JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 54, NO. 5, PP. 558–585 (2017)

Research Article

Hope and Anxiety in Physics Class: Exploring Their Motivational Antecedents and Influence on Metacognition and Performance

Antonio González,[1] María-Victoria Carrera Fernández,[1] and Paola-Verónica Paoloni[2]

[1]*Universidad de Vigo, Vigo, Spain*
[2]*Universidad Nacional de Río Cuarto, Córdoba, Argentina*

Received 14 August 2015; Accepted 26 October 2016

Abstract: Recent research on achievement in science asserts that motivation, emotion, and metacognition are important driving forces for learning. This study sought to examine the relationships between two physics class emotions (hope and anxiety), their motivational predictors (instrumentality and self-efficacy), and their effects on metacognitive problem solving strategies (planning, monitoring, and evaluation) and performance. Data were collected from 520 grade 11 Spanish students (54.7% girls). Structural equation models (SEM), followed by a bootstrap procedure, were used to examine direct and mediated relationships. The results supported the model, suggesting that instrumentality and self-efficacy negatively predicted anxiety, and enhanced hope, planning, monitoring, evaluation, and performance; metacognitive strategies and performance were negatively predicted by anxiety, and were positively predicted by hope; metacognitive strategies positively predicted performance. Furthermore, the hypothesized mediated relations were also statistically significant. The interpretation of these findings, their implications for physics teaching and learning, and future lines of research are discussed. © 2016 Wiley Periodicals, Inc. J Res Sci Teach 54:558–585, 2017
Keywords: instrumentality; self-efficacy; hope; anxiety; metacognitive strategies

Research on academic emotions has given rise to an unprecedented number of publications in the last decade underscoring the crucial role emotions play in the learning-process, including the sciences (Sinatra, Broughton, & Lombardi, 2014). Thus, Chiang and Liu (2014) assert that conceptual change in science education is heavily influenced by feelings and emotions. However, Fortus (2014, p. 828) claims that “affect lies off our radar screens and is under-appreciated as a central issue in science education.” As Tomas and Ritchie (2012, p. 27) recognize, “very few studies have focused on the role of student emotions in learning science.”

Motivation itself is a primary determining factor of academic emotions (Bandura, 1993; Pekrun & Perry, 2014; Zeidner, 2014). Of the array of motivational constructs determining emotions, two stand out from the rest: perception of control of situations and activities (e.g., self-efficacy) and task-value (e.g., instrumentality). According to these authors, students experience certain emotions when they both feel in control of or lack control of activities and outcomes that are important.

Correspondence to: A. González; E-mail: aglez@uvigo.es
DOI 10.1002/tea.21377
Published online 29 December 2016 in Wiley Online Library (wileyonlinelibrary.com).

An outcome of academic emotions is the use (or absence of use) of cognitive and metacognitive learning strategies. In physics, as in other similar subjects, problem solving is a fundamental activity for acquiring the knowledge needed to pass the subject (Taasoobshirazi & Farley, 2013b). Thus, developing problem solving expertise has become a central concern for science education researchers and teachers (Mualen & Eylon, 2010; Taasoobshirazi & Farley, 2013a), who aim to foster the students' use of strategies and skills, particularly metacognitive ones (Davidson & Sternberg, 1998).

Hence, the aim of the present study is to assess two academic emotions in the physics class as well as their predictors and outcomes. In a recent review of the literature on motivation and attitude in science and technology, Potvin and Hasni (2014) verified that most of the studies analyzed offered no explicit definition of these constructs. In the following section, therefore, previous research will be reviewed in order to adequately define the constructs assessed in the present study i.e., emotions (hope and anxiety), motivation (instrumentality and self-efficacy), and problem solving metacognitive strategies (planning, monitoring, and evaluation).

Theoretical Framework

Emotions: Anxiety and Hope

Currently, there is an array of approaches for the analysis of academic emotions. Some authors have examined emotions globally by contrasting positive and negative emotions, whereas others have sought to analyze the so called "discrete emotions." This perspective predominates in educational contexts and science teaching in particular.

Pekrun and Perry (2014) define academic emotions as affective arousal that is directly linked to achievement activities (e.g., studying) or achievement outcomes (success and failure). One of the most widely assessed academic emotions in the literature is anxiety. Academic anxiety arises when students believe their cognitive and/or motivational skills may be overwhelmed by the demands of a highly valued academic situation (Pekrun & Perry, 2014; Sinatra et al., 2014; Zeidner, 2014). Though some degree of anxiety may be helpful in the learning process, a high level of anxiety impedes optimum performance in science learning (Hong, 2010). Anxiety of learning science can paralyze students whose intelligence and hard work should otherwise allow them to perform well. According to Hong (2010) and Sinatra et al. (2014), high levels of science anxiety result in poor performance in science courses, antiscientific attitudes, scientific illiteracy, and avoidance of careers in science.

Chiang and Liu (2014) and Feldman and Kubota (2015) contend that research in science education has tended to focus on negative attitudes and emotions. Thus, positive emotions such as hope have received less attention than anxiety in science teaching (Sinatra et al., 2014). Hope is defined as the process of thinking about one's goals along with the motivation to move toward these goals (agency), and the ways to achieve those goals (pathways) (Snyder, 2005; Snyder et al., 2002). Students experience this activating positive emotion when they feel they are sufficiently enabled to plan and put into practise the cognitive and motivational strategies needed to achieve their academic goals (Ciarrochi, Heaven, & Davies, 2007; Day, Hanson, Maltby, Proctor, & Wood, 2010; Valle, Huebner, & Suldo, 2006).

Like emotions in general, anxiety and hope would be located on a conceptual continuum between the trait-state dichotomy: emotions experienced in a general academic context, such as at high school (trait-emotion); emotions experienced in a specific course, such as physics (course-specific emotion); and emotions experienced in a single achievement situation, such as a particular laboratory session (state-emotion) (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011; Pekrun, Goetz, & Perry, 2005; Pekrun & Perry, 2014). These authors designed the Achievement Emotions

Questionnaire (AEQ) to assess all three modalities of achievement emotions (trait, course-specific, and state) in each of the three types of achievement settings (classroom, studying, and exams). The present study assesses anxiety (a negative activating emotion) and hope (a positive activating emotion) in the physics classroom. These two scales of the AEQ have been repeatedly applied for evaluating different academic emotions in secondary education (Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010; Goetz, Frenzel, Lüdtke, & Hall, 2011; Pekrun, Goetz, Titz, & Perry, 2002; Pekrun et al., 2011).

In this study, class-related anxiety and hope were specifically selected owing to their characteristics, in accordance with the control-value model of achievement emotions (Pekrun & Perry, 2014). Both emotions activate students' behaviors in response to future events, while this activation may be pleasant or unpleasant for the learner. According to these and other authors (Day et al., 2010; Sinatra et al., 2014; Zeidner, 2014), both emotions represent two opposite ways of coping with the demanding requirements of a class in a difficult subject i.e., students who perceived the demands of physics as a challenge experienced hope, while those who viewed the subject as a threat experienced anxiety.

In their control-value theory of achievement emotions, Pekrun and Perry (2014) proposed different types of "control and value appraisals" as antecedents of emotions. Control appraisals include self-efficacy expectations, self-concept, causal attributions, expectancies, competence beliefs, and perceived control. Value appraisals encompass utility value, usefulness, instrumentality, intrinsic value, attainment value, achievement value, domain value, relevance, and importance. As for the possible effects or impact of academic emotions, Chiang and Liu (2014), Pekrun and Perry (2014), and Zeidner (2014) assert that emotions influence academic engagement and performance.

Motivation: Instrumentality and Self-Efficacy

Perceived academic instrumentality is the perception of connectedness between current classroom behaviors and desired future outcomes or goals (Husman, Derryberry, Crowson, & Lomax, 2004; Simons, Dewitte, & Lens, 2004). These authors differentiate endogenous from exogenous instrumentality. Endogenous instrumentality occurs when a student understands the ways in which gaining competence in a task (e.g., learning the course content) can help achieve future goals. Exogenous instrumentality occurs when performance in a task (e.g., receiving good grades) is perceived as being important for the attainment of a future goal. This construct has developed within the context of the literature of "future time orientation" and "future time perspective" (Husman et al., 2004; Husman & Lens, 1999; Nieswandt & Shanahan, 2008). Future time orientation is the degree to which, and the way in which the chronological future is integrated into the present life-space of an individual through motivational goal-setting processes. Future time perspective consists of the mental perception, at a certain moment in time, of events that in reality happen in temporal succession and with longer or shorter time intervals between them (Simons et al., 2004; Tabachnick, Miller, & Reylea, 2008).

Perceived instrumentality is related to other motivational constructs such as attainment value and utility value (Eccles & Wigfield, 2002; Gungor, Eryilmaz, & Faklioglu, 2007; Husman et al., 2004; Schneider et al., 2016; Simpkins, Price, & García, 2015). Attainment value is the importance of doing well in a task, and is linked to the relevance of engaging in a task to confirm salient or important aspects of one's identity and self-schema (Eccles & Wigfield, 2002). Utility value or usefulness refers to how a task relates to personal goals such as future plans or occupational and career goals. According to Eccles and Wigfield (2002) and Husman et al. (2004), utility value is similar to the construct of instrumentality.

Husman et al. (2004) designed the Perceived Instrumentality Scale to assess endogenous and exogenous instrumentality, which has been used in several studies in secondary education (DeBacker & Nelson, 1999; Tabachnick et al., 2008).

Moreover, self-efficacy (or expectancy of efficacy) has been defined as the belief in one's ability to perform a specific task (Bandura, 2006). According to this author, students construct their self-efficacy beliefs through information integration drawn from four sources: personal mastery experiences, vicarious learning experiences, social persuasion, and the interpretation of physiological states. These sources of information have also proven to be decisive for constructing self-efficacy in the learning of science subjects (Britner & Pajares, 2006; Zeldin, Britner, & Pajares, 2008) and in physics (Sawtelle, Brewe, & Kramer, 2012; Taasoobshirazi & Sinatra, 2011).

In order to evaluate self-efficacy in the learning of science subjects, Glynn, Taasoobshirazi, and Brickman (2009) designed a scale which is part of the Science Motivation Questionnaire (SMQ). The scale has been used on numerous occasions to evaluate efficacy in science and non-science subjects (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Glynn, Taasoobshirazi, & Brickman, 2007; Glynn et al., 2009; Taasoobshirazi & Sinatra, 2011; Zeyer et al., 2013).

Problem Solving and Metacognition

The ability to correctly set up and solve physics problems is critical for success at multiple levels on physics courses. Most of the tasks completed by students in high school level physics courses in class, for homework, and on tests involve setting up and solving problems (Davidson & Sternberg, 1998; Taasoobshirazi & Farley, 2013b). Though there is no overall consensus among authors as to the stages involved in the problem solving process, the first step is reading and comprehension of the problem and the last is the analysis of the results obtained.

Studies on problem solving have tended to compare experts with novices in this task (Kuo, Hull, Gupta, & Elby, 2013; Mualen & Eylon, 2010; Taasoobshirazi & Farley, 2013a). These authors assert that the techniques and strategies necessary for expert problem solving are quite complex, and students fail to develop them spontaneously. The differences between experts and novices are based on the use of metacognitive strategies, among other aspects.

Most recent studies have focused on the role of metacognition in science learning and problem solving (Adler, Zion, & Mevarech, 2016; Schraw, Crippen, & Hartley, 2006; Taasoobshirazi & Farley, 2013a, 2013b; Thomas, 2013; Zepeda, Richey, Ronevich, & Nokes-Malach, 2015). In spite of minor differences, these authors consider that metacognition consists of two key dimensions that enable learners to understand (knowledge of cognition), and monitor (regulation of cognition) their cognitive processes. Furthermore, regulation of cognition contains at least three main components; planning, monitoring, and evaluation. *Planning* is comprised of goal setting, activating relevant background knowledge, selecting appropriate strategies for learning, and budgeting time; it includes thinking about what one needs in order to accomplish a goal and about how one intends to achieve that goal. *Monitoring* involves the self-testing skills necessary to control the process of learning, ensuring that things make sense within the accepted cognitive frameworks, judging whether understanding is sufficient, and searching for connections or conflicts with what is already known. *Evaluation* refers to appraising the products and processes of learning i.e., it is the ability to assess the usefulness of the learning strategies adopted. Some authors consider these self-regulatory strategies as a modality of cognitive academic engagement. According to Cleary and Zimmerman (2012) and Sinatra et al. (2014), this type of engagement includes a continuum ranging from low cognitive engagement (shallow processing) to high metacognitive engagement (deep processing).

In science in general, and particularly in physics, these metacognitive or self-regulatory strategies have been shown to be useful for enhancing the learning processes (Schraw et al., 2006; Sinatra & Taasoobshirazi, 2011; Thomas, 2013; Wang & Chen, 2014; Yuruk, Beeth, & Andersern, 2009).

The Physics Metacognition Inventory was designed and validated by Taasoobshirazi and Farley (2013b; see also Taasoobshirazi, Bailey, & Farley, 2015) and provides information about the regulation of cognition during physics problem solving, as well as assessing the self-regulatory strategies of planning, monitoring, and evaluation.

The Links Between Variables

Academic performance was positively correlated with self-efficacy (Feldman & Kubota, 2015; Glynn et al., 2011), perceived instrumentality (Greene, Miller, Crowson, Duke, & Akey, 2004; Malka & Covington, 2005; Simons et al., 2004), and metacognitive strategies (Cleary & Zimmerman, 2012). Self-efficacy and academic performance negatively correlated with academic anxiety (Goetz et al., 2012; Pekrun et al., 2002, 2011). Most of these results were obtained in subjects unrelated to science.

To our knowledge, no study has assessed perceived instrumentality or hope in the physics class specifically. Moreover, the few studies that have analyzed metacognitive problem-solving strategies in physics (Taasoobshirazi & Farley, 2013a, 2013b; Taasoobshirazi et al., 2015) have not related them to other relevant variables. As for self-efficacy, it was positively related to performance in physics, with values ranging from $r = 0.30$ to $r = 0.55$ (Britner, 2008; Sawtelle et al., 2012), but other relations to instrumentality, anxiety, hope, or metacognitive strategies have as yet to be explored. Regarding anxiety, Laukenmann et al. (2003) analyzed a construct named "physics performance anxiety" in a sample of grade 8 students, and found that anxiety was a negative predictor ($\beta = -0.25$) of performance in physics. Goetz et al. (2010, 2011) measured class-related anxiety in physics in grade 11 students and found that this emotion was negatively correlated with achievement ($r = -0.55$).

The Spanish Context

After a 6-year period of compulsory primary education, schoolchildren in Spain begin a 4-year period of Compulsory Secondary Education (CSE) (Year 7–10). In the 10th and final year of CSE, adolescents must choose between two study options i.e., a 2-year pre-university or pre-vocational course. Almost 87% of Spanish adolescents aged 15–18 are enrolled in school, of which 80% follow the pre-university course while the remaining 20% do pre-vocational training (INEE, 2015).

Students on the pre-university course must choose one of the three streams of baccalaureate: art, science-technology or humanities-social sciences. The scientific-technological stream includes physics as a compulsory subject. Additionally, each stream of baccalaureate gives preferential access to specific undergraduate courses i.e., the science-technology stream gives preferential access to science degrees and courses (e.g., mathematics and physics), health science (e.g., medicine and nursing), engineering, and architecture (IFIIE, 2013). Though men predominate on certain university degrees such as engineering and architecture, in other disciplines the ratio between both genders is either similar, or women outnumber men, as is the case of medicine and nursing.

There are characteristics that differentiate the first-year baccalaureate (Year 11) students from other students. In the first place, many adolescents studying this stream of Baccalaureate wanted to get into those degrees with the highest entry "cut-off scores" (e.g., medicine, biomedical sciences, or engineering). In addition, if they passed their Year 11 subjects, their Grade Point

Average (GPA) for the year would make up about 15% of their final mark for university entrance, which underscored the need to get the highest marks in all subjects.

Furthermore, most teachers and students considered the subject of physics to be particularly difficult. The most common reasons for this view were as follows: to understand it properly, the student needs a high level of mathematics; in secondary education, the content is too extensive and diverse; in order to understand much of the content, students need to have a high level of abstraction; and students must have problem-solving skills that require complex integration strategies (see Kuo et al., 2013; Oon & Subramaniam, 2011). However, physics continues to be a compulsory subject in Science-technology Baccalaureate and its content is a prerequisite for many degrees accessed through this stream of Baccalaureate. These circumstances all led to higher levels of stress in Year 11 students than those experienced by students on other courses.

Skinner and Pitzer (2012) consider the analysis of negative emotions in contexts from which individuals cannot voluntarily exit particularly important, i.e., in physics class when it is a compulsory subject.

The Current Study

Owing to the lack of integrated research simultaneously assessing perceived instrumentality, self-efficacy, anxiety, hope, planning, monitoring, evaluation, and performance in science, the purpose of this study was to use structural equation models (SEM) to explore the relationship between these variables in physics in secondary education. In this sense, Taasoobshirazi and Farley (2013b) recommend examining how metacognition interacts with other variables critical for learning physics.

The theoretical framework for the present study was based on the models proposed by Pekrun and colleagues (Pekrun & Linnenbrink-García, 2012; Pekrun & Perry, 2014). These authors suggest that academic emotions (e.g., class-related hope and anxiety) are influenced by motivational variables (e.g., instrumentality and self-efficacy), and determine the levels of engagement (e.g., planning, monitoring, and evaluation), and achievement (e.g., performance in physics). The hypothesized paths between these variables are depicted in Figure 1. Moreover, most of the research previously reviewed provides evidence for these proposals.

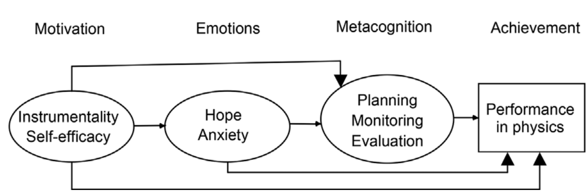

Figure 1. The hypothesized model of relations.

As shown in Figure 1, the model proposes that instrumentality and self-efficacy predict class anxiety and hope, which, in turn, predict differences in metacognition (planning, monitoring, and evaluation) that subsequently predict academic performance. Therefore, in this study we expected that (i) anxiety would be negatively predicted by instrumentality and self-efficacy, and would negatively predict planning, monitoring, evaluation, and performance; (ii) hope would be positively predicted by instrumentality and self-efficacy, and would positively predict planning, monitoring, evaluation, and performance; (iii) metacognitive self-regulatory strategies would positively predict performance; (iv) anxiety and hope would mediate the effects of instrumentality and self-efficacy on planning, monitoring, and evaluation; (v) the effects of anxiety and hope on performance would be mediated by metacognitive strategies; finally (vi) emotions and metacognitive strategies would mediate the positive associations of instrumentality and self-efficacy with performance.

In the present study, only two emotions were selected due to the limitations of SEM. This type of analysis should not include more than 25–30 indicators (Byrne, 2010). Besides hope and anxiety, the hypothesized model included two motivational variables as predictors and three metacognitive strategies as outcomes, which underscored the need for limiting the number of emotions to be evaluated.

Need for Research

Overall, the current study broadens our knowledge base on the theory of science motivation, emotion, and engagement by: (i) analyzing instrumentality and hope, i.e., two constructs that have not been previously assessed in physics; (ii) measuring anxiety and metacognitive strategies, two variables scarcely examined in the literature on physics; and (iii) assessing the relationships between these variables and self-efficacy and performance through SEM. These theoretical contributions are also relevant to physics educators in terms of their practical implications.

In the first place, the focus on self-efficacy was justified on two grounds: its role as a powerful predictor of academic emotions and performance (Britner, 2008; Pekrun & Perry, 2014; Sawtelle et al., 2012), and the absence of any previous study assessing its relation to instrumentality, emotions, and metacognitive strategies in either physics or science.

Second, instrumentality was evaluated due to the characteristics of the construct itself and the nature of the sample under study. As to the construct, Husman et al. (2004) and Simons et al. (2004) sustain that instrumentality includes the perceived importance of grades and the acquired competence to fulfill personal goals. Furthermore, although instrumentality is a relevant predictor of academic emotions (Pekrun & Perry, 2014), it has not been researched in physics. As for the sample, most science-technology baccalaureate students valued both their final grades and the knowledge acquired in the subject. High performance is a decisive factor for them to be able to choose the university degrees they want, namely those requiring the highest grades in all subjects. Finally, the contents covered in physics were essential for most university degrees.

Third, class-related hope was examined for the following reasons: it has not been previously evaluated in physics, though it has been extensively analyzed in other subjects (Pekrun et al., 2002, 2011; Snyder et al., 2002); it is positively correlated with academic performance in different subjects and educational levels (Feldman & Kubota, 2015; Pekrun et al., 2011); and it has been mentioned by authors such as Sinatra et al. (2014), who underscored the need to analyze positive emotions in science education.

Fourth, anxiety in science has been well documented in the literature (Hong, 2010; Mallow, 2006; Mallow et al., 2010), and numerous studies have applied the "Anxiety about Physics Assessment," a subscale of the Physics Motivation Questionnaire (PMQ). Notwithstanding, most of these studies (Abraham & Barker, 2015a, 2015b; Taasoobshirazi & Carr, 2009; Taasoobshirazi & Farley, 2013a; Taasoobshirazi & Sinatra, 2011) synthesized all of the subscales of the questionnaire into one single index. Thus, very few studies (Goetz et al., 2010, 2011; Laukenmann et al., 2003) have specifically evaluated anxiety in physics.

Fifth, the research examining the impact of metacognitive problem-solving strategies in physics is scant (Taasoobshirazi & Farley, 2013b). As asserted by these authors, this lack of research is worrying given the significance of problem-solving in physics. Even fewer studies have analyzed the motivational and emotional predictors of these strategies. This has led Taasoobshirazi et al. (2015, pp. 2,782) to recommend the use of SEM to explore how metacognition interacts with other variables, such as motivation, to predict achievement in physics.

Finally, all of these variables were simultaneously analyzed by SEM, a method of analysis that provides significant advantages over correlational and regression analyses, as indicated in the section on the outline of data analyses and design.

An additional reason for assessing these variables was that, to a certain extent, they are all under the teacher's influence. Physics instructors can enhance students' self-efficacy (Zusho, Pintrich, & Coppola, 2003), explicitly inform them of the instrumentality of the subject (Abraham & Barker, 2015b), encourage behavior that raises hope in their students (Snyder, 2005), reduce anxiety in class (Hong, 2010; Mallow, 2006), and develop problem-solving metacognitive strategies (Thomas, 2013). These practical contributions are taken up in greater detail in the section on implications for science teaching.

Method

Participants

The sample consisted of 520 students (54.8% girls) enrolled in the first year of the Science-technology Baccalaureate (Year 11) at different schools in the Northwest of Spain. At the end of the academic year (June), the mean age of participants was $M = 16.81$ years ($SD = 0.64$), with no statistically significant differences by gender examined with an ANOVA (mean for women $M = 16.77$, $SD = 0.62$; mean for men $M = 16.85$, $SD = 0.65$) [F (1,518) = 2.02, $p < 0.156$, $\eta^2 = 0.004$].

The school board provided access to both the students' and their parents' data with the latter's prior informed consent. In terms of origin, 92% of students were born in Spain. As for the parents' academic status, 23% were university graduates, 29% had undertaken further education (Year 12), and 48% had completed or failed to finish CSE (Year 10). The data on the students' origin and the academic status of parents were similar to the general high school population in Spain for the academic year 2014 (CEE, 2015).

Following a multistage sampling design (Whittemore, 1997), first four rural populations with fewer than 5,000 inhabitants and then four urban populations with more than 80,000 inhabitants were randomly selected. A total of 22 schools were selected; 16 state schools and 6 private schools. This proportion of state to private schools reflected rates among the total number of schools teaching Baccalaureate in this area of Spain. Four state schools belonged to primarily rural populations with fewer than 5,000 inhabitants. The remaining private (6) and state schools (12) were randomly selected from four main populations ranging from 80,000 to 370,000 inhabitants. Finally, data were obtained from all of the students enrolled in the Science-technology Baccalaureate in each of the schools selected, with the number of students per class ranging from 15 to 29.

This sample is comparable to the samples from Bøe and Henriksen (2013), Abraham and Barker (2015a), Chow, Eccles, and Salmela-Aro (2012), Cottaar (2012), Goetz et al. (2010, 2011, 2012), Nieswandt and Shanahan (2008), and Rozek, Hyde, Svoboda, Hulleman, and Harackiewicz (2015), for assessing senior secondary students from Australia, Canada, Finland, Germany, the Netherlands, Norway, and the United States. In many of these studies, adolescents were enrolled in a compulsory science subject based on the degree they were aspiring to.

Measures

Instrumentality. To assess the perceived instrumentality of physics, the Perceived Instrumentality Scale (Husman et al., 2004) was applied. This scale contained four items, two assessed endogenous instrumentality (e.g., "What I learn in the course of physics will be important for my success in my future occupational success"), and two items evaluated exogenous instrumentality (e.g., "I must pass the course of physics in order to reach my academic goals").

In previous research, the reliability indices (Cronbach's alpha) for this scale were satisfactory, with values of $\alpha = 0.79$ (DeBacker & Nelson, 1999), $\alpha = 0.86$ (Husman et al., 2004), and $\alpha = 0.92$ (Tabachnick et al., 2008). This scale was applied to a sample of high school students during biology classes (DeBacker & Nelson, 1999), and undergraduates enrolled in both non-science and science courses (Husman et al., 2004; Tabachnick et al., 2008).

Self-Efficacy. To evaluate perceived self-efficacy for physics, an adapted version of the Self-efficacy scale of the Science Motivation Questionnaire (SMQ) (Glynn et al., 2009) was applied. The original items from the SMQ referred to "science" in general (e.g., "I believe I can master knowledge and skills in the science course"). In the present study, the items specifically referred to "physics" (e.g., "I believe I can master knowledge and skills in the physics course"). The scale contained four items assessing the perceived capacity for successful learning of the contents of physics, to adequately perform required tasks, and to pass the course (e.g., "I am confident I will do well on the physics tests").

Different authors have made similar adaptations of the SMQ to physics by simply changing the word "science" to "physics." In this way, they obtained the Physics Motivation Questionnaire (PMQ) and applied this instrument to Year 11 students (Abraham & Barker, 2015a, 2015b), and undergraduates enrolled in different physics courses (Taasoobshirazi & Carr, 2009; Taasoobshirazi & Farley, 2013a). On the College of Education website of the University of Georgia (https://coe.uga.edu/outreach/programs/science-motivation), Shawn M. Glynn presents the PMQ and the SMQ-II, an updated version of the SMQ.

Furthermore, in the present study we carried out the CFA to test the structure of this subscale. The indices obtained confirmed that the hypothesized unifactorial structure of the subscale fitted the data well, χ^2/df = 1.93; AGFI = 0.982; CFI = 0.998; RMSEA = 0.043; SRMR = 0.011.

The reliability of this scale in previous research was adequate, with indices ranging from $\alpha = 0.83$ (Bryan, Glynn, & Kittleson, 2011; Glynn et al., 2011) to $\alpha = 0.88$ (Glynn et al., 2009; Taasoobshirazi & Glynn, 2009). This scale was applied to upper secondary school students in the subjects of biology, chemistry, and physics (Zeyer et al., 2013), and was also applied to undergraduates enrolled in science (Glynn et al., 2007, 2011; Taasoobshirazi & Glynn, 2009; Taasoobshirazi & Sinatra, 2011) and non-science degrees (Glynn et al., 2009).

Hope and Anxiety. Hope and anxiety were assessed using two Class-Related Emotion Scales taken from the AEQ of Pekrun et al. (2005). The class-related *Hope* scale consisted of four items (e.g., "I am hopeful that I will make good contributions in physics' class" or "My hopes that I will be successful in physics' class motivate me to invest a lot of effort." The class-related *Anxiety* scale contained four items (e.g., "I am scared that I might say something wrong in physics' class, so I'd rather not say anything" or "Thinking about physics class makes me feel uneasy").

In previous research, the reliability values for these two scales ranged from $\alpha = 0.79$ to $\alpha = 0.84$ for the hope scale, and from $\alpha = 0.86$ to $\alpha = 0.89$ for the anxiety scale (Goetz et al., 2010, 2011; Pekrun et al., 2002, 2011). These subscales of hope and anxiety were applied to high school students (Grade 11) in different subjects such as mathematics and physics (Goetz et al., 2010, 2011).

Metacognitive Strategies. To assess metacognitive strategies in physics problem solving, three scales of Regulation of Cognition, taken from the Physics Metacognitive Inventory (Taasoobshirazi & Farley, 2013b), were applied. The *Planning* scale consisted of five items (e.g., "Before solving a physics problem, I identify all the important parts of the problem" or "Before I start solving a physics problem, I plan how I am going to solve it"). The *Monitoring* scale included four items (e.g., "While solving a physics problem, I ask myself questions about how well I am doing" or "While solving a physics problem, I ask myself if I am meeting my goals"). The *Evaluation* scale contained three items (e.g., "After solving a physics problem, I double check my answer" or "After solving a physics problem, I look back to see if I did the correct procedures").

The reliability indices obtained in previous studies were $\alpha = 0.68$ for planning, $\alpha = 0.78$ for evaluation, and $\alpha = 0.87$ for monitoring (Taasoobshirazi & Farley, 2013b). A recent confirmatory study (Taasoobshirazi et al., 2015) indicated that these subscales are a valid, reliable, and efficient instrument for assessing student metacognition for physics problem-solving. The samples in both studies were introductory-level college students. These three subscales of planning, monitoring, and evaluation were also applied to a sample of high school students (González & Paoloni, 2015b) to assess metacognitive strategies in chemistry problem solving.

The Spanish version of the applied instruments was designed by employing cross-cultural scale translation (Hambleton & Patsula, 1998). The original scales were translated from English into Spanish (forward-translation) by a team of translators and expert lecturers on motivation, emotion, and physics. Using this translated version in Spanish, the scales were translated into English (back-translation). The team of translators and lecturers selected the items that matched the initial meaning as well as writing the instructions and setting the format of the scale, which was identical to the English version. Finally, the Spanish version of the scales was applied to a sub-sample of adolescents in order to previously evaluate the clarity and adequacy of each item.

Academic Performance. As an objective indicator of academic performance in physics in the students' final year score, an aggregate measure of the students' achievement throughout the academic year was used. In the Spanish education system, scores ranged from 1 (*very deficient*) to 10 (*excellent*). The pass mark was a score $\geq$5. The final score was calculated by the physics instructor on the basis of the results of 8–10 written continuous assessment exams, and to a lesser extent, daily homework (mainly problem-solving tasks), participation in classroom activities and laboratory sessions.

Although there is no officially prescribed marking system for the schools which participated in this study, the norm for calculating the final mark is to weight around 80% to the final exam mark and the remaining 20% to homework, participation in classroom activities, and laboratory work. Exams normally involve written assignments on theory and problem-solving. Homework and laboratory activities were assessed together with the written work produced by the students (notebooks, projects, and practical tasks). Thus, while a certain degree of teacher subjectivity in evaluating cannot be disregarded, it was considered to be low as it was based on written documents.

On the other hand, though there is no prescriptive syllabus for all Year 11 physics teachers in Spain, the content and evaluation of the subject are strictly conditioned by a nationwide external exam for gaining access to university. The exams, referred to in Spain as *Selectividad* (selectivity), are taken at the end of Year 12 and include questions on the Year 11 syllabus. Both the *Selectividad* syllabus and the type of exam are similar nationwide. Thus, the contents and evaluation criteria for physics were very similar for all the students in the sample.

The final score on a subject as indicator of academic performance was extensively used in previous research in science teaching (see Britner, 2008; Britner & Pajares, 2006; Cottaar, 2012; Glynn et al., 2007, 2011; Gungor et al., 2007; Sawtelle et al., 2012; Taasoobshirazi & Sinatra, 2011).

Procedure

Data were obtained over a 9-month period: students responded to the instrumentality and self-efficacy scales in October, to the emotional scales in December, and to the metacognitive scales in April. The school secretaries reported the mean final grades in June. Students freely volunteered to participate in the study and completed their paper-and-pencil questionnaires in their classrooms during school time. The total time required to complete all the measures (28 items) was approximately 15 minutes, 5 minutes for each stage in the evaluation. One researcher and the students' tutor were present during data collection, and checked that each questionnaire was completed. Students were informed of the aims of the research and reminded of the importance of providing sincere responses.

All the adolescents voluntarily took part in the study and no incentives were given for their participation. Students were guaranteed strict confidentiality and the questionnaires remained anonymous. In order to match students' responses across all assessment moments, participants were asked to fill in each questionnaire with a randomly assigned individual code instead of their names. Students were never asked to include any information that would possibly identify them and were assured that the results would not impact on their grades.

The study was conducted in accordance with the Deontological Code of the Official College of Psychologists of Spain, and was approved by the University of the first author of the study. Once the schools had been selected, letters were sent to the principals explaining the study and requesting their collaboration. School principals were later contacted by telephone to confirm their participation. If the school principal agreed to participate in the study, the assessment was conducted, otherwise, a new school was selected. A written authorization from parents or legal tutors was also obtained. Parents and teachers were informed about the aims of the study.

Among the 569 students who responded to the first scales in October, 27 failed to attend class in December or April, and 22 others had changed school before the end of the academic year in June; thus, the final sample consisted of questionnaires filled out by 520 students. Significant differences were analyzed between the students who were not present in class during the evaluation and had not completed all of the scales, and the students who had filled out the questionnaires. Comparisons of the 27 learners who had not completed the emotional and metacognitive scales and the 542 students who had filled out all these measures showed no significant differences between groups in motivational variables. In instrumentality, the mean values were $M = 3.41$ (SD = 0.97) and $M = 3.39$ (SD = 0.96) respectively; the means in self-efficacy were $M = 3.41$ (SD = 0.49) and 3.46 (SD = 0.97). A MANOVA showed no statistically significant differences [F (1,567) = 0.76, $p < 0.783$, $\eta^2 = 0.000$]. Moreover, the analysis of emotions and metacognitive strategies showed no significant differences between the 22 adolescents who changed school during the academic year and the 520 students who completed all the questionnaires. The respective means in hope were $M = 3.14$ (SD = 0.78) and $M = 3.20$ (SD = 0.90); $M = 2.15$ (SD = 0.33) and $M = 2.09$ (SD = 0.57) in anxiety; $M = 2.98$ (SD = 0.40) and $M = 2.85$ (SD = 0.61) in planning; $M = 3.50$ (SD = 0.84) and $M = 3.26$ (SD = 1.07) in monitoring; and $M = 3.47$ (SD = 1.11) and $M = 3.42$ (SD = 1.14) in evaluation. A MANOVA showed no statistically significant differences [F (5,536) = 0.501, $p < 0.779$, $\eta^2 = 0.005$].

Outline of Data Analyses and Design

In this study, statistical analysis initially determined the reliability coefficients (Cronbach's alpha), the descriptive statistics, and the correlations between variables using the SPSS 22 statistical package. Confirmatory Factorial Analysis (CFA) of the scales was then undertaken to confirm the fit of the measurement model using AMOS22 software (Arbuckle, 2013). We used the data from this CFA to calculate two other indexes of reliability, the coefficient of composite reliability (CR) and the average variance extracted (AVE) (Hair, Black, Babin, Anderson, & Tatham, 2010). The CR coefficient indicated the internal consistency of the indicators of a latent variable and their value is not based on the number of items composing a factor. A CR ≥ 0.70 was considered to be adequate, and its interpretation is similar to that of the Cronbach's alpha. The AVE indicated the percentage of variance of the factor that had been captured by the construct, compared to the variance of the measurement error. An AVE around 0.50 or higher is considered to be an optimum value. Finally, a series of SEM was performed to contrast the proposed structural model.

In educational sciences, researchers are often interested in studying theoretical constructs (termed latent variables) that are inaccessible by direct measurement (Byrne, 2010). Because of these characteristics, the researchers must link latent variables to one that is observable (observed or manifest variables), thereby making the measurement possible. SEM is a robust statistical data analysis approach applied to the study of complex relationships among latent and manifest variables. The typical research questions that can be answered using SEM are related to how multiple variables interact with one another.

SEM explicitly recognizes that the latent variables are possibly measured by multiple indicators, and commonly consists of two major parts, a measurement model and a structural model. The relationships between both models are defined by the two-step model building approach (Anderson & Gerbing, 1988; Byrne, 2010). This approach emphasizes the analysis of both steps as two conceptually distinct models. In the first step, the measurement model (a CFA) provided information on construct validity by examining the links between observed variables or indicators (i.e., items) and latent variables or factors (i.e., constructs). According to Byrne (2010), only once we know that the measurement model is adequate, can we then trust the findings related to the assessment of a specified model of relations; testing the initially hypothesized (structural) model may not be meaningful unless the measurement model fits the data. If the applied items for a construct do not adequately measure that construct, the specified theory should be modified before the structural relationships are tested (Teo, Tsai, & Yang, 2013). In the second step, we tested if the hypothesized structural model fitted the data. This structural model differed from the measurement model in that the emphasis shifted from the relationships between constructs and their items to the nature and magnitude of the relationships between constructs.

The application of this two-step approach is frequent in science teaching (Brandriet, Ward, & Bertz, 2013; Bryan et al., 2011; Fortus, Adams, Krajcik, & Reiser, 2015; Glynn et al., 2011; Stamovlasis, Tstsipis, & Papageorgiou, 2012; Velayuthan & Aldridge, 2013; Xu, Villafañe, & Lewis, 2013; Zeyer, Bölsterli, Brovelli, & Odermatt, 2012; Zeyer et al., 2013).

In this study, the model fit in both analyses (CFA and SEM) was evaluated by the following indices: the indicator χ^2/df, which is considered to be acceptable when values are below 5; the adjusted goodness of fit index (AGFI) and the Comparative Fit Index (CFI), with adequate values above 0.90, and the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR) with values ranging from 0.08 to 0.05 or less, which are considered to be reasonable (Arbuckle, 2013; Byrne, 2010).

In the SEM, mediation analysis attempts to identify an intermediary process (mediator) that leads from the independent (exogenous, antecedent, or predictor) variable to the dependent (endogenous, outcome, or criterion) variable. In other words, in a simple mediational model, the independent variable is assumed to influence the mediator and, in turn, the mediator influences the dependent variable (Wu & Zumbo, 2008). A direct effect represents the influence of an independent variable on a dependent variable unmediated by another variable in the model. An indirect effect represents the influence of an independent variable on a dependent variable through a mediator. The total effect is the summation of the direct effect plus the indirect effect. As an example for a mediation model, class anxiety (i.e., independent variable) is hypothesized to affect metacognitive strategies (i.e., mediator), and in turn metacognitive strategies affect academic performance (i.e., dependent variable). In educational sciences, frequent questions suggest a similar chain of relations where an antecedent variable affects a mediating variable, which then exerts an influence on an outcome variable.

Mediation may be full (perfect, complete) or partial. A partially mediated relationship occurs when the effect of the mediator accounts for a significant amount of variance in the dependent variable, but the direct effect from the independent to dependent variable remains significant (Little, Card, Bovarird, Preacher, & Crandall, 2007). In a partially mediated relationship, both the direct and the indirect effects are significant. A fully mediated relationship requires the indirect effect to be significant and the direct effect to be not significant. According to Little et al. (2007), full and partial are essentially informal effect size descriptors and, in practice, they might be viewed as an indication of the magnitude or importance of a mediation effect in explaining the total effect, yet they are traditionally defined in terms of statistical significance.

However, as Tomarken and Waller (2005) point out, SEM is not a magical bullet and it cannot compensate for a poorly designed study. Analogously, Wu and Zumbo (2008) believe that the power of research in making causal claims (as occurs in SEM) does depend on how much control a researcher has in the design. In this sense, MacCallum and Austin (2000) and Wu and Zumbo (2008) observed the common use of SEM in cross-sectional designs, whose key feature was the concurrent measurement of the variables. Notwithstanding, these authors warn that the interpretation of the directional influences among variables may be problematic in cross-sectional designs, in line with the view that directional influences require some finite amount of time to operate. Consequently, these authors suggest that SEM analysis should be complemented with a modality of longitudinal design. In a type of longitudinal design, called "sequential design" by MacCallum and Austin (2000), different variables are measured on successive occasions and the SEM model specifies the influences of some variables on a given occasion on other variables on later occasions. This design is adequate when the researcher is interested in the pattern of influences operating over time among different variables. In applications of SEM to sequential designs, directional influences in a model are hypothesized as operating over some time interval, and fitting the model to the observed data yields estimates of such effects (MacCallum & Austin, 2000). Moreover, Wu and Zumbo (2008) recommend a level of design control named "precedence" as a minimum, in which the observation or measurement of the independent variable precedes the observation of the dependent variable in time; this is the lowest level of control required to appropriately make a causal inference, as in SEM.

The variables in the present study were assessed over a 4-month period in order to improve the empirical adequacy of the design. A similar sequential design was applied in recent research in science teaching and learning, with intervals of 6 months (Brandriet et al., 2013; Sha, Schunn, Bathgate, & Ben-Eliyahu, 2016; Xu et al., 2013), 2 years (Robnet, Chemers, & Zurbriggen, 2015), or 3 years (Fortus et al., 2015) for the measurement of independent and dependent variables.

Results

Preliminary Analyses

Table 1 shows the bivariate correlations between variables, descriptive statistics, and reliability coefficients (Cronbach's alpha, CR, and AVE). The mean scores were similar in instrumentality, self-efficacy, hope, monitoring, and evaluation; slightly lower in planning, and very low in anxiety. The mean of anxiety in physics class ($M = 2.09$) was similar to values obtained

Table 1
Bivariate correlations, descriptive statistics, and reliability coefficients

Variable	1	2	3	4	5	6	7	8
1. Instrumentality	-							
2. Self-efficacy	0.42	-						
3. Hope	0.32	0.42	-					
4. Anxiety	−0.39	−0.45	−0.26	-				
5. Planning	0.36	0.39	0.32	−0.30	-			
6. Monitoring	0.46	0.46	0.41	−0.37	0.32	-		
7. Evaluation	0.42	0.49	0.47	−0.41	0.31	0.47	-	
8. Performance	0.42	0.50	0.47	−0.40	0.45	0.52	0.52	-
Mean	3.39	3.45	3.20	2.09	2.86	3.26	3.42	7.25
SD	0.97	0.99	0.80	0.57	0.61	1.07	1.14	1.55
Cronbach's alpha	0.85	0.85	0.79	0.73	0.74	0.88	0.87	-
Composite reliability	0.81	0.80	0.77	0.80	0.92	0.80	0.74	-
Average variance extracted	0.52	0.51	0.50	0.50	0.50	0.50	0.50	-

Note: All correlations were significant ($p < 0.001$). For all variables: $n = 520$.

in previous research where the same scale had been applied. Thus, the means of anxiety in physics obtained by German Year 11 students were $M = 1.90$ (Goetz et al., 2010), between $M = 1.90$ and $M = 1.91$ (Goetz et al., 2011), and $M = 1.67$ (Goetz et al., 2012). Likewise, the mean value of anxiety in mathematics for these students ranged from $M = 1.92$ to $M = 2.03$.

In terms of correlations, all variables were positively correlated, apart from anxiety. As for the reliability indexes, all were within the limits established by Hair et al. (2010). In all cases, the Cronbach's alpha and CR values were higher than the minimum limit (0.70), whereas the percentages for the AVE were adequate, all coming close to the 50% mark.

In order to evaluate gender differences in the measured variables, a MANOVA was performed, showing mean differences by gender were not statistically significant [Wilks' $\Lambda = 0.978$; $F(7,512) = 1.641$; $p < 0.122$; $\eta^2 = 0.022$].

Measurement Model

Due the complexity of the hypothesized relationships between variables, a two-step approach was used to confirm the final model in line with procedures described by Byrne (2010). The first step was to test the measurement model through CFA using the AMOS 22 software (Arbuckle, 2013). The CFA included 7 latent variables and 28 items. All indicators obtained asymmetry and kurtosis indices below |1.96|, confirming the univariate normality assumption (Byrne, 2010). All covariances between latent constructs were statistically significant ($p < 0.01$).

The measurement model with covariances among all constructs fitted the data well, $\chi^2 = 480.3$, df = 329, $p < 0.001$; χ^2/df = 1.46; AGFI = 0.926; CFI = 0.975; RMSEA = 0.030; SRMR = 0.036. The standardized factor loadings (see Table 2) represent the relationships between the indicators and the latent variables. These standardized factor loadings ranged from 0.54 (Plan2) to 0.89 (Eval3), and all were statistically significant ($p < 0.001$).

Structural Model

Thereafter, a SEM was performed to corroborate our initial hypotheses regarding the relationships between variables (Figure 1). The indexes revealed the model fit the data well, $\chi^2 = 504.4$, df = 352, $p < 0.001$; χ^2/df = 1.43; AGFI = 0.923; CFI = 0.977; RMSEA = 0.029;

Table 2
Communalities, standardized factor loadings, skewness, and kurtosis of the items

Variable	Item	Communality	Factor Loading	Skewness	Kurtosis
Instrumentality	Inst1	0.59	0.77	−0.216	−1.03
	Inst2	0.57	0.73	−0.122	−0.900
	Inst3	0.68	0.81	−0.128	−0.851
	Inst4	0.58	0.75	−0.231	−0.989
Self-efficacy	SeEf1	0.50	0.72	−0.206	−0.952
	SeEf2	0.59	0.77	−0.172	−1.091
	SeEf3	0.63	0.78	−0.229	−1.011
	SeEf4	0.66	0.79	−0.249	−1.110
Hope	Hope1	0.50	0.70	0.042	−0.819
	Hope2	0.55	0.75	−0.114	−0.838
	Hope3	0.43	0.70	−0.140	−0.630
	Hope4	0.40	0.62	−0.221	−0.754
Anxiety	Anxi1	0.36	0.62	0.205	−0.565
	Anxi2	0.41	0.61	0.407	−0.045
	Anxi3	0.50	0.69	0.244	−0.302
	Anxi4	0.40	0.61	0.461	−0.157
Planning	Plan1	0.40	0.61	−0.096	−0.973
	Plan2	0.39	0.54	−0.071	−0.840
	Plan3	0.34	0.57	−0.040	−0.931
	Plan4	0.47	0.61	−0.126	−0.939
	Plan5	0.48	0.69	−0.204	−0.952
Monitoring	Moni1	0.61	0.82	−0.155	−0.932
	Moni2	0.61	0.77	−0.223	−0.944
	Moni3	0.79	0.87	−0.157	−1.099
	Moni4	0.59	0.77	−0.182	−0.969
Evaluation	Eval1	0.64	0.80	−0.322	−1.044
	Eval2	0.65	0.81	−0.241	−0.978
	Eval3	0.82	0.89	−0.385	−1.048

SRMR = 0.036. The analysis of the statistically significant direct effects (see Figure 2) showed instrumentality and self-efficacy positively predicted hope, planning, monitoring and evaluation, and negatively predicted anxiety. Hope positively predicted planning, monitoring, evaluation, and performance. Anxiety negatively predicted planning, monitoring, and evaluation. These self-regulatory metacognitive strategies positively predicted performance.

However, several leading authors on the model of self-efficacy have reported the existence of reciprocal relations between self-efficacy and anxiety. Thus, Bandura (1993, p.132) affirmed that "perceived efficacy to exercise control over potentially threatening events plays a central role in anxiety arousal." In describing the sources of self-efficacy, Bandura (1997, p. 106) stated that "in judging their capabilities, people rely partly on somatic information conveyed by physiological and emotional states" such as reactions to stress or anxiety. In synthesizing these views, Mills, Pajares, and Herron (2005, p.279) maintain that "anxiety serves as both a source and effect of self-efficacy beliefs." Similar views have been expressed regarding science teaching; for example, Britner and Pajares (2006, p.487) claim that "the existing degree of self-efficacy ... affects the interpretation of affective states." Moreover, Zeldin et al. (2008, p.1037) state that "powerful emotional arousal, such as anxiety, can effectively alter individuals' beliefs about their capabilities."

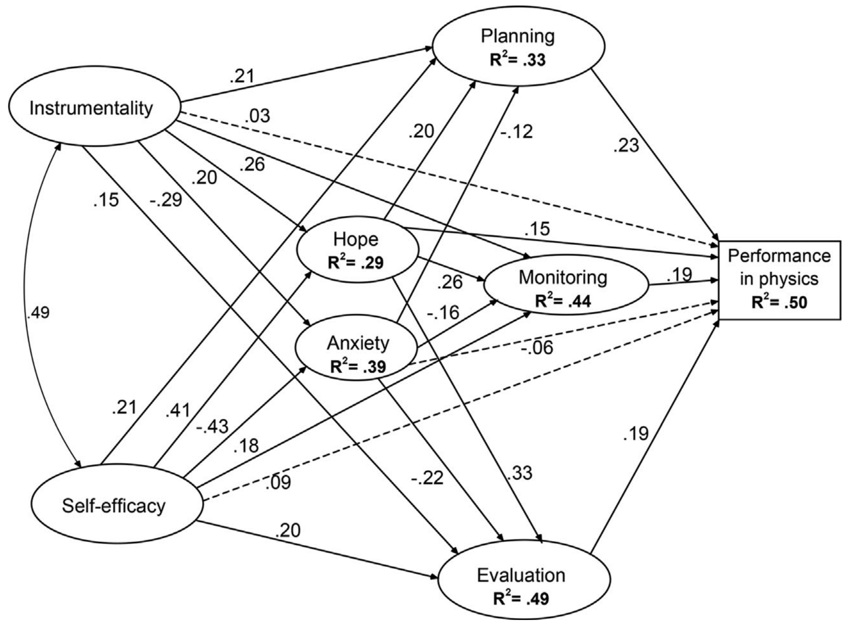

Figure 2. The final structural equation model between motivation, emotion, metacognition, and performance in physics.
Note: Values are standardized parameter estimates. Dashed lines represent non-significant paths ($p > 0.05$). For clarity of presentation, observed indicators were not drawn.

Hence, though the results of the present study corroborated that self-efficacy influenced anxiety, the possibility of emotions influencing motivation cannot be ruled out, in line with the assertions of authors on the model of self-efficacy. This warranted the need for a new analysis of the variables in the following sequence: Emotions → Motivation → Metacognition → Performance. The results indicated that this second model fitted the data well [χ^2/df = 1.56; AGFI = 0.918; CFI = 0.970; RMSEA = 0.033; SRMR = 0.040]. The fit indices of the first model were χ^2/df = 1.43; AGFI = 0.923; CFI = 0.977; RMSEA = 0.029; SRMR = 0.036. These results indicate that (i) the values of the fit indices of both models were within the cut-off criteria ($\geq$0.90 for AGFI and CFI, and $\leq$0.08 for RMSEA and SMR); and (ii) the first model fitted the data better than the second, given that the indices were closer to optimum values in both cases (1.00 for AGFI and CFI, and 0.00 for RMSEA and SMR). According to the hypothesis postulated by Bandura, Pajares and colleagues, class anxiety significantly and negatively predicted self-efficacy. The inverse results were found for class-related hope.

It is worth noting, however, that to ensure an adequate evaluation of reciprocal relations between variables, the most appropriate design is longitudinal as each variable is evaluated at several intervals over a specified period of time (see Fortus et al. (2015) and Robnet et al. (2015) for examples of this longitudinal design in science teaching).

Finally, the last stage of data analyses was to establish the partial or total mediation between variables. The AMOS 22 software computes an estimation of indirect effect, and significance of a specific effect that can then be tested by bootstrapping confidence interval based on randomly selected samples (Preacher & Hayes, 2008). The key principle underlining the bootstrapping procedure is that it enables the researcher to simulate repeated subsamples from an original database, allowing the assessment of the stability of parameter estimates and reporting their values with a greater degree of accuracy. Bootstrapping estimates the indirect effect in each resampled data set and establishes a confidence interval for a specific indirect effect (Byrne, 2010; Preacher & Hayes, 2008). The data obtained in the previous step (Figure 2) revealed that the direct effects that linked instrumentality and self-efficacy to performance were not statistically significant. In addition, the direct path form anxiety to performance was also non-significant. The remaining paths of the model were statistically significant. This indicated there was a partial mediation between some variables (these appear at the top of Table 3) and a total mediation between other variables (these appear at the bottom of Table 3).

Table 3
Effects on planning, monitoring, evaluation, and performance

		Indirect Effect		
Predictor → Criterion	Total Effect[a]	Sum (p)[b]	CI[c]	Direct effect (p)
Partial mediation				
Instrumentality → planning	0.283	0.074 (0.020)	0.014, 0.157	0.210 (0.01)
Instrumentality → monitoring	0.360	0.096 (0.002)	0.037, 0.173	0.264 (0.01)
Instrumentality → evaluation	0.278	0.131 (0.002)	0.075, 0.209	0.147 (0.01)
Self-efficacy → planning	0.339	0.133 (0.021)	0.033, 0.220	0.206 (0.01)
Self-efficacy → monitoring	0.353	0.172 (0.002)	0.102, 0.304	0.181 (0.01)
Self-efficacy → evaluation	0.434	0.233 (0.002)	0.160, 0.351	0.200 (0.01)
Hope → performance	0.309	0.159 (0.003)	0.099, 0.235	0.149 (0.01)
Total mediation				
Instrumentality → performance	0.267	0.234 (0.003)	0.165, 0.333	0.032 (0.58)
Self-efficacy → performance	0.405	0.315 (0.003)	0.243, 0.406	0.091 (0.11)
Anxiety → performance	−0.156	−0.100 (0.002)	−0.179, −0.040	−0.056 (0.20)

[a]All the total effects were significant ($p < 0.001$).
[b]The probability associated with the sum of standardized indirect effects was estimated using the two-sided bias-corrected confidence interval bootstrap test of AMOS 22 (confidence level = 95%; samples = 5,000).
[c]CI = confidence interval.

With regards to partial mediation, the effects from instrumentality and self-efficacy to planning, monitoring, and evaluation were mediated by hope and anxiety. Moreover, planning, monitoring, and evaluation mediated the relationships between hope and performance (see top of Table 3).

As for total mediation, hope, anxiety, planning, monitoring, and evaluation mediated the intense effects of instrumentality and self-efficacy on performance. Finally, planning, monitoring, and evaluation mediated the negative association between anxiety and performance. In all three cases, the direct effects were not statistically significant (see bottom of Table 3).

Discussion

In the last 2 years of secondary education (Years 11 and 12), many students have to enroll in compulsory science subjects which they feel may overstretch their abilities (the subjects are considered to be very difficult) and the purpose or utility of which may not be immediately apparent. The control-value theory of achievement emotions (Pekrun & Linnenbrink-García, 2012; Pekrun & Perry, 2014) posits that this combination of low perceived self-efficacy and instrumentality may generate high levels of anxiety in students and reduce hope. Furthermore, according to Pekrun and colleagues, these motivational and emotional states determine students' engagement and performance.

Grounded in this theoretical context, the results from the present study corroborated and extend existing work providing a richer understanding of some antecedents (perceived instrumentality and self-efficacy) and outcomes (metacognitive strategies and performance) of hope and anxiety in physics class in the first year of the Scientific-technological Baccalaureate (Year 11). The first step was to assess the adequacy of the evaluation instruments applied for measuring these variables in physics, and they have shown to be satisfactory in terms of reliability and validity.

The current study provides three main contributions to research in science teaching and learning, i.e., the analysis of key theoretical, empirical, and applied issues.

To begin with a theoretical perspective, this study assessed several highly relevant constructs in a science subject within the context of education. As mentioned in the introduction, self-efficacy, instrumentality, hope, anxiety, and metacognitive strategies are all variables extensively evaluated in the academic context. However, these constructs have scarcely been assessed in science teaching and education, and even fewer studies have analyzed how they are related to academic performance. In order to assess the role of these variables, a theoretical model was designed though this has rarely been applied in research on science subjects; that is, the model proposed by the control-value theory of achievement emotions (Pekrun & Linnenbrink-García, 2012; Pekrun & Perry, 2014), which coincides in many aspects with Bandura's model (Bandura, 1997) in term of the interrelations between self-efficacy, anxiety, engagement, and performance. Both models hypothesized that academic emotions are influenced by motivational variables, and determine the levels of engagement and performance. This model has been verified in a wide range of subjects and at different levels of education. The present study is the first to test this model in a science subject using SEM analysis, a procedure that offers several advantages over correlational and regression procedures. SEM allows for the analysis of statistically non-normal data, enables theoretical knowledge to be introduced into model specification, can test multiple dependent and independent variables simultaneously, and takes into account the role of mediating variables and not just the direct influence of one variable on another (Byrne, 2010; Tomarken & Waller, 2005).

Secondly, from an empirical point of view, the present study confirmed previous results obtained from studies on non-science courses in relation to anxiety, self-efficacy, and academic performance. Moreover, the findings of the present work advance our understanding of the subject of physics by unveiling new direct and mediated relationships between instrumentality, self-efficacy, hope, anxiety, planning, monitoring, evaluation, and performance. Both of these issues are dealt with in the two following sections on confirmation of previous research and new contributions.

Thirdly, from an applied perspective for science teaching, the results of this study underscore the need for implementing an array of classroom interventions, given that all the measured variables were to a large extent under the influence of the science teachers themselves. Having substantiated the key role of hope and anxiety in science teaching and learning, interventions designed to nurture hope and reduce anxiety in class are suggested as a way of working on these emotions and their predictors directly. These interventions are discussed in the section on implications for science teaching.

Confirmation of Previous Research

As hypothesized, students who experienced most anxiety in the physics class obtained lower academic performance levels overall. In comparison, students with more hope in obtaining good results in physics performed better. These results are in line with the findings of previous studies

(Ciarrochi et al., 2007; Day et al., 2010; Goetz et al., 2012; Pekrun et al., 2002, 2011; Valle et al., 2006; Zeidner, 2014), which reported significant effects of these emotions on performance in different subjects.

As for motivational predictors of emotions, students with higher self-efficacy experienced more hope and less anxiety in physics class, and achieved higher performance levels in physics at the end of the academic year. Furthermore, students who were most aware of the relation between learning physics and their future academic and career goals performed better. Moreover, a statistically significant correlation was found between self-efficacy and instrumentality: students who thought they were capable of passing their physics exams also thought it was relevant for fulfilling their future personal aspirations. These results corroborated the findings of many previous studies, primarily in fields other than science teaching and learning (Bandura, 2006; Britner, 2008; Greene et al., 2004; Malka & Covington, 2005; Pekrun et al., 2002, 2011; Sawtelle et al., 2012; Walker & Greene, 2009; Zusho et al., 2003).

New Contributions

With regard to the direct relationships between variables, this study found that the most hopeful and less anxious students used planning strategies more frequently prior to beginning the problem-solving process, supervised strategies during the process, and carried out a final evaluation of the process. As for the predictors of emotions, those students who were most aware of the relation between the subject of physics and their personal goals experienced less anxiety in class, were more hopeful in achieving good marks, and used more metacognitive problem-solving strategies. The most efficacious students also used these strategies more frequently. Finally, the regular application of all these strategies anticipated a better performance.

However, the main contribution of this study is related to the results on mediated relations between variables obtained by SEM. First, hope and anxiety partially mediated the association of both instrumentality and self-efficacy with planning, monitoring, and evaluation. Students with higher levels of perceived instrumentality and self-efficacy planned, monitored, and evaluated the problem-solving process to a greater degree, partly due to the fact that they experienced higher levels of hope and lower levels of anxiety in the physics classroom.

Secondly, some of the intense effects of hope and anxiety on performance were mediated by metacognitive strategies. The most hopeful students obtained higher grades in physics in part because they used more planning, monitoring, and evaluation strategies during problem-solving in physics. In contrast, the most anxious students achieved lower performance ratings in physics because they used fewer self-regulatory strategies. These results supported the previsions of Zeidner (2014) who observed that high anxious students devoted a considerable amount of their cognitive and attentional resources to self-regulate intrusive thoughts and worries rather than to process the demands of academic tasks, resulting in underperformance.

Thirdly, hope, anxiety, and metacognitive strategies fully mediated the positive effects from instrumentality and self-efficacy on performance ($\beta = 0.267$ and $\beta = 0.405$, respectively): the most hopeful and efficacious adolescents obtained better grades because they were less anxious and exhibited higher levels of hope and metacognitive strategies, three personal characteristics that considerably enhanced academic achievement. Furthermore, the results substantiate an alternative model where hope and anxiety predicted the motivational variables of self-efficacy and instrumentality. In this case, the most anxious students were less efficacious and considered the subject of physics to be of little use for their future goals; the most hopeful students were confident they were capable of passing their exams, and believed physics would be useful for meeting their goals.

In short, the results of this study revealed that hope and anxiety were associated with opposing characteristics in students, both in terms of motivational predictors and outcomes. As for predictors of both emotions, perceived instrumentality and self-efficacy positively predicted hope, and negatively predicted anxiety. With regard to the outcomes of these emotions, metacognitive self-regulatory strategies and academic performance were positively predicted by hope and negatively predicted by anxiety.

Implications for Science Teaching

Identifying the variables that predict the emotions experienced in an activity, the levels of engagement in carrying it out, and performance in achieving the outcome is a major challenge for teachers in order to guide decisions about which interventions could be effective in improving student achievement (Chow et al., 2012). All of these interventions are grounded on the assertion of Adler et al. (2016), Bøe and Henriksen (2013), Hazari, Cass, and Beattie (2015), and Zepeda et al. (2015) that it is feasible to improve students' motivation, emotions, metacognition, and engagement via classroom instruction.

The present study has corroborated the positive results associated to class-related hope, and the negative results derived from anxiety in the physics class. The findings of this study have several practical implications for the teaching of science subjects, and an array of classroom interventions has been carried out to promote positive emotions and to diminish negative ones, to enhance their predictors (i.e., perceived instrumentality and self-efficacy), and to provide training in metacognitive strategies in order to reduce anxiety and raise hope.

As class-related hope was found to be a powerful predictor of the use of metacognitive strategies and performance in physics, the following instructional strategies for enhancing students' class hope, which are in line with the recommendations of Snyder et al. (2002) and Snyder (2005), are worth mentioning: spend time interacting with students and care about them; strive to help students to set clear and reasonably challenging learning goals; set up step-by-step sequences so that the information unfolds in a clear and comprehensible manner; establish an atmosphere where students can feel free to say that they do not understand something; encourage students in the pursuit of their academic goals; and reward students for efforts expended at learning how to learn, along with acquiring the necessary information so as to become effective problem solvers.

In contrast, high levels of anxiety predicted low metacognitive strategies and performance. Several authors (Chiang & Liu, 2014; Kim & Hodges, 2012) claim teachers can promote positive emotions in classrooms and prevent the negative ones (such as anxiety) by means of different teaching strategies: attributing the students' failures to controllable factors such as effort or learning strategies; taking their students' psychological characteristics into consideration when designing appropriate plans; and using multimedia to reduce the occurrence of negative emotions. Other interventions aim to alleviate the symptoms of anxiety by reducing higher levels of activation or by modifying the way they are perceived by the subject; furthermore, relaxation is a technique used to deal with anxiogenic situations (see Zeidner, 2014).

In the present study, the results showed that students who had to attend classes and study a subject that (in their opinion) was very difficult and of no usefulness to them, led to experiencing anxiety. However, the opposite response prevailed when students were aware that their grades and the contents of a subject would be crucial for achieving their own personal goals. In a similar context, Hulleman, Godes, Hendricks, and Harackiewicz (2010) carried out an intervention primarily aimed at encouraging students to discover the relevance and usefulness of what they were learning (a new method of mathematical problem-solving); this intervention enhanced students personal interest and enjoyment with this task. Analogously, Jang (2008) provided students "a rationale," a verbal explanation as to why putting effort during an uninteresting and difficult activity (a lesson of statistics for pre-service teachers) was a useful and worthwhile thing to do; this rationale enhanced students' perceived importance, effort, and persistence on the task. An intervention undertaken with parents of adolescents by Rozek et al. (2015) also focused on the usefulness of science for students, exploring potential connections between science and current and future goals of adolescents. All these interventions, and similar ones, aim to enhance the students' "motivation to learn," as defined by Brophy (2009) as engaging purposefully in curricular activities by adopting their goals and thus trying to learn the concepts or master the skills that they were designed to develop. Students who are motivated to learn will not necessarily find learning activities interesting, pleasurable or exciting, but they will find them meaningful and worthwhile. In this same line, Malka and Covington (2005) recommend persuading students that academic success will critically contribute to attain valued personal goals, especially to socioeconomically disadvantaged students and minorities.

Self-efficacy is affected especially by vicarious learning and modeling, and peer models are usually the most effective because they are most similar to the learner (Bandura, 2006). Indeed, students are more likely to increase their own self-efficacy when observing a model of similar ability level performing the skill (Schraw et al., 2006; Schunk & Meece, 2006). Moreover, instructors can help students maintain and increase self-efficacy by communicating the role of effort to attain learning, and the applications of science in daily life issues; by modeling specific strategies or ways of thinking for learning science in class (Zusho et al., 2003); and by training students in self-regulatory processes (Cleary & Zimmerman, 2012).

According to several authors in the field of academics, a "reciprocal causation" (Pekrun & Linnenbrink-García, 2012) or a "cyclical interaction" (Zimmerman, 2011) occurs between emotions, motivation, and engagement. Thus, Pekrun and Perry (2014) or Zeidner (2014) contend that academic anxiety arises when students believe their skills (e.g., metacognitive strategies) may be overwhelmed by the demands of an academic task (e.g., problem-solving); but when students consider these skills and strategies enable them to overcome learning tasks, hope arises. Likewise, Cleary and Zimmerman (2012) have underscored that metacognitive strategies can minimize the experience of academic anxiety and foster the appearance of academic hope. Hence, Thomas (2013) and Zohar and Barzilai (2013) identified approaches for infusing metacognition in instructional practices within and across all science subject areas: repeated explicit training and practice for activating and applying metacognition in multiple problems and contexts; explications and discussions in which teachers talked with their students about metacognitive thinking and learning; and modelling in which the teacher demonstrates how he/she activates and applies metacognitive strategies in the course of learning and problem-solving. Likewise, Yuruk et al. (2009) and Zohar and Barzilai (2013) recognize that metacognition is almost invisible to science teachers, which highlights the need for pre- and in-service teacher training in the knowledge and practice of metacognition as the only means of encouraging teachers to use self-regulatory strategies in the classroom.

Limitations and Future Research

Although this study was carefully designed and undertaken, some findings should be interpreted with caution given their limitations, which may offer a number of additional avenues for further research.

In terms of measures, the present work only evaluated perceived instrumentality to assess the value of physics. Future research could focus on the role of other close constructs such as importance or usefulness (Abraham & Barker, 2015b; Eccles & Wigfield, 2002). In addition, this study only assessed a modality of cognitive engagement, metacognitive self-regulatory strategies.

Future research may shed light on other modalities of engagement (emotional and behavioral) or at the very opposite end to engagement i.e., disaffection (Skinner & Pitzer, 2012).

The emotional scales administered in this study have been extensively validated and applied for measuring academic emotions (Goetz et al., 2010, 2011, 2012; Pekrun & Bühner, 2014; Pekrun et al., 2002, 2005, 2011). Notwithstanding, these and other authors have pointed out that students' academic emotions are complex and dynamic phenomena that are difficult to evaluate. Thus, besides questionnaires, other instruments have been employed to evaluate academic emotions such as multiple observational approaches (Reisenzein, Junge, Studtmann, & Huber, 2014), different tools employed in the neurosciences (Immordino-Yang & Christodoulou, 2014), and measures of autonomic nervous system activity (Kreibig & Gendolla, 2014). Likewise, in the context of science teaching, Bellocchi and Ritchie (2015), and Tomas, Rigano, and Ritchie (2016) have proposed a "multimethod paradigm" for assessing academic emotions by applying alternative procedures to scales such as direct observation and the analysis of interviews, diaries, video, and audio. A further line of research would be to contrast the results of studies using these alternative instruments with the data obtained from questionnaires.

The present study analyzed two predictors of hope and anxiety, i.e., self-efficacy and instrumentality. Future research may examine other antecedents of academic emotions related to control appraisals, such as self-concept or perceived control, and to value beliefs such as utility value or attainment value (Pekrun & Perry, 2014). Furthermore, the construct of the positive emotion of hope is conceptually aligned to self-efficacy, and certain items on the scales used for evaluating them in this study were similar. Further research could seek to explore the relationships between self-efficacy and other positive academic emotions, such as enjoyment and pride (Pekrun et al., 2011).

The physics performance measure in this study was based on the final grade obtained by students at the end of the course, which was in line with other recent studies in science teaching and learning (see Britner, 2008; Britner & Pajares, 2006; Chow et al., 2012; Cottaar, 2012; DeBacker & Nelson, 1999; Goetz et al., 2010, 2012; Glynn et al., 2007, 2011; Gungor et al., 2007; Rozek et al., 2015; Sawtelle et al., 2012; Taasoobshirazi & Sinatra, 2011; Zusho et al., 2003). Thus, the physics performance measure consisted of the final grade awarded by physics teachers. The fact that the testing conditions and the tests themselves varied should be kept in mind, as well as the influence of these factors on the results obtained in this study, and the extrapolation of the data. Further research is required to assess this measure of performance in comparison to other previously used measures such as identical questionnaires for all students (Sha et al., 2016; Taasoobshirazi & Carr, 2009), a blended examination from an external institution (Jack, Lin, & Yore, 2014; Xu et al., 2013), or a national normed assessment (Brandriet et al., 2013; González & Paoloni, 2015a).

In terms of design, this work assessed the relationships among measured variables throughout an entire academic year applying a sequential design (MacCallum & Austin, 2000). Our findings would be enriched by analyzing the reciprocal relationships between motivation, emotion, engagement, and performance along several academic years by applying a longitudinal design, in line with Ciarrochi et al. (2007) and Robnet et al. (2015). This design would allow us to explore what Skinner and Pitzer (2012) referred to as "cycles of engagement and disaffection."

Finally, this study analyzed quantitative data, but research needs to be complemented with qualitative studies (e.g., Hazari et al., 2015; Hong, 2010; Kapon, 2016; Nieswandt & Shanahan, 2008), in order to understand the detailed and subtle reasons that drive students to engage in academic tasks.

References

Abraham, J., & Barker, K. (2015a). An expectancy-value model for sustaining enrolment intentions of senior secondary physics students. Research in Science Education, 45(4), 509–526.

Abraham, J., & Barker, K. (2015b). Exploring gender differences in motivation, engagement, and enrolment behavior of senior secondary physics students in New South Wales. Research in Science Education, 45, 59–73.

Adler, I., Zion, M., & Meravech, Z. R. (2016). The effect of explicit environmentally oriented metacognitive guidance and peer collaboration on students' expressions of environmental literacy. Journal of Research in Science Teaching, 53(4), 620–663.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. Psychological Bulletin, 103(3), 411–423.

Arbuckle, J. (2013). AMOS 22. User's guide. Chicago, IL: SmallWaters Corporation.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. Educational Psychologist, 28(3), 117–148.

Bandura, A. (1997). Self-efficacy. The exercise of control. New York: Freeman.

Bandura, A. (2006). Adolescent development from an agentic perspective. In F. Pajares & T. Urdan (Eds.), Self-efficacy beliefs of adolescents (pp. 1–43). Greenwich, CT: Information Age.

Bellocchi, A., & Ritchie, S. M. (2015). "I was proud of myself that I didn't give up and I did it": Experiences of pride and triumph in learning science. Science Education, 99(4), 638–668.

Bøe, M. V., & Henriksen, E. K. (2013). Love it or leave it: Norwegian students' motivation and expectations for post compulsory physics. Science Education, 97(4), 550–573.

Brandriet, A., Ward, R. M., & Bretz, S. L. (2013). Modeling meaningful learning chemistry using structural equation modeling. Chemistry Educational Research and Practice, 14, 421–430.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physics, and earth science classes. Journal of Research in Science Teaching, 45, 955–970.

Britner, S. L., & Pajares, F. (2006). Sources of self-efficacy beliefs of middle school students. Journal of Research in Science Teaching, 43, 485–499.

Brophy, J. (2009). Developing students' appreciation for what is taught in school. Educational Psychologist, 43(3), 132–141.

Bryan, R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent in high school students learning science. Science Education, 95, 1049–1065.

Byrne, B. (2010). Structural equation modeling with AMOS. Basic concepts, applications, and programming. New York: Routledge.

CEE (Consejo Escolar del Estado). (2015). Informe 2015 sobre el estado del sistema educativo [Report 2015 about the state of the educational system]. Madrid: Ministerio de Educación.

Chiang, W., & Liu, C. (2014). Scale of academic emotions in science education: Development and evaluation. International Journal of Science Education, 36, 908–928.

Chow, A., Eccles, J., & Salmela-Aro, K. (2012). Task-value profiles across subjects and aspirations to physical and IT-related sciences in the United States and Finland. Developmental Psychology, 48, 1612–1628.

Ciarrochi, J., Heaven, P., & Davies, F. (2007). The impact of hope, self-esteem, and attributional style on adolescents' school grades and emotional well-being: A longitudinal study. Journal of Research in Personality, 41, 1161–1178.

Cleary, T., & Zimmerman, B. J. (2012). A cyclical self-regulatory account of student engagement: Theoretical foundations and applications. In S. Chistenson, A. Reschly, & C. Wylie (Eds.), Handbook of research on student engagement (pp. 237–257). New York: Springer.

Cottaar, A. (2012). Low (linear) teacher effect on student achievement in pre-academic physics education. Journal of Research in Science Teaching, 49, 465–488.

Day, L., Hanson, K., Maltby, J., Proctor, C., & Wood, A. (2010). Hope uniquely predicts objective academic achievement above intelligence, personality, and previous academic achievement. Journal of Research in Personality, 44, 550–553.

Davidson, J., & Sternberg, R. J. (1998). Smart problem solving: How metacognition helps. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), Metacognition in educational theory and practice (pp. 47–68). London: LEA.

DeBacker, T. K., & Nelson, R. M. (1999). Variations on an expectancy-value model of motivation in science. Contemporary Educational Psychology, 24, 71–94.

Eccles, J., & Wigfield, A. (2002). Motivational beliefs, values, and goals. Annual Review of Psychology, 53, 109–132.

Feldman, D., & Kubota, M. (2015). Hope, self-efficacy, optimism, and academic achievement: Distinguishing constructs and levels of specificity in predicting college grade-point average. Learning and Individual Differences, 37, 210–216.

Fortus, D. (2014). Attending to affect. Journal of Research on Science Teaching, 51, 821–835.

Fortus, D., Adams, L., Krajcik, J., & Reiser, B. (2015). Assessing the role of curriculum coherence in student learning about energy. Journal of Research on Science Teaching, 52, 1408–1425.

Glynn, S., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science Motivation Questionnaire II: Validation with science majors and nonscience mayors. Journal of Research on Science Teaching, 48, 1159–1176.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. Journal of Research in Science Teaching, 44, 1088–1097.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2009). Science Motivation Questionnaire: Construct validation with nonscience majors. Journal of Research in Science Teaching, 46, 127–146.

Goetz, T., Cronjaeger, H., Frenzel, A. C., Lüdtke, O., & Hall, N. C. (2010). Academic self-concept and emotions relations: Domain specificity and age effects. Contemporary Educational Psychology, 35, 44–58.

Goetz, T., Frenzel, A., Lüdtke, O., & Hall, N. (2011). Between-domain relations of academic emotions: Does having the same instructor make difference? Journal of Experimental Education, 79, 84–101.

Goetz, T., Nett, U., Martiny, S., Hall, N., Pekrun, R., et al. (2012). Students' emotions during homework: Structures, self-concept antecedents, and achievement outcomes. Learning and Individual Differences, 22, 225–234.

González, A., & Paoloni, P. V. (2015a). Engagement and performance in physics: The role of class instructional strategies, and student's personal and situational interest. Journal of Psychodidactics, 20(1), 25–45.

González, A., & Paoloni, V. (2015b). Perceived autonomy support, expectancy, value, metacognitive strategies and performance in chemistry: A structural equation model in undergraduates. Chemistry Education Research and Practice, 16, 640–653.

Greene, B., Miller, R., Crowson, M., Duke, B., & Akey, K. (2004). Predicting high school students' cognitive engagement and achievement: Contributions of classroom perceptions and motivation. Contemporary Educational Psychology, 29, 462–482.

Gungor, A. A., Eryilmaz, A., & Fakioglu, T. (2007). The relationship of freshmen's physics achievement and their related affective characteristics. Journal of Research on Science Teaching, 44, 1036–1056.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). Multivariate data analysis. New Jersey: Pearson.

Hambleton, R., & Patsula, L. (1998). Adapting tests for use in multiple languages and cultures. Social Indicators Research, 45, 153–171.

Hazari, Z., Cass, C., & Beattie, C. (2015). Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development. Journal of Research in Science Teaching, 52(6), 735–762.

Hong, Z. (2010). Effects of a collaborative science intervention on high achieving students' learning anxiety and attitudes toward science. International Journal of Science Education, 32, 1971–1988.

Hulleman, C., Godes, O., Hendricks, B., & Harackiewicz, J. (2010). Enhancing interest and performance with a utility value intervention. Journal of Educational Psychology, 102, 880–895.

Husman, J., Derryberry, W., Crowson, H., & Lomax, R. (2004). Instrumentality, task value, and intrinsic motivation: Making sense of their independent interdependence. Contemporary Educational Psychology, 29, 63–76.

Husman, J., & Lens, W. (1999). The role of the future in student motivation. Educational Psychologist, 34, 113–125.

IFIIE. (2013). Informe del sistema educativo español. 2013. [Report about the Spanish educational system. 2013]. Madrid: Ministerio de Educación.

Immordino-Yang, M. H., & Christodoulou, J. A. (2014). Neuroscientific contributions to understanding and measuring emotions in educational contexts. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 607–624). New York: Routledge.

INEE (Instituto Nacional de Evaluación Educativa). (2015). Panorama de la educación. Indicadores de la OCDE. Informe español. [Education at a glance. OECD indicators. Spanish report]. Madrid: Ministerio de Educación.

Jack, B. M., Lin, H., & Yore, L. D. (2014). The synergistic effect of affective factors on student learning outcomes. Journal of Research in Science Teaching, 51(8), 1084–1101.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. Journal of Educational Psychology, 100, 798–811.

Kapon, S. (2016). Doing research in school: Physics inquiry in the zone of proximal development. Journal of Research in Science Teaching, 53(8), 1172–1197.

Kim, C., & Hodges, C. (2012). Effects of an emotion control treatment on academic emotions, motivation, and achievement in an online mathematics course. Instructional Science, 40, 173–192.

Kreibig, S. D., & Gendolla, G. H. E. (2014). Autonomic nervous system measurement of emotion in education and achievement settings. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 625–642). New York: Routledge.

Kuo, E., Hull, M., Gupta, A, & Elby, A. (2013). How students blend conceptual and formal mathematical reasoning in solving physics problems. Science Education, 97(1), 32–57.

Laukenmann, M., Bleicher, M., Fuss, S., Gläser-Zakuda, M., Mayrin, P., & von Mayrin, C. (2003). An investigation of the influence of emotional factors on learning in physics instruction. International Journal of Science Teaching, 25(4), 489–507.

Little, T., Card, N., Bovaird, J., Preacher, K., & Crandall, C. (2007). Structural equation modeling of mediation and moderation with contextual factors. In T. Little, J. Bovaird, & N. Card, (Eds.), Modeling contextual effects in longitudinal studies (pp. 207–230). New Jersey: LEA.

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. Annual Review of Psychology, 51, 201–226.

Malka, A., & Covington, M. (2005). Perceiving school performance as instrumental to future goal attainment: Effects on grades performance. Contemporary Educational Psychology, 30, 60–80.

Mallow, J. V. (2006). Science anxiety: Research and action. In J. J. Mintzes & W. H. Leonard (Eds.), Handbook of college science teaching (pp. 3–14). Arlington, VA: NSTA Press.

Mallow, J. V., Kastrup, H., Bryant, F. B., Hislop, N., Shefner, R., & Udo, M. (2010). Science anxiety, science attitudes, and gender: Interviews from a binational study. Journal of Science Education and Technology, 19, 356–369.

Mills, N., Pajares, F., & Herron, C. (2005). A reevaluation of the role of anxiety: Self-efficacy, anxiety, and their relation to reading and listening proficiency. Foreign Language Annals, 39(3), 276–295.

Mualen, R., & Eylon, B. S. (2010). Junior high school physics: Using a qualitative strategy for successful problem solving. Journal of Research in Science Teaching, 47, 1094–1115.

Nieswandt, M., & Shanahan, M. (2008). "I just want the credit"- perceived instrumentality as the main characteristic of boys' motivation in a grade 11 science course. Research in Science Education, 38, 3–29.

Oon, P., & Subramaniam, R. (2011). On the declining interest in physics among students-from the perspective of teachers. International Journal of Science Education, 33(5), 727–746.

Pekrun, R., & Bühner, M. (2014). Self-report measures of academic emotions. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 561–579). New York: Routledge.

Pekrun, R., Goetz, T., Frenzel, A., Barchfeld, P., & Perry, R. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). Contemporary Educational Psychology, 36, 36–48.

Pekrun, R., Goetz, T., & Perry, R. (2005). Achievement Emotions Questionnaire (AEQ)–user's manual. University of Munich: Department of Psychology.

Pekrun, R., Goetz, T., Titz, W., & Perry, R. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. Educational Psychologist, 37 (2), 91–105.

Pekrun, R., & Linnenbrink-García, L. (2012). Academic emotions and student engagement. In S. Christenson, A. Reschly, & C. Wylie (Eds.), Handbook of research on student engagement (pp. 259–282). New York: Springer.

Pekrun, R., & Perry, R. (2014). Control-value theory of achievement emotions. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 120–141). New York: Routledge.

Potvin, P., & Hasni, A. (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, 85–129.

Preacher, K. P., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods, 40(3), 879–891.

Reisenzein, R., Junge, M., Studtmann, M., & Huber, O. (2014). Observational approaches to the measurement of emotions. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 580–606). New York: Routledge.

Robnet, R., Chemers, M., & Zurbriggen, E. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. Journal of Research in Science Teaching, 52, 847–867.

Rozek, C. S., Hyde, J. S., Svoboda, R. C., Hulleman, C. S., & Harackiewicz, J. M. (2015). Gender differences in the effects of a utility value intervention to help parents to motivate adolescents in mathematics and science. Journal of Educational Psychology, 107(1), 195–206.

Sawtelle, V., Brewe, E., & Kramer, L. (2012). Exploring the relationship between self-efficacy and retention in introductory physics. Journal of Research on Science Teaching, 49, 1096–1112.

Schneider, B., Krajcik, J., Lavonen, J., Salmela-Aro, K., Broda, M., Spiecer, J., et al. (2016). Investigating optimal learning moments in U.S. and Finish science classes. Journal of Research in Science Teaching, 53(3), 400–421.

Schraw, G., Crippen, K., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Research in Science Education, 36, 111–139.

Schunk, D. H., & Meece, J. L. (2006). Self-efficacy development in adolescence. In F. Pajares & T. Urdan (Eds.), Self-efficacy beliefs of adolescents (pp.71–96). Greenwich, CT: Information Age.

Sha, L., Schunn, C., Bathgate, M., & Ben-Eliyahu, A. (2016). Families support their children's success in science learning by influencing interest and self-efficacy. Journal of Research in Science Teaching, 53(3), 450–472.

Simons, J., Dewitte, S., & Lens, W. (2004). The role of different types of instrumentality in motivation, study strategies, and performance: Know why you learn, so you'll know what you learn! British Journal of Educational Psychology, 74, 343–360.

Simpkins, S. D., Price, C. D., & García, K. (2015). Parental support and high-school students' motivation in biology, chemistry, and physics: Understanding differences among Latino and Caucasian boys and girls. Journal of Research in Science Teaching, 52(10), 1386–1407.

Sinatra, G., Broughton, S., & Lombardi, D. (2014). Emotions in science education. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 415–436). New York: Routledge.

Sinatra, G., & Taasoobshirazi, G. (2011). Intentional conceptual change: The self-regulation of science learning. In B. J. Zimmeraman & D. H. Schunk (Eds.), Handbook of self-regulation of learning and performance (pp. 203–216). London: Routledge.

Skinner, E., & Pitzer, J. (2012). Developmental dynamics of student engagement, coping, and everyday resilience. In S. Christenson, A. Reschly, & C. Wylie (Eds.), Handbook of research on student engagement (pp. 21–44). New York: Springer.

Snyder, C. R. (2005). Teaching: The lessons of hope. Journal of Social and Clinical Psychology, 24, 72–84.

Snyder, C., Shorey, H., Cheavens, J., Pulvers, K., Adams, V., & Wiklund, C. (2002). Hope and academic success in college. Journal of Educational Psychology, 94, 820–826.

Stamovlasis, D., Tstsipis, G., & Papageorgiou, G. (2012). Structural equation modeling in assessing students' understanding of the state changes of matter. Chemistry Education Research and Practice, 13, 357–368.

Taasoobshirazi, G., Bailey, M., & Farley, J. (2015). Physics Metacognition Inventory, part II: Confirmatory factor analysis and Rasch analysis. International Journal of Science Education, 37, 2769–2786.

Taasoobshirazi, G., & Carr, M. (2009). A structural equation model of expertise in college physics. Journal of Educational Psychology, 101(3), 630–643.

Taasoobshirazi, G., & Farley, J. (2013a). A multivariate model of physics problem solving. Learning and Individual Differences, 24, 53–62.

Taasoobshirazi, G., & Farley, J. (2013b). Construct validation of the Physics Metacognition Inventory. International Journal of Science Education, 35, 447–459.

Taasoobshirazi, G., & Glynn, S. H. (2009). College students solving chemistry problems: A theoretical model of expertise. Journal of Research on Science Teaching, 46, 1070–1089.

Taasoobshirazi, G., & Sinatra, G. (2011). A structural equation model of conceptual change in physics. Journal of Research on Science Teaching, 48, 901–918.

Tabachnick, S., Miller, R., & Reylea, G. (2008). The relationships among students' future-oriented goals and subgoals, perceived task instrumentality, and task-oriented self-regulation strategies in an academic environment. Journal of Educational Psychology, 100, 629–642.

Teo, T., Tsai, L. T., & Yang, C. (2013). Applying structural equation modeling (SEM) in educational research: An introduction. In M. S. Khine (Ed.), Applications of structural equation modeling in educational research and practice (pp. 3–22). Boston: Sense Publishers.

Thomas, G. T. (2013). Changing the metacognitive orientation of a classroom environment to stimulate metacognitive reflection regarding the nature of physics learning. International Journal of Science Education, 35, 1183–1207.

Tomarken, A. J., & Waller, N. G. (2005). Structural equation modeling: Strengths, limitations, and misconceptions. Annual Review of Clinical Psychology, 1, 31–65.

Tomas, L., Rigano, D., & Ritchie, S. M. (2016). Students' regulation of their emotions in a science classroom. Journal of Research in Science Teaching, 53(2), 234–260.

Tomas, L., & Ritchie, S. M. (2012). Positive emotional responses to hybridised writing about a socio-scientific issue. Research in Science Education, 42, 25–49.

Valle, M., Huebner, E., & Suldo, S. (2006). An analysis of hope as a psychological strength. Journal of School Psychology, 44, 393–406.

Velayuthan, S., & Aldridge, J. M. (2013). Influence of psychosocial classroom environment on students' motivation and self-regulation in science learning: A structural equation modeling approach. Research in Science Education, 43, 507–527.

Walker, C., & Greene, B. (2009). The relations between student motivational beliefs and cognitive engagement in high school. The Journal of Educational Research, 102, 463–471.

Wang, J., & Chen, S. (2014). Exploring mediating effect of metacognitive awareness on comprehension of science texts through structural equation modeling analysis. Journal of Research on Science Teaching, 51, 175–19.

Whittemore, A. (1997). Multistage sampling designs and estimating equations. Journal of the Royal Statistical Society. Series B, Statistical Methodology, 59(3), 589–602.

Wu, A. D. & Zumbo, B. (2008). Understanding and using mediators and moderators. Social Indicators Research, 87, 367–392.

Xu, X., Villafañe, S. M., & Lewis, J. E. (2013). College students' attitudes toward chemistry, conceptual knowledge and achievement: Structural equation model analysis. Chemistry Educational Research and Practice, 14, 188–200.

Yuruk, Y., Beeth, M., & Andersen, Ch. (2009). Analyzing the effect of metaconceptual teaching practices on students' understanding of force and motion concepts. Research in Science Education, 39, 449–475.

Zeidner, M. (2014). Anxiety in education. In R. Pekrun & L. Linnembrink-García (Eds.), International handbook of emotions in education (pp. 265–288). New York: Routledge.

Zeldin, A., Britner, S., & Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers. International Journal in Science Teaching, 45, 1036–1058.

Zepeda, C., Richey, J. E., Ronevich, P., & Nokes-Malach, T. J. (2015). Direct instruction of metacognition benefits adolescent science learning, transfer, and motivation: An *in vivo* study. Journal of Educational Psychology, 107(4), 954–970.

Zeyer, A., Bölsterli, K., Brovelli, D., & Odermatt, F. (2012). Brain type or sex differences? A structural equation model of the relation between brain type, sex, and motivation to learn science. International Journal of Science Education, 34(5), 779–802.

Zeyer, A., Çetin-Dindar, A., Md Zain, A. N., Juriševič, M., Devetak, I., & Odermatt, F. (2013). Systemizing: A cross-cultural constant for motivation to learn science. Journal of Research on Science Teaching, 50, 1047–1067.

Zimmerman, B. J. (2011). Motivational sources and outcomes of self-regulated learning and performance. In B. J. Zimmerman & D. H. Schunk (Eds.), Handbook of self-regulation of learning and performance (pp. 49–64). New York: Routledge.

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science Education, 49, 121–169.

Zusho, A., Pintrich, P., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. International Journal of Science Education, 25, 1081–1094.