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The role of motivation on secondary school students' causal attributions to choose or abandon chemistry

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The present investigation aims to analyze the effect of motivation on students' causal attributions to choose or abandon chemistry when it first becomes optional in the secondary education curriculum in Spain. Attributions to the effect of the family and to the teacher and classroom methodology were found to be common predictors of the choice to all the students in the sample. However, our analyses point to a significant effect of the students' motivation in other types of attributions. In the case of at-risk of abandonment students, specific causal attributions to the effect of friends and to the subject's relationship with mathematics were found. On the other hand, the effect of media was a significant predictor only in the case of highly-motivated students. Our study provides several suggestions for teachers, schools, and administrations to design counseling strategies to help students make the right choices.

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Introduction

The society of the 21st century needs scientifically literate citizens able to understand the ongoing technological progress and to make decisions about science-related issues in a responsible and efficient way (Hurd, 1998; Roth and Lee, 2004; Gil-Pérez and Vilches, 2005; Holbrook and Rannikmae, 2009; Blanco-López *et al.*, 2015; OECD, 2016). This fact places the role of science education in a pivotal position (DeBoer, 2000; European Commission, 2004; Rocard *et al.*, 2007; Dillon, 2009). Despite this, in many countries, STEM subjects (Science, Technology, Engineering, and Mathematics) are not compulsory during the whole secondary education and, in the last few decades, the number of students taking these courses has significantly decreased. This lowering is observed both at the university level (Oon and Subramaniam, 2010; Ulriksen *et al.*, 2010) and in secondary education (Lyons, 2006a, 2006b; Smyth and Hannan, 2006; Solbes *et al.*, 2007; Bøe *et al.*, 2011; Solbes, 2011; Bøe, 2012; Bennett *et al.*, 2013), and concerns the educational community worldwide. This is not a problem to downplay, since the decision is usually taken very early, around the age of 15–16 depending on the country, and defines the students' future trajectories in the STEM track (European Commission, 2004; Tripney *et al.*, 2010; Bennett *et al.*, 2013; BøE and Henriksen, 2013; Mujtaba and Reiss, 2014). For example, according to official reports, a third of secondary school students in Spain opt out of taking chemistry at the age of 15, when it first becomes optional (Consejería de Educación y Cultura del Principado de Asturias, 2019). Furthermore, this situation eventually leads to a shortage of qualified professionals working in STEM fields, which are of utmost importance for the economy and development of a country (Salta *et al.*, 2012; Salonen *et al.*, 2018; Moore and Burrus, 2019; Smith and White, 2019; Avargil *et al.*, 2020). This is a matter of concern especially in chemistry and chemistry-related disciplines owing to the number of job options that they offer in different areas of industry and academia (Solano *et al.*, 2011; Ogunde *et al.*, 2017).

Early interest in science seems to be a key factor for young adolescents to pursue scientific studies and careers. In fact, most of STEM students make their choice during high school (Tai *et al.*, 2006; Maltese and Tai, 2011). The choice of STEM studies once they are not compulsory anymore is complex and a number of variables seem to explain it (Cleaves, 2005; Bennett *et al.*, 2013; Sha *et al.*, 2015). In the last few years, thorough research has been undertaken to disentangle the factors underlying students' future decisions (see, for example, Cerinsek *et al.*, 2013; Potvin and Hasni, 2014; Nugent *et al.*, 2015; Palmer *et al.*, 2017; Shirazi, 2017; Reinhold *et al.*, 2018). These different variables are usually related to each other and can be divided into those intrinsic and extrinsic to the students (Palmer *et al.*, 2017). The former include, among others, their motivation and attitudes towards science, their interest in it, their

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perceptions of science and scientific subjects, their future intentions of pursuing a STEM career, their prior achievement in STEM subjects, or their gender. On the other hand, extrinsic factors encompass, for instance, their social and cultural background, the influence of teachers, the support from family and friends, the influence of media, and their participation in other out-of-school activities. A brief description of the factors influencing the decision of choosing or opting out physics and chemistry subjects is presented in the theoretical framework.

Theoretical framework

Motivation towards science and students' choices

Topics like motivation, interest, and attitudes toward science have been the subject of exhaustive research (Osborne *et al.*, 2003; Cerinsek *et al.*, 2013; Potvin and Hasni, 2014). Motivation to learn science is a key factor influencing STEM performance (see, for example, Glynn *et al.*, 2007, 2009; Bryan *et al.*, 2011; Glynn *et al.*, 2011; Bae and DeBusk-Lane, 2018; Ardura and Pérez-Bitrián, 2019). This psychological construct has also been related to the choice of and the persistence in STEM courses both at secondary (see, for example, Mujtaba and Reiss, 2014; Sheldrake *et al.*, 2015; Sheldrake, 2016; Palmer *et al.*, 2017; Ardura and Pérez-Bitrián, 2018) and tertiary levels (see, for example, Salta *et al.*, 2012; Cerinsek *et al.*, 2013; Shedlosky-Shoemaker and Fautch, 2015; Aeschlimann *et al.*, 2016). For instance, Ardura and Pérez-Bitrián (2019) recently showed that secondary school students with higher motivation towards physics & chemistry achieve better grades in this subject and are more interested in scientific options (Ardura and Pérez-Bitrián, 2018).

Motivational factors have actually been suggested to be the strongest predictors of high-school students' future persistence in science (Lau and Roeser, 2002; Ardura and Pérez-Bitrián, 2018). Interestingly, motivation towards science varies with the educational level, as it was found to be higher in students at college than at high school (Tüysüz *et al.*, 2010). In addition, it also depends on the specific discipline (Debacker and Nelson, 2000; Simpkins *et al.*, 2015). Focusing on physics and chemistry, Salta and Koulougliotis (2020) have recently observed that motivation to learn chemistry among Greek undergraduate students is higher than motivation to learn physics.

According to the Social Cognitive Theory developed by (Bandura, 1986, 2001, 2012), motivation to learn science can be defined as the "internal state that arouses, directs, and sustains science-learning behavior" (Glynn *et al.*, 2011, p. 1160). Motivation is a multidimensional trait and therefore consists of many factors which influence the self-regulated learning described in the Social Cognitive Theory, and include intrinsic motivation, extrinsic motivation, self-determination, and self-efficacy (Glynn and Koballa Jr., 2006; Glynn *et al.*, 2011). Intrinsic motivation refers to the inherent satisfaction, interest and enjoyment in learning science, whereas extrinsic motivation involves the learning of science because it leads to an external reward, such as better career options or achieving a higher grade (Ryan and Deci, 2000). In addition, self-determination refers to the control that students believe they have over their learning of science (Black and Deci, 2000). Finally, self-efficacy accounts for the students' confidence in succeeding in science (Lawson *et al.*, 2007; Ferrell and Barbera, 2015).

Several studies in different countries have shown that not all these factors contribute equally to the overall motivation towards science (Glynn *et al.*, 2011; Salta and Koulougliotis, 2015; Schumm and Bogner, 2016; Ardura and Pérez-Bitrián, 2018; Salta and Koulougliotis, 2020). Their effect on students' preference for future scientific studies is not the same either. Among all of them, extrinsic motivation seems to be the most important one associated with future preferences for scientific studies. Mujtaba and Reiss (2014), and Ardura and Pérez-Bitrián (2018) found that career motivation was the best predictor of this decision. However, both extrinsic and intrinsic aspects are related to chemistry aspirations, even in students from disadvantaged backgrounds (Mujtaba *et al.*, 2018). Self-efficacy has also been claimed to be a key factor in students' future participation in science (Palmer *et al.*, 2017). In fact, van Aalderen-Smeets *et al.* (2019) found that incremental STEM ability beliefs predicted positive self-efficacy beliefs and increased students' intention of pursuing scientific studies. On the other hand, the lack of science self-efficacy in students who obtain good grades and are highly motivated towards developing a career in science seems to support their choice of opting out physics & chemistry (Ardura and Pérez-Bitrián, 2018).

The effect of the students' perceived difficulty and the subject's relationship with mathematics on students' choices

The perceived difficulty of science has been recently linked to students' scientific competencies (Chi *et al.*, 2017), academic achievement (House and Telese, 2017; England *et al.*, 2019), anxiety (England *et al.*, 2019) and students' disengagement (Patall *et al.*, 2018). Science subjects are generally considered as difficult (Osborne *et al.*, 2003; Cleaves, 2005; Lyons, 2006b; Solbes *et al.*, 2007; Bøe *et al.*, 2011; Solbes, 2011), this perception being one of the main causes of students' science disaffection among Spanish secondary school students (Solbes *et al.*, 2007; Solbes, 2011). In this vein, studies on the effect of this variable on students' future choices have been previously tackled. For instance, several investigations confirmed the negative effect of perceived difficulty, as it has been claimed to be one of the predictors of students' choices (Stokking, 2000; Smyth and Hannan, 2006; Solbes, 2011; Palmer *et al.*, 2017; Shirazi, 2017). Moreover, Palmer *et al.* (2017) suggested, in light of similar findings, that changing students' perceived difficulty could be a useful way to reduce science abandonment. Backing these results, Tripney *et al.* (2010) found that the difficulty of the subject was the main reason argued by secondary school students in the UK to explain their decision to abandon STEM options at this educational level. This result is in line with the fact that learners' expectations of academic success have been related to their perception of the subject difficulty (Bøe *et al.*, 2011; Bøe, 2012).

One of the cognitive factors related to students' success in science is their mathematical ability (Spencer, 1996; Wagner *et al.*, 2002; Hahn and Polik, 2004; Lewis and Lewis, 2007; Cooper and Pearson, 2012; Scott, 2012; Xu *et al.*, 2013; Villafañe *et al.*, 2016). Both teachers and students believe that a good mathematical background is important to study science (Semela, 2010). In this line, Slavin (2008) concluded that if university students are enrolled in mathematics courses, their retention in introductory physics courses is more likely than if they are not taking them. Moreover, it has been claimed that low levels of mathematics self-efficacy are related to STEM careers avoidance both at university (Zeldin *et al.*, 2008) and at secondary levels (Brown *et al.*, 2016; Huang *et al.*, 2019).

The effect of the teacher and the classroom methodology on students' choices

Recent studies reported the relevance of teachers and teaching practices in secondary school students' retention in the STEM pipeline (Cerinsek *et al.*, 2013; Reinhold *et al.*, 2018). For instance, upper secondary school students emphasized the importance of teachers, irrespective of their interest in the subject, when they were asked to explain their choices and their ideas to improve science education (Broman and Simon, 2015). When students have high expectations about their teachers, they are more likely to choose a STEM major (Lee *et al.*, 2015). Besides, in a recent review, McDonald (2016) found evidence supporting the key role of high-quality teachers to promote scientific literacy among young learners. Moreover, experienced teachers seem to be able to awake an early interest in STEM in their students (Lichtenberger and George-Jackson, 2013).

In a more personal dimension, teachers are some of those relevant people able to influence students' choice of science courses in different ways (see, for example, Breakwell and Beardsell, 1992; Stake, 2006; Cerinsek *et al.*, 2013; Vedder-Weiss and Fortus, 2013; Ing, 2014; Mujtaba and Reiss, 2014; Nugent *et al.*, 2015; Sha *et al.*, 2016). In particular, good teachers seem to be more influential than parents and peers (Cerinsek *et al.*, 2013). It is also worth noting that, according to Palmer *et al.* (2017), students believe that interest, enjoyment, and ability are more relevant when it comes to making the decision than advice from teachers, parents, or peers. Another study uncovered that teachers' personal traits like their empathy or their sense of humor are related to students' good learning experiences (Shirazi, 2017).

Teaching practices have also been related to students' persistence in the STEM track. Using cluster analysis, Potvin and Hasni (2018) found that a group of students labeled as 'pessimistic dropouts' had received mainly an unchallenging traditional instruction in science and technology. In the same vein, Juuti and Lavonen (2016) linked good pedagogical practices to students' intentions to enroll in upper secondary school physics courses. Among the most effective teaching and learning approaches, student-centered and active learning strategies have been proposed to maintain students' interest in science and, consequently, their retention at secondary school science subjects (Broman and Simon, 2015; McDonald, 2016; Shirazi, 2017). Finally, the environment that teachers promote in their classrooms has also been proposed as an important aspect of the quality of the learning experience (Shirazi, 2017).

Family, friends and science choice

In addition to teachers, family and friends are probably those key persons who affect students' decision about pursuing scientific studies the most. However, in the recent study by Avargil *et al.* (2020), environmental factors, which include the influence of family and friends, were not as important as personal factors such as self-efficacy. Among family-related aspects, parents' support is a key factor influencing students' science behaviors (Stake, 2006; Buday *et al.*, 2012; Mujtaba and Reiss, 2014; Nugent *et al.*, 2015; Sha *et al.*, 2016; Halim *et al.*, 2018). This does not only include support when it comes to choosing science at secondary education or as a career, but also when getting involved in increasing the children's achievement, interest, and involvement in science (Halim *et al.*, 2018). This is important to boost their motivation, which in turn pushes them to opt for future science studies (Simpkins *et al.*, 2015; Sha *et al.*, 2016).

Parents' level of education has been discussed to influence students' science choices. In this regard, Harackiewicz *et al.* (2012), or Anderhag *et al.* (2013) concluded that students whose parents had a higher level of education were more likely to choose science subjects. However, Stokking (2000), and Maltese and Tai (2011) observed that parents' educational level was non-significant in students' choice. Parents' pedagogical actions and resources provision seem to be important (Lyons, 2006b; Sha *et al.*, 2016). Besides, the quality of the parent-child interactions is also crucial (Lyons, 2006b; Vedder-Weiss and Fortus, 2013; Ing, 2014; Simpkins *et al.*, 2015). Additionally, parents' income seems to be also influential in students' STEM choice (Moakler Jr. and Kim, 2014; Avargil *et al.*, 2020).

The influence from peers is the least important factor among the effect of people's advice (Palmer *et al.*, 2017). The lesser influence of peers in relation to parents is in line with the results reported by Lyons (2006b), and Cerinsek *et al.* (2013). The importance of peer interactions among adolescents accounts for reciprocal influences in their attitudes and motivation towards science (Breakwell and Beardsell, 1992; Osborne *et al.*, 2003; Vedder-Weiss and Fortus, 2013). For example, having friends and classmates who are more interested in science and have more positive attitudes towards science, makes students have more favorable attitudes towards science, and increases their performance and engagement in optional science activities (Breakwell and Beardsell, 1992). In fact, it is easier for peers who share a similar interest in science to picture them as scientists in the future (Stake and Nickens, 2005). It is clear that classmates have an impact on career aspirations in science, yet the relationship is complex and thus, the influence is not completely understood (Wang and Staver, 2001).

The effect of out-of-school learning and media on students' choices

School science is often less authentic than real science in society and, hence, both can be generally considered as different entities (Breakwell and Beardsell, 1992; Osborne *et al.*, 2003; Braund and Reiss, 2006). Thus, Braund and Reiss (2006) suggest that school science has to be complemented with a variety of out-of-school activities, which are actually more motivating and engaging for students (Quigley, 2014). Among these ways of extracurricular learning, field trips, visits to science museums, science festivals, science-related books and magazines, or science-related TV shows need to be mentioned (Braund and Reiss, 2006). Sha *et al.* (2015) pointed out the relevance of both science learning at school and at home to students' science choices. In this manner, out-of-school learning opportunities are generally positive for improving motivation and attitudes towards science, as well as students' interest in scientific topics (Potvin and Hasni, 2014), which eventually influences future career choices in STEM (Dabney *et al.*, 2012).

Especially the mass media, which include printed, visual, and digital media, play a key role in influencing students' decisions. In this regard, movies and popular TV series or shows which are of scientific content can influence students' science aspirations and future decisions (Cerinsek *et al.*, 2013). A very clear example of an influencing program is the American sitcom *The Big Bang Theory*, or in general, different programs in *Discovery Channel*. In this regard, whereas Bennett and Hogarth (2009) concluded that science in the media does not really influence students' engagement in science, Cerinsek *et al.* (2013) found that popular science TV channels and programs were the out-of-school activities that had the strongest influence on students' choice of staying in the STEM track.

Description and aims of the current investigation

As stated above, science early abandonment may eventually lead to a high degree of scientific illiteracy. This issue could prevent citizens from understanding the scientific and technical advances or societal problems involving challenging situations which have to do with science. This fact could turn into a problem when people face critical science-related decisions. For this reason, research on persistence in the science pipeline has become increasingly relevant during the last decades. In this paper, we undertake an investigation on the causal attributions of secondary school students' decisions about continuing or not taking physics & chemistry courses, once the subject becomes optional for the first time in the Spanish educational system. Previous investigations made clear that students who are motivated towards science are more likely to stay in the science track when they have to make a decision about it (Salta *et al.*, 2012; Palmer *et al.*, 2017; Ardura and Pérez-Bitrián, 2018; Mujtaba *et al.*, 2018). For this reason, the present investigation also sought to deepen in the reasons argued by students to make their decision as a function of their motivation towards physics & chemistry. To this aim, we used the findings of a previous study that found the existence of three different motivational profiles towards physics & chemistry among secondary school students (Ardura and Pérez-Bitrián, 2019). With all this in mind, the main purpose of the current investigation was to analyze the causal attributions that these three groups of students invoke to explain why they chose or abandoned physics & chemistry. Three research questions served as guidance in our study:

RQ1. Which are the most common causal attributions for choosing physics & chemistry as a function of the students' motivational profile?

RQ2. Are there any relationships among students' causal attributions and their motivational traits?

RQ3. Which causal attributions are the best predictors of students' choices?

Method

Sample and context

The data gathering took place in the context of the physics & chemistry subject, right at the point when the students had to decide whether to choose this subject or not once it becomes optional in the Spanish educational system (*i.e.* when the students started their 4th secondary school year at the age of 15). At this level of the Spanish educational system, chemistry and physics are taught together as a single subject. For this reason, the instruments used in data gathering referred simultaneously to physics & chemistry, so that the students would think of both disciplines integrated into the same subject. The data collection was conducted using a convenience sampling based on the accessibility of a total of 15 Spanish schools (5 private and 10 public). The sample comprised 1060 students, whose average age was 15.03 years. 49.2% of participants were boys and 50.8% were girls. For this study, data were collected from two types of students. First, students who had chosen physics & chemistry (n = 695, 65.6%; PC students) and, second, students who had decided to leave the subject (n = 365, 34.4%; non-PC students). All the schools, families, and students gave their informed consent to be participants in the data gathering.

Data collection procedure

The schools were first contacted to explain the aims of the study. Once they agreed and parents gave their informed consent, the researchers explained the data gathering procedure to the principals and teachers. Then, the teachers allowed access to each classroom and explained the objectives and procedure to the students who voluntarily provided the data for this investigation. The anonymity during the course of the investigation and once the results were to be communicated, was ensured. Two different modalities were employed to answer the survey: online or paper-based. Regardless of the modality employed, the data collection took place at schools with the supervision of the teachers in charge of each class.

Instruments and variables

Academic achievement in physics & chemistry. Academic achievement in physics & chemistry was measured by means of the final grade in the subject, which is measured in a 10-point scale in the Spanish educational system. We will refer to this grade as grade average. Following previous works (Ardura and Pérez-Bitrián, 2018, 2019) and owing to the unavailability of a standardized instrument to measure students' achievement in the context of physics & chemistry in Spain, the students' final grade was chosen for the purposes of the current investigation. In particular, the physics & chemistry point average was obtained according to the framework of assessment of the Spanish secondary school learning standards (Jefatura del Estado, 2013).

Motivation towards physics & chemistry. Five different motivational traits towards physics & chemistry were measured using the Spanish version adapted to physics & chemistry (Ardura and Pérez-Bitrián, 2018) of the Science Motivation Questionnaire II (SMQII) (Glynn *et al.*, 2011). Based on the Social Cognitive Theory, the SMQII allows the measurement of five motivational components: self-determination, self-efficacy, intrinsic motivation, grade motivation, and career motivation. Five items are associated with each dimension, so that the instrument comprises a total of 25 items that are measured using a 5-point Likert-type scale (from 0 to 4). Thus, the score of each latent variable ranges from 0 to 20. Self-determination measures the degree of control the students think they have when they learn physics & chemistry through items like '*I study hard to learn physics & chemistry*'. Self-efficacy is related to the students' beliefs about their ability to be successful in the subject and it is measured using items like '*I am sure I can understand physics & chemistry*'. Students' interest in learning topics related to the subject (intrinsic motivation) is measured using items like '*I enjoy learning physics & chemistry*'. Grade motivation is a type of extrinsic motivation that is measured through items such as '*It is important that I get an "A" in physics & chemistry*'. Finally, career motivation is related to the students' motivation towards a future career in the field of physics & chemistry and it is measured using items like, for instance, '*Knowing physics & chemistry will give me a career advantage*'.

The SMQII was validated for the Spanish population of secondary school students in a previous study (Ardura and Pérez-Bitrián, 2018). An exploratory factor analysis rendered a factor structure identical to the original instrument (Glynn *et al.*, 2011). Besides, a confirmatory factor analysis, using structural equation modeling, verified the exploratory results (χ^2/df = 2.90; GFI = 0.89, CFI = 0.92, RMSEA = 0.07, SRMR = 0.05) showing, overall, a satisfactory fit to the data. The suggested cut-off values for a good fit are: $1 < \chi^2/\mathrm{df} < 3$, GFI > 0.90, CFI > 0.90, SRMR $<$ 0.08, and RMSEA < 0.06 (Hu and Bentler, 1999; Hair *et al.*, 2010). The Cronbach's alpha statistic for each latent variable was computed to assess reliability yielding: 0.87 for self-determination, 0.86 for self-efficacy, 0.88 for intrinsic motivation, 0.82 for grade motivation, and 0.92 for career motivation (Ardura and Pérez-Bitrián, 2018). Therefore, this previous validation allowed us to use the latent variables extracted from the Spanish version of the SMQII.

Since our sample comprised PC and non-PC students, invariance testing was carried out to evidence that group comparisons were supported (Rocabado *et al.*, 2020). Four different models were compared to test for invariance. To test for configural invariance no constraints were applied to the model. To assess metric invariance, factor loadings were constrained for the two groups. Scalar invariance implies the constriction of factor loadings and item intercepts. Finally, the strictest invariance (conservative invariance), in which the factor loadings, item intercepts, and error variances were constrained for the two groups. To be able to compare scales scores between groups, conservative invariance must be achieved. All these models showed an acceptable fit to data: configural (χ^2/df = 2.95; CFI = 0.905; SRMR = 0.062; RMSEA = 0.047), metric (χ^2/df = 2.84; CFI = 0.896; SRMR = 0.073; RMSEA = 0.048), scalar (χ^2/df = 2.90; CFI = 0.882; SRMR = 0.078; RMSEA = 0.056), and conservative (χ^2/df = 3.07; CFI = 0.867; SRMR = 0.082; RMSEA = 0.068).

The evaluation of $\Delta\chi^2$ to assess metric invariance rendered no significant differences between the metric and the configurational model (p = 0.237, ΔCFI = 0.009; ΔSRMR = 0.011; ΔRMSEA = 0.001). Likewise, scalar invariance was achieved (p = 0.197, ΔCFI = 0.014; ΔSRMR = 0.005; ΔRMSEA = 0.008). Finally, conservative invariance was found through the comparison between the conservative and the scalar models (p = 0.153, ΔCFI = 0.015; ΔSRMR = 0.004; ΔRMSEA = 0.012). The cut-off values regarding metric invariance are ΔCFI $<$ 0.01; ΔSRMR $<$ 0.003; ΔRMSEA = 0.015 (Chen, 2007). The results for the individual motivational subscales confirmatory analyses and invariance tests are collected in Tables 5 and 6 (see Appendix).

Causal attribution questionnaires (CAQ). Several useful instruments have been developed in previous studies to measure different variables to understand science abandonment (see, for example, Stake, 2006; Cerinsek *et al.*, 2013; Vedder-Weiss and Fortus, 2013; Ing, 2014; Mujtaba and Reiss, 2014). However, since our sample comprised students who had chosen physics & chemistry and others who abandoned this subject, two different, yet parallel, specific questionnaires had to be designed *ad hoc* for our investigation (CAQ for PC students and CAQ for non-PC students). These two instruments were based on previous research on the topic and designed to assess students' attributions to explain why they had or had not chosen physics & chemistry when it becomes an optional subject for the first time. After a preliminary analysis with the teachers and a pilot study with the students, we decided to rule out attributions to out-of-school learning from our instrument given the little exposure of the students in the sample to this type of activities. Therefore, six different causal attributions were evaluated using a total of 27 items: teacher and classroom methodology (10 items), students' perceived difficulty of the subject (4 items), subject's relationship with mathematics (3 items), the effect of friends (3 items), the effect of the family (4 items), and the effect of media (3 items). To allow comparison, both instruments were designed to account for the same attributions and the items were drafted to gather the same information for each subsample of students (PC and non-PC students). For instance, one of the items of the teacher and classroom methodology dimension was: '*I chose physics & chemistry because I had a good teacher* *last year'*, in the questionnaire addressed to students who chose the subject and *'I opted out physics & chemistry because I had a bad teacher last year'* in the questionnaire for non-PC students. This parallel approach was retained in the design of all items of both instruments (see Tables 7 and 8 in the Appendix). A 5-point Likert-type scale, from 0 to 4, was used to assess the students' answers. It is important to note that, despite we will next provide evidence for parallelism between the causal attribution questionnaires, the equivalent dimensions may not belong to the same construct.

Validity and reliability of the causal attribution questionnaires (CAQ). As stated above, two parallel CAQ were developed being meant to assess PC students' causal attributions and non-PC students' causal attributions, respectively. The validation of these two instruments was undertaken in a two-step fashion. First, exploratory factor analyses (EFA) were conducted to identify the underlying factors in the total number of items in both instruments (Field, 2009). These analyses allowed to define the latent variables related to the different causal attributions, which were previously taken into consideration during the process of the instruments' design. Second, confirmatory factor analyses (CFA) were undertaken to corroborate the structures found in the EFA by using Structural Equation Models (SEM) (Blunch, 2013; Byrne, 2016). Regarding the validation, both samples (PC students and non-PC students) were randomly split into two subsets to perform subsequently EFA and CFA. Therefore, 347 and 348 PC students were included in the EFA and the CFA, respectively, in the validity analysis of the CAQ for this group of students. In the case of the CAQ for non-PC students, 194 and 171 subjects were taken into consideration for the EFA and the CFA, respectively.

Exploratory factor analyses of the CAQ. In the case of the CAQ for PC students, the EFA was performed using a Principal Component Analysis (PCA) of the original 27 items of the instrument. Using the Kaiser–Guttman rule, 6 factors were extracted and then rotated using an orthogonal rotation (varimax) which accounted for 69.27% of the variance. Before the extraction, the Kaiser–Meyer–Olkin statistic (KMO = 0.896) and the Barlett's test of sphericity (χ^2 = 5425.65, $p < 0.01$) confirmed the adequacy of the sample for this analysis. All factor loadings were bigger than 0.60 (see Table 7). Using this technique, the six factors extracted and their corresponding explained variance were: attributions to the teacher and classroom methodology (31.90%), to the students' perceived difficulty of the subject (11.14%), to the subject's relationship with mathematics (9.54%), to the effect of the family (6.59%), to the effect of media (5.86%), and to the effect of friends (4.24%).

The same approach for the EFA was followed in the case of the CAQ for non-PC students. The KMO statistic (KMO = 0.893) and the Barlett's test of sphericity (χ^2 = 3069.53, $p < 0.01$) backed the adequacy of the data for this analysis. The PCA of the original 27 items, using the Kaiser–Guttman rule, uncovered the same 6 underlying factors which were extracted and rotated using varimax to account for 68.04% of the variance. All factor loadings were bigger than 0.45 (see Table 8). In this case, the corresponding explained variance of the factors extracted were: attributions to the teacher and classroom methodology (34.60%), to the students' perceived difficulty of the subject (11.30%), to the subject's relationship with mathematics (7.86%), to the effect of friends (5.32%), to the effect of media (5.16%), and to the effect of the family (3.80%). EFA rendered the same structure for both PC and non-PC students' subsamples regarding the underlying factors found and the items associated with each of these factors.

Confirmatory factor analyses of the CAQ. After the EFA, a CFA was carried out on both instruments. These analyses endorsed the six-factor structure found in the exploratory phase. To test the goodness of fit of the structural equation models to the data, several indices were computed (Blunch, 2013). Among them, the most commonly used are the Goodness of Fit Index (GFI), the Comparative Fit Index (CFI), the Root Mean Square Error Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). In the instrument designed for PC students, the selected fit indices were: χ^2/df = 2.590, GFI = 0.92, CFI = 0.93, RMSEA = 0.06, SRMR = 0.07. In turn, the fit indices for the instrument designed for non-PC students were slightly worse, but still acceptable according to the general standards: χ^2/df = 1.967, GFI = 0.90, CFI = 0.89, RMSEA = 0.07, SRMR = 0.08.

Reliability of the CAQ. Given the congeneric nature of the structural equation models employed in the CFA, reliability was analyzed using the statistic omega (Komperda *et al.*, 2018). Regarding the CAQ for PC students, the omegas were: 0.914 for attributions to the teacher and classroom methodology, 0.858 for the attributions to the students' perceived difficulty of the subject, 0.774 for the attributions to the subject's relationship with mathematics, 0.753 for the attributions to the effect of media, 0.858 for the attributions to the effect of the family, and 0.702 for the attributions to the effect of friends. Concerning the CAQ for students who abandoned the subject, the omegas were: 0.890 for attributions to the teacher and classroom methodology, 0.873 for the attributions to the students' perceived difficulty of the subject, 0.741 for the attributions to the subject's relationship with mathematics, 0.674 for the attributions to the effect of media, 0.867 for the attributions to the effect of the family, and 0.785 for the attributions to the effect of friends.

Procedure and analyses

Previous work using the same sample of students uncovered the existence of three different secondary school students' motivational profiles towards physics & chemistry (Ardura and Pérez-Bitrián, 2019). In this previous work, students in the sample were grouped using the following procedure. The first group was that of students who abandoned physics & chemistry (non-PC students) when it first becomes optional in the Spanish educational system. These students presented the lowest levels in the five motivational traits measured by the SMQII

(Ardura and Pérez-Bitrián, 2019). Second, a cluster analysis using the five motivational traits measured using the SMQII allowed the grouping of the students who chose the subject (PC students) into two different groups: students with high levels in the five motivational traits measured by the SMQII towards physics & chemistry and students with average motivational levels towards physics & chemistry (Ardura and Pérez-Bitrián, 2019). Since academic performance in physics & chemistry of the latter group was also average (Ardura and Pérez-Bitrián, 2019) and given the previously found relevance of motivation and academic performance on students' choices, we can characterize them as at-risk of abandonment students (Ardura and Pérez-Bitrián, 2018). It was also showed that considering these three groups of students is relevant to study their future options related to the choice of physics & chemistry when it becomes optional. Thus, the groups formed in this previous investigation (Ardura and Pérez-Bitrián, 2019) were used to accomplish the aims of the present study.

Descriptive and correlation analyses were undertaken. The Pearson correlation coefficient was used to measure the strength and direction of the relationships between the different pairs of variables. This coefficient ranges from −1 to +1. Absolute values around 0.2 or lower, 0.5, and 0.7 or higher, are associated with weak, moderate, and strong correlations, respectively. The mean comparisons among the three groups were carried out using the Analysis of Variance (ANOVA). The effect sizes were estimated using the omega squared statistic. It has been suggested that values of 0.01, 0.06, and 0.14 correspond to small, medium, and large effects, respectively (Field, 2009). Finally, multinomial logistic regression was used to accomplish the main objective of this study. This statistical technique is a multiple regression in which the outcome variable is categorical, and the predictor variables are continuous or categorical. In our case, the outcome variable was the belonging to one of the three groups of students and the predictor variables were the attributional variables (Field, 2009). The contribution of each attribution to the model was assessed using the odds ratio, which is an indicator of the resulting change in the odds of belonging to one of the three groups when the predictor changes in one unit. To ease the understanding of the results, the effects of the predictors will be presented through an estimation of their impact on the probability of choosing physics & chemistry in a modeled student who abandoned the subject. The model fit was assessed using the model chi-square statistic and the Cox and Snell's and Nagelkerke's R^2, as well as the estimation of the rate of classification improvement of the model. All computations were carried out using SPSS and AMOS (Arbuckle, 2010).

Results

We will firstly present the results of the descriptive and inferential analyses. Second, the correlation analyses will be reported. Finally, the results of the multinomial logistic model will be described. For the purposes of our study, all the results will be presented in a disaggregated fashion using the aforementioned three motivational groups of students: those with high motivation (PC students), average motivation (PC students) and low motivation (non-PC students).

Descriptive and mean difference analyses

Table 1 presents the mean score, the standard deviations, and the ANOVA results for the comparison of the six attributions studied in the present investigation across the three groups of students. The highest attributional levels were found in attributions to the subject's relationship with mathematics in the three cases. Attributions to the students' perceived difficulty of the subject and attributions to the effect of media showed also high levels, especially in the case of the highly-motivated and low-motivated students. On the other hand, the effect of friends on the decision presented the lowest scores in all three groups (see Table 1). The ANOVA mean comparison of the scores in the different attributional variables in the three groups of students rendered statistically significant differences in all the variables (see Table 1). The highest effect sizes were found in the case of attributions to media and to family, whereas attributions to friends and to students' perceived difficulty presented the lowest effect size.

Post hoc analyses rendered non-significant differences only in attributions to the students' perceived difficulty (between students with high and low motivation), attributions to friends

Table 1 Descriptive and inferential statistics of the attributional variables for the three groups under study

	PC students				Non-PC students				
	High motivation		Average motivation		Low motivation				
	M	SD	M	SD	M	SD	F	p	ω^2
TEACHER	1.91	1.64	1.13	1.20	1.20	1.08	32.590	<0.001	0.06
DIFFICULTY	2.28	1.77	1.02	1.00	2.17	1.31	20.506	<0.001	0.04
MATH	2.56	1.77	1.19	1.18	2.23	1.35	35.831	<0.001	0.06
FRIENDS	0.64	0.78	0.93	0.88	0.34	0.72	22.102	<0.001	0.04
MEDIA	2.25	1.41	0.95	1.02	1.41	1.05	70.024	<0.001	0.12
FAMILY	1.60	1.32	0.93	1.03	0.87	0.81	51.832	<0.001	0.09

TEACHER: attributions to the teacher and classroom methodology; DIFFICULTY: attributions to students' perceived difficulty of the subject; MATH: attributions to the subject's relationship with mathematics; FRIENDS: attributions to the effect of friends; MEDIA: attributions to the effect of media; FAMILY: attributions to the effect of the family.

(between highly-motivated and averaged-motivated students), and attributions to media (between the groups of average and low-motivated students). The rest of the pair-wise comparisons yielded statistically significant differences. For instance, these analyses revealed that highly-motivated students attributed their choice to the effect of the family to a greater extent than students with average motivation. A similar effect was found in attributions to the effect of media but, in this case, low-motivated students showed higher levels than average-motivated students (see Table 1). The levels of attributions to the students' perceived difficulty of the subject and to the subject's relationship with mathematics ran parallel being the highest in the group of highly-motivated students. These levels are lower in the case of non-PC students and even more in the case of students with average motivation. The attributions to the teacher and classroom methodology were more important for highly-motivated students than for students with average and low motivation. Finally, attributions to the effect of friends presented the lowest scores among all the attributions in the three groups. In spite of this fact, students with average motivation presented a significantly higher level of attributions to the effect of friends on the decision than the rest of the students.

Correlation analyses

Table 2 displays the correlation coefficients corresponding to all pairs of variables included in this study for the three groups of students. The strongest relationships among attributional variables themselves in the three groups of students were found between: (i) attributions to the teacher and classroom methodology and attributions to the students' perceived difficulty of the subject with correlations around 0.500**, (ii) attributions to students' perceived difficulty and attributions to the subject's relationship with mathematics with correlations around 0.400**, and (iii) attributions to the effect of friends and the effect of the family, whose correlation coefficients in the three groups reached 0.350** on average (see Table 2).

The strongest correlations between attributional and motivational variables were: (i) those between attributions to the students' perceived difficulty and self-efficacy (0.407** for highly-motivated students, 0.499** for average-motivated students, and −0.573** for non-PC students), (ii) attributions to the subject's relationship with mathematics and self-efficacy (0.372** for highly-motivated students, 0.324** for average-motivated students, and −0.319** for non-PC students), and (iii) attributions to the effect of media and intrinsic motivation (0.544** for highly-motivated students, 0.521** for average-motivated students, and −0.358** for non-PC students).

With regards to the correlations that involve the different causal attributions and academic achievement in physics & chemistry (grade average), it is worth noting that the strongest relationships were found in the case of attributions to the students' perceived difficulty, with positive correlation coefficients for students who opted for PC (0.406** for highly-motivated students and 0.354** for average-motivated students) and a negative coefficient for those who abandoned the subject (−0.441**). Besides, a significant positive correlation was detected in the case of grade average and attributions to the subject's

Table 2 Correlations between the variables under study[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
TEACHER (1)	1	0.498**	0.199**	0.213**	0.202**	0.279**	0.155**	0.054	0.014	0.094	0.085	0.284**
		0.571**	0.119*	0.273**	0.251**	0.205**	0.241**	0.016	0.043	0.230**	0.078	0.158**
DIFFICULTY (2)	0.489**	1	0.438**	0.214**	0.210**	0.222**	0.183**	0.113	−0.125*	0.407**	0.130*	0.406**
			0.318**	0.213**	0.268**	0.115*	0.316**	0.062	0.006	0.499**	0.132**	0.354**
MATH (3)	0.276**	0.529**	1	0.126*	0.224**	0.077	0.302**	0.082	−0.100	0.372**	0.118	0.338**
				−0.003	0.219**	0.128**	0.332**	0.214**	0.077	0.324**	0.145**	0.072
FRIENDS (4)	0.323**	0.106*	0.085	1	0.177**	0.409**	0.009	−0.063	−0.022	−0.075	−0.089	−0.129*
					0.166**	0.333**	0.002	−0.030	−0.012	0.033	0.012	−0.047
MEDIA (5)	0.379**	0.392**	0.372**	0.236**	1	0.108	0.544**	0.193**	0.041	0.168**	0.088	−0.030
						0.218**	0.521**	0.300**	0.130**	0.292**	0.142**	0.028
FAMILY (6)	0.352**	0.307**	0.223**	0.335**	0.332**	1	−0.110	0.035	0.125*	−0.019	0.123*	−0.001
							0.024	0.202**	0.217**	0.024	0.209**	0.001
IM (7)	−0.258**	−0.380**	−0.294**	0.021	−0.358**	−0.015	1	0.261**	0.071	0.321**	0.063	0.104
								0.371**	0.102*	0.424**	0.193**	0.106*
CM (8)	−0.047	−0.101	−0.211**	0.176**	−0.181**	0.017	0.602**	1	0.013	0.215**	0.106	0.146*
									0.101*	0.181**	0.263**	0.038
SD (9)	−0.180**	−0.139**	−0.105*	−0.142**	−0.161**	−0.055	0.430**	0.250**	1	−0.134*	0.012	0.009
										0.183**	0.397**	0.206**
SE (10)	−0.347**	−0.573**	−0.319**	−0.071	−0.243**	−0.154**	0.524**	0.309**	0.413**	1	0.138*	0.357**
											0.324**	0.328**
GM (11)	−0.204**	−0.291**	−0.149**	−0.122*	−0.296**	−0.135**	0.465**	0.311**	0.577**	0.617**	1	0.170**
												0.258**
GRADE AVG (12)	−0.214**	−0.441**	−0.099	−0.117*	−0.148**	−0.174**	0.273**	0.100	0.320**	0.490**	0.484**	1

[a] The lower part of the table corresponds to non-PC students and the upper part corresponds to PC students. Correlations in bold refer to highly-motivated students and coefficients in italics refer to students with average motivation. TEACHER: attributions to the teacher and classroom methodology; DIFFICULTY: attributions to students' perceived difficulty of the subject; MATH: attributions to the subject's relationship with mathematics; FRIENDS: attributions to the effect of friends; MEDIA: attributions to the effect of media; FAMILY: attributions to the effect of the family; IM: intrinsic motivation; CM: career motivation; SD: self-determination; SE: self-efficacy; GM: grade motivation; GRADE AVG: grade average. $^{*}p < 0.05$; $^{**}p < 0.01$.

relationship with mathematics only in the group of highly-motivated students. In turn, no significant correlations were found in the other two groups of students (see Table 2). Finally, grade average was slightly related to attributions to the teacher and classroom methodology, directly with regards to students who chose the subject and inversely for those who opted it out (see Table 2).

Multinomial logistic regression model

The multinomial regression model we present in this study was built to predict belonging to the three motivational categories (students with high, average, and low motivation) using the attributional variables as predictors. It is important to bear in mind that students in the first two groups had chosen physics & chemistry, whereas those in the last one had abandoned it in the very first moment they had the possibility.

The multinomial logistic regression model was statistically significant ($\chi^2 = 343.03$; $p < 0.001$). The predictors' power was measured using the R^2 of Cox and Snell and R^2 of Nagelkerke, and reached values of 0.28 and 0.31, respectively. The model was able to predict 54.9% of cases in the sample. The usability of the model to predict can be assessed by computing the proportional-by-chance accuracy rate classification. An improvement over 25% has been proposed as an acceptable standard (Petrucci, 2009). In our study, the proportional-by-chance accuracy rate classification to set a 25% prediction improvement is 42.5%. Therefore, the performance of the variables in our model was better than could be reasonably expected by chance. The cases classification is shown in Table 3.

Table 4 collects the logistic model coefficients and the odds ratios (OR) for each predictor variable. The group of non-PC students acted as the reference category for the comparison of their attributions with highly-motivated students and average-motivated students, both of whom decided to choose the subject when it becomes optional in the Spanish educational system.

For highly-motivated students, the strongest predictor of choosing physics & chemistry was attributions to family ($B = 0.73$, $p < 0.001$; OR = 2.08). Thus, a one-point increase in this attribution would raise the probability of choosing the subject for a modeled non-PC student with average values in the rest of the attributions from 0.299 to 0.470. Regarding the average-motivated students, a slightly less favorable effect was found for this attribution ($B = 0.50$, $p < 0.001$; OR = 1.64). In turn, attributions to the teacher and classroom methodology are somewhat more important for students with average motivation ($B = 0.53$, $p < 0.001$; OR = 1.69), than for highly-motivated students ($B = 0.45$, $p < 0.001$; OR = 1.56). It is interesting to note that, while attributions to the effect of media is a strong predictor for highly-motivated students ($B = 0.65$, $p < 0.001$; OR = 1.92), it is not a significant predictor for their average-motivated counterparts (see Table 4).

Attributions to the students' perceived difficulty of the subject displayed a similar behavior in both groups of students: when this attribution increases by one unit, the odds of choosing physics & chemistry when it becomes optional is reduced by around 50% (see Table 4). In turn, attributions to the subject's relationship with mathematics is a weak significant predictor only for average-motivated students ($B = -0.21$, $p < 0.01$; OR = 0.81). Therefore, if this attribution increases in one point, the probability of choosing the subject for the non-PC modeled student would decrease from 0.433 to 0.382. In the same vein, a significant effect of attributions to the effect of friends was found in students with average motivation ($B = 0.37$, $p < 0.001$; OR = 1.44) but not in highly-motivated students.

Table 3 Classification table

Observed	Predicted High motivation	Average motivation	Low motivation	Percentage correct
High motivation	**120**	88	68	43.5%
Average motivation	51	**266**	102	63.5%
Low motivation	52	117	**196**	53.7%
Overall percentage	21.0%	44.4%	34.5%	**54.9%**

Table 4 Multinominal logistic regression results

		95% CI for odds ratio		
	B (SE)	Lower	Odds ratio (OR)	Upper
PC highly-motivated *vs.* non-PC students				
Intercept	−2.30 (0.26)***			
TEACHER	0.45 (0.09)***	1.30	1.56	1.88
DIFFICULTY	−0.46 (0.10)***	0.52	0.63	0.77
MATH	0.13 (0.08)	0.97	1.13	1.33
FRIENDS	−0.08 (0.12)	0.72	0.92	1.18
MEDIA	0.65 (0.09)***	1.60	1.92	2.31
FAMILY	0.73 (0.11)***	1.68	2.08	2.57
PC average-motivated *vs.* non-PC students				
Intercept	0.26 (0.18)			
TEACHER	0.53 (0.09)***	1.43	1.69	2.01
DIFFICULTY	−0.58 (0.09)***	0.47	0.57	0.67
MATH	−0.21 (0.07)**	0.71	0.81	0.93
FRIENDS	0.37 (0.11)***	1.17	1.44	1.78
MEDIA	−0.04 (0.09)	0.81	0.96	1.13
FAMILY	0.50 (0.99)***	1.35	1.64	1.20

TEACHER: attributions to the teacher and classroom methodology; DIFFICULTY: attributions to students' perceived difficulty of the subject; MATH: attributions to the subject's relationship with mathematics; FRIENDS: attributions to the effect of friends; MEDIA: attributions to the effect of media; FAMILY: attributions to the effect of the family. ** $p < 0.01$; *** $p < 0.001$

Discussion

The relationship between students' motivation to learn science and their preferences for future science studies has been clearly evidenced by numerous investigations in the field (Mujtaba and Reiss, 2014; Sheldrake *et al.*, 2015; Sheldrake, 2016; Palmer *et al.*, 2017; Ardura and Pérez-Bitrián, 2018, 2019). In a further step, the present work aimed to investigate the students' explanations of their choices when they face the possibility of choosing or abandoning physics & chemistry for the first time in their school curriculum, as a function of their motivational levels towards the subject. To this aim, participants were divided into three groups, as described in the methods section. In addition to the group of non-PC students, a cluster analysis revealed the existence of two different groups of PC students in terms of their motivational traits: those with high and those with average motivation towards the subject, respectively (Ardura and Pérez-Bitrián, 2019). It is important to bear in mind that the subsample of students who, having chosen the subject, presented average levels of motivation and academic achievement in physics & chemistry, were identified as at-risk of abandonment students.

Our first research question was: which are the most common causal attributions for choosing physics & chemistry as a function of the students' motivational profile? Students with average motivation presented a set of attributional levels ranging from 0.93 (attributions to the effect of friends and attributions to the effect of the family) to 1.19 (attributions to the subject's relationship with mathematics) in the six attributions investigated. Therefore, these at-risk of abandonment students present low levels of attributions and none of them stands out from the others. In turn, the other two groups of students (*i.e.* highly-motivated PC students and low-motivated non-PC students) displayed a more heterogeneous pattern, yet quite similar between them. In both groups, a higher preference for attributions to the subjects' relationship with mathematics, to the students' perceived difficulty of the subject, and to the effect of media was found. The highest levels were found in both groups for attributions to students' perceived difficulty of the subject and to the subject's relationship with mathematics. It is worth noting that these two attributions behaved similarly in the three groups and, in fact, both were highly correlated. This finding is consistent with previous investigations reporting that students' perceptions of STEM are related to its relationship with mathematics (Slavin, 2008; Zeldin *et al.*, 2008; Semela, 2010; Brown *et al.*, 2016).

Attributions to the effect of media were significantly higher in the case of highly-motivated students than in the other two groups, with the largest effect size of all attributions. In contrast with our results, an investigation in the context of Spain reported that students were not interested in TV science and no effects were found in the students' attitudes towards this subject (de Moya Guirao and García Molina, 2013). In the case of attributions to the teacher and classroom methodology, the highest levels were found in highly-motivated students, despite these students displayed the highest levels of self-efficacy and self-determination (Ardura and Pérez-Bitrián, 2018). This result seems to point to the fact that students' expectations about physics & chemistry teachers play a more important role in the case of highly-motivated students in spite of their higher autonomy. Remarkably, attributions to the students' perceived difficulty of the subject were correlated with attributions to teacher and classroom methodology in the three groups of students. This finding could mean that previous experiences with teachers may result in causal attributions to perceived difficulty. These findings support previous evidence by Patall *et al.* (2018), who reported that students' perceived difficulty is minimized when teachers provide autonomy-supporting orientation to them.

Attributions to family presented a medium-large effect size in the mean comparisons across the three groups of students. The highest and lowest levels of this attribution were found in students with high and low motivation, respectively. These results reflect how the former are more influenced by their families in their decisions than the latter. In light of these results, highly-motivated students seem to receive more encouragement from their families to continue in the STEM pipeline than their counterparts, or simply that family inputs are more relevant to them. This finding is consistent with that of Rice *et al.* (2013), who reported that perceived social support increases students' positive attitudes towards science. Attributions to friends were the least important for all the students. However, it is interesting to note that the highest level of this attribution was found in participants with average motivation. Thus, in this case, advice from peers becomes competitive with the rest of the reasons that students argue to choose physics & chemistry. Interestingly, this is not the case neither for highly-motivated students nor for students with low motivation, who clearly focus on other reasons to choose or abandon the subject, respectively.

The second research question was: are there any relationships among students' causal attributions and their motivational traits? Overall, attributions to the students' perceived difficulty of the subject, to its relationship with mathematics and to the effect of media presented the largest significant correlations with students' motivation and academic performance. The motivational traits involved were, mainly, intrinsic motivation, self-efficacy, and grade motivation. Correlations in the sample subsets of students with high and average motivation behaved distinctly than those found in low-motivated students, as positive and negative correlation coefficients were found for the former and for the latter, respectively.

For PC students, the level of attributions to the students' perceived difficulty of the subject becomes higher as students' motivation increases. This finding could be explained bearing in mind that this type of students may link this attribution to obtaining good grades. In fact, grade motivation was found to be the motivational trait with the highest level among students with high and average motivation in a previous study (Ardura and Pérez-Bitrián, 2018). As regards low-motivated students, attributions to the students' perceived difficulty of the subject are inversely related to intrinsic motivation, self-efficacy, and grade motivation. Therefore, the lesser motivated the students are, the higher relevance of attributions to the perceived difficulty, in line with previous studies (Solbes *et al.*, 2007; Solbes, 2011; Shirazi, 2017).

Attributions to the subject's relationship with mathematics displayed a similar pattern with regards to its relationship with motivation. In this case, the highest correlations were found with intrinsic motivation and self-efficacy. In the case of PC students, the level of these attributions becomes higher as these two motivational traits increase. In turn, for students with low motivation (*i.e.*, non-PC students), the opposite trend was found. Consequently, motivation towards physics & chemistry seems to be linked to the students' perceptions of mathematics, as reported in previous research (Slavin, 2008; Semela, 2010; Cooper and Pearson, 2012; Scott, 2012; Villafañe *et al.*, 2016).

Interestingly, the level of attributions to the effect of media is dependent on students' intrinsic motivation. In students with high and average motivation, as intrinsic motivation increases, the level of students' attributions to media becomes higher. However, in low-motivated students, the opposite trend was found, as a negative correlation coefficient was encountered. This distinct effect of motivation on students' attributions to media may help explain the seemingly contradictory findings reported by previous studies (Bennett and Hogarth, 2009; Cerinsek *et al.*, 2013) as, in view of our results, the effect of media seems to depend on students' motivation.

Our third research question was: which causal attributions are the best predictors of students' choices? We have just discussed the disparity in students' attributions as a function of their motivation. With the aid of our multinomial logistic regression, we have been able to uncover the best predictors of students' choice, among the different attributions considered in our work. The models for the comparison between both groups of PC students (highly-motivated and average-motivated) and those who opted the subject out share common grounds in attributions to the effect of the family, to teacher and classroom methodology, and to perceived difficulty of the subject. However, attributions to the subject's relationship with mathematics, to friends, and to the effect of media behaved distinctly in the multinomial regression models. First, we will discuss the set of common significant predictors of the models and, second, the rest of them.

The strongest positive predictor of the choice of physics & chemistry for highly-motivated students was attributions to the effect of the family. In the case of students with average motivation, this attribution was also the most important together with attributions to the teacher and classroom methodology. These results are in line with several previous investigations that found social support as a way to stimulate students' motivation and positive attitudes towards science (Stake, 2006; Rice *et al.*, 2013; Mujtaba and Reiss, 2014; Nugent *et al.*, 2015) and, consequently, their intentions to continue their studies in chemistry-related options (Simpkins *et al.*, 2015; Sha *et al.*, 2016). This finding provides additional evidence for the well-known relationship between parental engagement in students' education and children's motivation for school work (Hoover-Dempsey *et al.*, 2010). Besides, using Phelan, Davidson and Cao's model (1991), the transition between family and school cultures seems to be more difficult for students with average motivation, as they are less influenced by their families than highly-motivated students. Besides, our findings also confirm that teachers are especially relevant in the retention of students in the science track in secondary schools as reported in previous studies (Cerinsek *et al.*, 2013; Reinhold *et al.*, 2018). It is interesting to note that, in contrast with Cerinsek's *et al.* (2013), in our study, family seems to be as influential as teachers and classroom dynamics for PC students with average motivation, or even higher for their highly-motivated peers.

Another source of social influence is the effect of friends. Interestingly, our analyses uncovered a differential effect of attributions to friends. On the one hand, this attribution was a significant predictor of students' choices for students with average motivation, being the odds ratio similar to that of the attributions to the teacher and classroom methodology and to the effect of the family. On the other hand, for the highly-motivated peers, this attribution did not contribute significantly to the regression model. This result may be explained invoking the fact that the latter students could have a clearer and more grounded vision of their choice which, in turn, would prevent them from seeking advice from their friends. However, the vocational options of at-risk of abandonment (*i.e.*, average-motivated) students could be less clear and, consequently, their friends could be a source of advice to make their final decision. In fact, the well-known importance of peers in teenagers' identity formation and in the shaping of their personality during adolescence, eventually leads to an influence on students' motivation and attitudes towards science (Vedder-Weiss and Fortus, 2013). Therefore, in light of our findings, this effect seems particularly important in the decision of choosing or abandoning the subject for at-risk students.

The level of attributions to the students' perceived difficulty of the subject was the only negative predictor of students' choice for both groups of PC students. Therefore, it is less likely that students choose the subject if they make this kind of attributions. It is interesting to note that, despite being highly correlated with attributions to the perceived difficulty, attributions to the subject's relationship with mathematics displayed a different behavior for students with high and average motivation. These attributions were a negative statistically-significant predictor for the latter but were non-significant for the former. Thus, attributions to the subject's relationship with mathematics may prevent average-motivated students from taking physics & chemistry as an optional subject, but this attribution is not relevant for their highly-motivated peers. A possible explanation for this finding could be that highly-motivated students assume more easily than their average-motivated peers the presence of mathematics in the subject as a necessary tool for chemistry.

Previous studies on the effect of media on students' uptake in physics & chemistry were somehow inconclusive (Bennett and Hogarth, 2009; Cerinsek *et al.*, 2013). Our analyses revealed that the variable attributions to the effect of media was a significant predictor for highly-motivated students but it was non-significant for their average-motivated counterparts. Thus, in light of our findings, media seem important only for highly-motivated students. This would imply that, for media to be influential on their decisions, students need to be previously motivated towards physics & chemistry. In this way, intrinsic motivation could be playing a particularly important mediating role between the effect of media and students' choices.

Conclusions and educational implications

In light of the findings of the present study, several conclusions and their corresponding educational implications both for schools and chemistry teachers can be drawn. Since our computations revealed that the effect of some of the attributions are motivation-dependent, these suggestions are two-fold. On the one hand, several recommendations can be given for all students and, on the other hand, other advice will refer specifically to students with a particular level of motivation.

In general, one of the best predictors of the students' choice was attributions to the effect of the family. In this line, it would be useful to strengthen the bonds and collaboration between the schools and the families. They should actually work together to counsel the youngsters when they face the decision. Indeed, this shared work should be not only in advising them, but also in providing supporting environments to learn science outside class, so that students can get interested in science out of school. This way, the advice is eventually more meaningful. Again, bearing in mind our results, these actions seem particularly important in the case of students with an average motivation for physics & chemistry. Attributions to the teacher and classroom methodology are also among the best predictors of students' choices. Consequently, improving teachers' skills through continuing training should be encouraged by schools and administrations to raise the quality of chemistry education, in terms not only of new methodologies and learning approaches, but also of making science more appealing and related to everyday life. The findings reported in our investigation suggest that this policy could lead to a higher persistence of students in the chemistry track.

Interestingly, as stated above, our analyses envisioned that some causal attributions argued by secondary students to explain their choices when they face the possibility of taking optionally physics & chemistry depend on their level of motivation. Therefore, schools should specifically design their counseling activities as a function of students' motivation for both chemistry and physics. First, students who were characterized in previous studies as at-risk of abandonment (Ardura and Pérez-Bitrián, 2019), presented very low levels in all the attributions investigated. It seems that these students lack of good reasons to continue with the subject, which in turn, may lead to the abandonment of the subject in the near future. In view of these results, students with average motivation are those who need counseling the most. Thus, it seems important that schools design specific actions for these students before they have to make the decision of continuing or not in the science pipeline. For this group of students, the relevance of peers in their decision is also remarkable. This result may imply that working on the students' social interactions could be key to promote scientific options amongst the most doubtful students. Besides, attributions to the subject's relationship with mathematics were found to be crucial for this type of students. Therefore, it seems important that teachers of both subjects work together to facilitate students' knowledge transfer between the two areas (Pospiech *et al.*, 2019). This would probably ease students' understanding of the role played by mathematics in science as a tool rather than as a threat.

Second, in the case of the students who abandoned the subject, our results point to a decrease in the level of attributions to the perceived difficulty as students' motivation increases. Therefore, if teachers plan their classes considering students' motivation as an aim, besides the evident benefits in learning, it is possible that attributions to perceived difficulty would be minimized in future choices. This could lead to an increase in the students' retention in science as this type of attribution has been claimed to be one of the main predictors of chemistry abandonment (Smyth and Hannan, 2006; Solbes, 2011; Palmer *et al.*, 2017; Shirazi, 2017).

Third, it is worth noting that only highly-motivated students attributed their choice to the effect of media and, moreover, it was one of the predictors that contributed the most to explain this type of students' decision to choose the subject. Since the same trend was not found in students with average motivation, using media to promote physics & chemistry should simultaneously involve working on students' motivation towards the subject, as intrinsic motivation could be a mediating variable between attributions to media and students' choices.

Limitations and prospect

The findings uncovered in our investigation must be interpreted bearing several limitations in mind. First, the information gathered was self-reported. Thus, data could be biased by students' self-perceptions or by socially desirable responding. We expect the size of the sample to be large enough to overcome this effect, but subsequent investigations should be undertaken to replicate our results. The second limitation of this study is related to the way the variable "attributions to the students' perceived difficulty of the subject" was defined. For this definition, we hypothesized that students would choose/abandon physics & chemistry because they believed the subject was easy/difficult. However, it could also be possible that students would perceive the difficulty of the subject as a challenge, *i.e.* as a positive reason to choose it (Shirazi, 2017). Therefore, further research should attempt to deepen in this possible effect. Third, as stated above, our computations revealed that there is an important effect of media on highly-motivated students' decision that is not present in students with average motivation. For this reason, we hypothesize a mediating role of students' intrinsic motivation between the effect of media and students' choices that should be confirmed by future studies. Fourth, given the gender gap found in previous investigations in the field (Stokking, 2000; Brotman and Moore, 2008; Sheldrake *et al.*, 2017; Ardura and Pérez-Bitrián, 2018, 2019; Ardura and Galán, 2019), future research on the effect of sex on students' causal attributions should be tackled. Finally, the factor structure of the SMQII has recently been questioned (Komperda *et al.*, 2018). For this reason, future investigations using different samples should address this problem.

Conflicts of interest

There are no conflicts to declare.

Appendix: Measurement Invariance and Factor Analysis Results

Table 5 Fit indexes for the CFA of the individual subscales of the SMQII by group of students (PC/non-PC students)

Invariance	χ^2/df	CFI	RMSEA	SRMR
Subscale: self-determination				
PC students	2.87	0.98	0.07	0.03
Non-PC students	3.05	0.97	0.08	0.05
Subscale: self-efficacy				
PC students	2.03	0.97	0.06	0.03
Non-PC students	1.84	0.99	0.05	0.03
Subscale: intrinsic motivation				
PC students	2.87	0.96	0.06	0.04
Non-PC students	3.05	0.94	0.07	0.06
Subscale: grade motivation				
PC students	2.38	0.99	0.05	0.03
Non-PC students	1.81	0.99	0.05	0.04
Subscale: career motivation				
PC students	3.06	0.90	0.06	0.07
Non-PC students	3.25	0.88	0.07	0.08

Table 6 Invariance tests of the individual subscales of the SMQII

Invariance	*p*	ΔCFI	ΔRMSEA	ΔSRMR
Subscale: self-determination				
Metric	0.324	0.009	0.007	0.013
Scalar	0.258	0.011	0.011	0.003
Conservative	0.137	0.014	0.014	0.015
Subscale: self-efficacy				
Metric	0.452	0.011	0.009	0.010
Scalar	0.321	0.008	0.001	0.013
Conservative	0.125	0.012	0.028	0.016
Subscale: intrinsic motivation				
Metric	0.231	0.022	0.007	0.007
Scalar	0.178	0.010	0.001	0.009
Conservative	0.104	0.014	0.031	0.021
Subscale: grade motivation				
Metric	0.347	0.011	0.007	0.010
Scalar	0.573	0.010	0.001	0.012
Conservative	0.216	0.012	0.031	0.018
Subscale: career motivation				
Metric	0.258	0.002	0.006	0.013
Scalar	0.201	0.017	0.016	0.005
Conservative	0.152	0.016	0.013	0.015

Table 7 Factor loadings for the EFA of the CAQ for PC students

	Factor loadings		
Item		Explained variance	Statement
Factor: attributions to the teacher and classroom methodology			
25	0.875	31.90%	I chose physics & chemistry because my teacher used to encourage students to work.
17	0.863		I chose physics & chemistry because my teacher was always willing to help me when I faced difficulties.
12	0.837		I chose physics & chemistry because my teacher from last year was close to the students.
2	0.821		I chose physics & chemistry because I had a good teacher last year.

Table 7 (*continued*)

Item	Factor loadings	Explained variance	Statement
21	0.820		I chose physics & chemistry because my teacher used to acknowledge my efforts.
14	0.792		I chose physics & chemistry because my teacher's explanations were very clear and understandable.
7	0.773		I chose physics & chemistry because my teacher was very enthusiastic at class.
19	0.765		I chose physics & chemistry because I liked classes last year.
8	0.689		I chose physics & chemistry because I had fun at class.
3	0.650		I chose physics & chemistry because students were very active at class.
Factor: attributions to the students' perceived difficulty of the subject			
20	0.771	11.14%	I chose physics & chemistry because studying the material was easy.
13	0.719		I chose physics & chemistry because I passed the subject easily.
26	0.704		I chose physics & chemistry because I managed to understand the subject contents with little effort.
6	0.664		I chose physics & chemistry because, overall, the topics were easy for me.
Factor: attributions to the subject's relationship with mathematics			
4	0.907	9.54%	I chose physics & chemistry because I like mathematics.
24	0.894		I chose physics & chemistry because it is related to mathematics and I am good at it.
16	0.777		I chose physics & chemistry because I like to solve numerical problems.
Factor: attributions to the effect of the family			
1	0.773	6.59%	I chose physics & chemistry because my family recommended me to take the subject.
9	0.754		I chose physics & chemistry because it is important for my family that I get good grades in this subject.
23	0.727		I chose physics & chemistry because my family expected from me to choose this subject.
15	0.618		I chose physics & chemistry because my family supported my decision of choosing the subject.
Factor: attributions to the effect of media			
10	0.819	5.86%	I chose physics & chemistry because I like to follow news related to physics & chemistry as, for instance, those related to environmental issues.
22	0.816		I chose physics & chemistry because reading scientific news prompts my curiosity and I want to learn more.
18	0.687		I chose physics & chemistry because I perceive from the media that this subject is very important in our society.
Factor: attributions to the effect of friends			
27	0.881	4.24%	I chose physics & chemistry because I wanted to be at the same class as my friends.
5	0.830		I chose physics & chemistry because my friends chose the subject too.
11	0.760		I chose physics & chemistry because my friends expected from me to do so.

Table 8 Factor loadings for the EFA of the CAQ for non-PC students

Item	Factor loadings	Explained variance	Statement
Factor: attributions to the teacher and classroom methodology			
25	0.860	34.60%	I opted out physics & chemistry because my teacher did not use to encourage students to work.
2	0.807		I opted out physics & chemistry because I had a bad teacher last year.
17	0.804		I opted out physics & chemistry because my teacher was never willing to help me when I faced difficulties.
21	0.803		I opted out physics & chemistry because my teacher did not use to acknowledge my efforts.
12	0.794		I opted out physics & chemistry because my teacher from last year was distant towards the students.
7	0.765		I opted out physics & chemistry because my teacher was very apathetic at class.
14	0.725		I opted out physics & chemistry because my teacher's explanations were unclear and incomprehensible.
3	0.721		I opted out physics & chemistry because students were passive at class.
19	0.610		I opted out physics & chemistry because I disliked classes last year.
8	0.519		I opted out physics & chemistry because the classes were boring.
Factor: attributions to the students' perceived difficulty of the subject			
6	0.834	11.30%	I opted out physics & chemistry because, overall, the topics were difficult for me.
13	0.813		I opted out physics & chemistry because I hardly passed the subject.
20	0.773		I opted out physics & chemistry because studying the material was difficult.
26	0.665		I opted out physics & chemistry because understanding the subject contents was hard for me.
Factor: attributions to the subject's relationship with mathematics			
24	0.858	7.86%	I opted out physics & chemistry because it is related to mathematics and I am not good at it.
4	0.840		I opted out physics & chemistry because I dislike mathematics.
16	0.735		I opted out physics & chemistry because I dislike to solve numerical problems.

Table 8 (*continued*)

Item	Factor loadings	Explained variance	Statement
Factor: attributions to the effect of friends			
5	0.814	5.32%	I opted out physics & chemistry because my friends opted out the subject too.
27	0.750		I opted out physics & chemistry because I wanted to be at the same class as my friends.
11	0.690		I opted out physics & chemistry because my friends expected from me to do so.
Factor: attributions to the effect of media			
10	0.761	5.16%	I opted out physics & chemistry because I am not interested in news related to physics & chemistry as, for instance, those related to environmental issues.
22	0.751		I opted out physics & chemistry because I am not curious about scientific news.
18	0.462		I opted out physics & chemistry because I do not perceive from the media that it is an important subject in our society.
Factor: attributions to the effect of the family			
15	0.743	3.80%	I opted out physics & chemistry because my family supported my decision of not choosing the subject.
1	0.699		I opted out physics & chemistry because my family did not recommend me to take the subject.
23	0.535		I opted out physics & chemistry because my family did not expect from me to choose this subject.
9	0.466		I opted out physics & chemistry because it is not important for my family that I get good grades in this subject.

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