Second handbook of research on teaching*, edited by R. Travers, 1098–1148. Chicago, IL: Rand McNally.

Simpson, R.D., T.R. Koballa Jr., J.S. Oliver, and F.E. Crawley III. 1994. “Research on the affective dimension of science learning.” In *Handbook of research on science teaching and learning*, edited by D. White, 211–235. New York: Macmillan Publishing Company.

Slater, T.F., J.R. Carpenter, and J.L. Safko. 1996. “Dynamics of a constructivist astronomy course for inservice teachers.” *Journal of Geoscience Education* 44(5): 523–528. doi: 10.5408/0022-1368-44.5.523

Stokes, A., and A.P. Boyle. 2009. “The undergraduate geoscience fieldwork experience: Influencing factors and implications for learning.” In *Historical Perspectives and*

Modern Approaches, edited by Steven J. Whitmeyer, David W. Mogk, and Eric J. Pyle, 291–311. Geological Society of America. doi: 10.1130/2009.2461(23).

Sjøberg, S., and C. Schreiner. 2010. *The ROSE Project: An Overview and Key Findings.* Norway: University of Oslo.

Teasdalea, R., P. Selkinb, and L. Goodellc. 2018. "Evaluation of student learning, self-efficacy, and perception of the value of geologic monitoring from Living on the Edge, an Integrate curriculum module." *Journal of Geoscience Education* 66(3): 186–204. doi: 10.1080/10899995.2018.1481354

Toma, R.B., I.M. Greca, and M.L. Orozco Gómez. 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. doi: 10.1080/02635143.2018.1561433

Trend, R. 2009. "Commentary: Fostering Students' Argumentation Skills in Geoscience Education." *Journal of Geoscience Education* 57(4): 224–232. https://files.eric.ed.gov/fulltext/EJ1164787.pdf

Tytler, R., and J. Osborne. 2012. "Student attitudes and aspirations towards science." In *Second international handbook of Science Education*, edited by B. J. Fraser, C. J. McRobbie, and K. G. Tobin, 597–625. Dordrecht (Netherlands): Springer.

Van der Hoeven Kraft, K.J., L.A. Srogi, J. Husman, S. Semken, and M. Fuhrman. 2011. "Engaging Students to Learn Through the Affective Domain: A new Framework for Teaching in the Geosciences." *Journal of Geoscience Education* 59: 71–84. doi: 10.5408/1.3543934a

Vázquez, A., and M.A. Manassero. 1999. "Response and scoring models for the 'Views on Science-Technology-Society' Instrument." *International Journal of Science Education* 21(3): 231-247

Vázquez, A., and M.A. Manassero. 2008. “El declive de las actitudes hacia la ciencia de los estudiantes: un indicador inquietante para la educación científica.” *Eureka sobre enseñanza y divulgación de las ciencias* 5(3): 274–292. https://revistas.uca.es/index.php/eureka/article/view/3740

Weekes, A.F., and J.R. Carpenter. 1993. “A Comparison of Two Approaches to a Course on the Geology of South Carolina for Teachers.” *Journal of Geological Education* 41(5): 412–419. doi: 10.5408/0022-1368-41.5.412

Wysession, M.E. 2012. “Implications for Earth and space in new K–12 science standards.” *EOS* 43: 465–466. doi:10.1029/2012EO460001

Young, J.M., and D.P. Shepardson. 2018. “Using Q Methodology to Investigate Undergraduates Student’s Attitudes toward the Geosciences.” *Science Education* 102: 195–214. doi: 10.1002/sce.21320

Zamalloa, T., J. Sanz, G. Maguregi, I. Echevarría, and L. Fernández. 2014. “Acercar la geodiversidad a través de las salidas de campo en la ESO. Una investigación con el profesorado de ciencias de Bizkaia.” *Enseñanza de las Ciencias* 32(3): 443–46. doi: 10.5565/rev/ensciencias.1282

Zembylas, M., and H. Barker. 2002. “Preservice teacher attitudes and emotions: Individual spaces, community conversations and transformations.” *Research in Science Education* 32: 329–351. doi: 10.1023/A:1020862000107

Zimmerman, H.T., and L.R. McClain 2016. “Family Learning Outdoors: Guided Participation on a Nature Walk.” *Journal of Research in Science Teaching* 53(6): 919–942. doi: 10.1002/tea.21254

Zuniga, K., J. Olson, and M. Winter. 2005. “Science education for rural Latino/a students: Course placement and success in science.” *Journal of Research in Science Teaching* 42(4): 376–402. doi:10.1002/tea.20064

Table 1. Description and sample items of the five dimensions of attitudes.

Research question	Dimensions of attitudes (No. of items)	Description and sample items
What are the students` attitudes towards geology?	Curiosity about geology (7)	To what extent students express curiosity about aspects of geology. 'I would like to know how rocks and fossils help us to know the history of life on Earth'
	Perception of geology and biology (5)	To what extent students find biology and geology interesting, easy, useful or enjoyable. 'geology is boring/enjoyable'
	Perception of physics and chemistry (7)	To what extent students find physics and chemistry interesting, easy, useful or enjoyable. 'Physics is enjoyable'
What are the key factors that influence these attitudes?	Evaluative belief about professional future (4)	To what extent students believe science degrees may lead to a job in the future. 'Chemistry has a professional future'
	Learning geology in and outside the classroom (10)	To what extent students value geology and geological activities. 'I like exercises with minerals and rocks'

Table 2. Component matrix for the five dimensions of attitudes.

Learning geology in and outside the classroom		Perception of physics and chemistry		Evaluative belief about professional future		Perception of geology and biology		Curiosity about geology	
Item	Load	Item	Load	Item	Load	Item	Load	Item	Load
18	-.738	13.4a	.810	13.3d	.508	13.1b	.794	8	-.752
17	-.674	13.4c	.777	13.3d	.793	13.1c	.783	9	-.702
20	-.665	13.4b	.771	13.4e	.727	13.1a	.734	10	-.665
19	-.647	13.3a	.726	13.1e	.699	13.1d	.662	7	-.610
13.2c	-.646	13.3c	.701			13.2a	.593	6	-.573
13.2a	-.622	13.3b	.687					5	-.570
15	-.591	13.4d	.583					22	-.405
13.2e	-.546								
23	-.526								
13.2d	-.526								

Table 3. Cronbach's alpha coefficients for the five dimensions of attitudes towards science/geology.

Dimensions of attitudes	Alpha coefficients
Learning geology in and outside the classroom	.911
Perception of physics and chemistry	.910
Evaluative belief about professional future	.854
Perception of geology and biology	.904
Curiosity about geology	.882

Table 4. Descriptive statistics for the valuation of geology.

	M	SD		1	2	3	4	5
1. Geology is enjoyable	2.87	1.43	*r*	1.000				
			n	1610				
2. Geology is easy	3.36	1.39	*r*	.457**	1.000			
			n	1594	1604			
3. Geology is interesting	3.16	1.50	*r*	.728**	.441**	1.000		
			n	1595	1592	1605		
4. Geology is useful	3.69	1.50	*r*	.512**	.313**	.561**	1.000	
			n	1586	1583	1585	1596	
5. Geology has a professional future	3.45	1.43	*r*	.399**	.204**	.457**	.569**	1.000
			n	1583	1579	1582	1576	1593

Table 5. Valuation of science subjects.

	Enjoyable	Easy	Interesting	Useful	Prof. Future
Biology	3.77	3.75	4.1	4.39	4.19
Geology	2.87	3.36	3.16	3.69	3.45
Physics	3.16	3.05	3.54	4.04	4.26
Chemistry	3.70	2.96	3.45	4.09	4.24

Table 6. Descriptive statistics and analysis of the differences between subgroups (academic factors).

	Geology is enjoyable			Geology is easy			Geology is interesting			Geology is useful			Geology has professional future		
	M	*SD*	$Z/\chi^2(p)$	*M*	*SD*	$Z/\chi^2(p)$	*M*	*SD*	$Z/\chi^2(p)$	*M*	*SD*	$Z/\chi^2(p)$	*M*	*SD*	$Z/\chi^2(p)$
Type of school ownership															
State	2.80	1.46	2.86	3.24	1.41	4.55	3.15	1.54	1.02	3.73	1.51	-1.13	3.53	1.45	-2.76
Private/semi-private	2.99	1.38	(0.004)	3.57	1.33	(<0.001)	3.21	1.45	(0.305)	3.64	1.49	(0.258)	3.33	1.40	(0.006)
Courses Geology in 4th grade															
Yes	3.07	1.41	-7.60	3.59	1.31	-8.56	3.39	1.45	-7.53	3.83	1.43	-4.60	3.54	1.37	-3.48
No	2.53	1.41	(<0.001)	2.98	1.44	(<0.001)	2.81	1.54	(<0.001)	3.46	1.59	(<0.001)	3.28	1.51	(<0.001)
Field trips															
Not done	2.83	1.41	200.44	3.27	1.38	79.27	3.21	1.53	169.29	3.72	1.48	108.73	3.44	1.40	79.94
1	1.85	1.21	(<0.001)	2.82	1.53	(<0.001)	2.12	1.38	(<0.001)	2.80	1.60	(<0.001)	2.70	1.49	(<0.001)
2	2.27	1.13		3.09	1.28		2.54	1.19		3.35	1.38		3.21	1.42	
3	2.88	1.32		3.36	1.30		3.16	1.32		3.57	1.41		3.41	1.33	
4	3.31	1.36		3.49	1.28		3.38	1.45		3.88	1.37		3.65	1.38	
5	3.51	1.31		3.91	1.29		3.70	1.34		4.21	1.33		3.83	1.32	
6	3.47	1.50		3.85	1.40		3.91	1.50		4.27	1.48		3.91	1.44	
Activities with minerals and rocks															
Not done	2.82	1.41	214.69	3.28	1.40	65.86	3.19	1.54	184.89	3.71	1.47	114.02	3.47	1.43	86.54
1	1.88	1.21	(<0.001)	2.86	1.56	(<0.001)	2.12	1.34	(<0.001)	2.93	1.70	(<0.001)	2.80	1.56	(<0.001)
2	2.34	1.13		3.21	1.33		2.72	1.21		3.34	1.38		3.12	1.26	
3	2.91	1.22		3.27	1.21		3.07	1.30		3.67	1.27		3.39	1.21	
4	3.35	1.32		3.69	1.29		3.56	1.35		3.78	1.36		3.62	1.45	
5	3.46	1.42		3.81	1.30		3.72	1.43		4.13	1.46		3.97	1.33	
6	3.86	1.57		3.80	1.41		4.24	1.57		4.71	1.47		4.03	1.48	
Laboratory activities Geo															
Not done	2.85	1.41	185.22	3.41	1.36	61.29	3.22	1.51	170.84	3.71	1.45	142.07	3.43	1.40	88.36
1	1.64	1.13	(<0.001)	2.61	1.59	(<0.001)	1.79	1.24	(<0.001)	2.60	1.64	(<0.001)	2.61	1.61	(<0.001)
2	2.32	1.15		3.03	1.31		2.63	1.33		2.98	1.28		2.93	1.26	
3	2.75	1.24		3.23	1.28		3.09	1.33		3.52	1.39		3.40	1.31	
4	3.14	1.30		3.51	1.31		3.31	1.35		3.99	1.31		3.76	1.25	
5	3.45	1.39		3.55	1.37		3.68	1.33		4.16	1.37		3.82	1.43	
6	3.56	1.57		3.78	1.39		3.86	1.57		4.39	1.53		3.89	1.47	
Geological models															
Not done	2.81	1.39	194.30	3.37	1.37	47.23	3.15	1.48	178.13	3.72	1.46	124.93	3.47	1.41	70.75
1	1.80	1.14	(<0.001)	2.83	1.58	(<0.001)	2.06	1.38	(<0.001)	2,76	1,68	(<0.001)	2,79	1,62	(<0.001)
2	2.29	1.14		3.04	1.40		2.59	1.39		3,15	1,56		2,94	1,30	
3	2.95	1.19		3.28	1.26		3.07	1.26		3,43	1,17		3,39	1,26	
4	3.40	1.34		3.62	1.25		3.62	1.24		4,09	1,30		3,70	1,26	
5	3.64	1.38		3.71	1.31		3.94	1.30		4,25	1,26		3,93	1,21	
6	3.65	1.68		3.76	1.46		4.04	1.68		4,49	1,59		3,90	1,64	

Table 7. Descriptive statistics and analysis of the differences between subgroups (informal educational activities).

Visits interpretation centre with…		Geology is enjoyable			Geology is easy			Geology is interesting			Geology is useful			Geology has a professional future		
		M	*SD*	*Z(p)*	*M*	*SD*	*Z(p)*	*M*	*SD*	*Z(p)*	*M*	*SD*	*Z(p)*	*M*	*SD*	*Z/(p)*
Family																
	No	2.77	1.43	-2.97 (0.003)	3.21	1.43	-3.92 (<0.001)	3.08	1.50	-2.12 (0.033)	3.63	1.53	-1.44 (0.148)	3.45	1.45	-0.10 (0.918)
	Yes	2.98	1.44		3.48	1.35		3.23	1.51		3.75	1.45		3.45	1.41	
Free time group																
	No	2.87	1.44	-0.68 (0.499)	3.34	1.38	-0.92 (0.359)	3.16	1.50	-0.34 (0.734)	3.69	1.49	-0.69 (0.491)	3.42	1.41	-1.78 (0.075)
	Yes	2.90	1.43		3.40	1.42		3.17	1.53		3.72	1.55		3.54	1.48	
Camps																
	No	2.93	1.46	1.86 (0.063)	3.38	1.40	-1.15 (0.251)	3.15	1.49	-0.35 (0.726)	3.67	1.50	-0.84 (0.401)	3.47	1.45	-0.69 (0.488)
	Yes	2.79	1.39		2.31	1.36		3.18	1.51		3.74	1.50		3.41	1.39	