Assessing motivation to learn chemistry: adaptation and validation of Science Motivation Questionnaire II with Greek secondary school students

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Abstract

In educational research, the availability of a validated version of an original instrument in a different language offers the possibility for valid measurements obtained within the specific educational context and in addition it provides the opportunity for valid cross-cultural comparisons. The present study aimed to adapt the Science Motivation Questionnaire II (SMQ II) for application into a different cultural context (Greece), a different age group (secondary school students) and with a focus on chemistry learning. Subsequently, the Greek version of Chemistry Motivation Questionnaire II (Greek CMQ II) was used in order to investigate Greek secondary school students' motivation to learn chemistry for the first time. The sample consisted of 330 secondary school students (163 boys - 167 girls) of which 146 were in lower secondary school (14-15 y) and 184 were in upper secondary school (16-17 y). Confirmatory factor analyses provided evidence for the validity of Greek CMQ II, as well as for configural, metric and scalar invariance, thus allowing meaningful comparisons between groups. The five motivation components of the original instrument namely grade motivation, career motivation, intrinsic motivation, self-efficacy, and self-determination were confirmed. Gender-based comparisons showed that girls had higher self-determination relative to the boys irrespective of age group. In addition, girls in lower secondary school had higher career and intrinsic motivation relative to the boys of the same age group. Age-based comparisons showed that lower secondary school students had higher grade motivation relative to upper secondary school students.

Keywords: motivation, assessment, validation, secondary school science, chemistry education

Introduction

The study of the role of motivation in learning science is constantly gaining the attention of science education researchers (Koballa and Glynn, 2007). In recent science education literature, motivation is considered as “a complex multidimensional construct that interacts with cognition to influence learning” (Taasoobshirazi and Sinatra, 2011, p. 904). Both cognitive and motivational learner characteristics interact within a specific learning environment in order to support or hinder conceptual change (Dole and Sinatra, 1998). Pintrich and his colleagues (1993) have adopted four general motivational constructs (namely goals, values, self-efficacy, and control beliefs) as potential mediators of the learner’s conceptual change and suggested that they may influence science learning both in the short term and over longer periods of time as well. In addition, a series of contextual factors, including the classroom environment, the teacher, the nature of academic tasks, and the assessment processes have been proposed to moderate the interactions between motivational constructs and science learning (Pintrich *et al.*, 1993).

The complex multidimensional nature of motivation has been brought out via the use of social cognitive theory which has been systematically employed over the last fifteen years in order to explain human learning and motivation in terms of reciprocal interactions involving personal characteristics (e.g., intrinsic motivation, self-efficacy, and self-determination), environmental contexts (e.g., high school), and behaviour (e.g., enrolling in advanced science or chemistry courses) (Bandura, 2001; Pintrich, 2003).

Concentrating on the role of motivation in learning science and more specifically chemistry as a distinct science subject, a recent study by Zusho *et al.* (2003) provided evidence that students' beliefs in relation with self-efficacy and task-value are significant predictors of their performance in chemistry. The same researchers also reported that students' judgments of their confidence to do well in the chemistry class decreased over time, and as a result students beliefs about the importance and/or usefulness of the chemistry course tended to deteriorate as well. Moreover, evidence has been provided that poor motivation to learn chemistry often leads students to turn away from advanced chemistry studies and chemistry related careers (Salta *et al.*, 2012).

The constantly increasing interest for the study of students' motivation to learn science has triggered the development of several instruments for measuring students' motivation based on different theoretical perspectives. From the perspective of social cognitive theory, Glynn and his colleagues (2011) have developed and evaluated the Science Motivation Questionnaire II (SMQ II). This instrument has been found to be a reliable and valid tool which leads to the assessment of the following five components of students' motivation to learn science in college courses in USA (Glynn *et al.*, 2011): intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation.

The main purpose of the present study has been the adaptation and validation of the chemistry specific version of SMQ II (ie the Chemistry Motivation Questionnaire II or briefly CMQ II) with Greek students (thus producing the Greek CMQ II). The rational behind this work lies on the need for the availability of valid measurements which will subsequently allow for cross-cultural comparisons in order to explore the proposed influence of the cultural context on the motivational constructs (Pintrich, 2003). Besides the different cultural context (Greece relative to USA), two additional factors are changed in the current study relative to the original work of Glynn *et al.* (2011): a) students belong to a younger age group and different educational level (secondary school relative to college) and b) the focus is on measuring motivation to learn a specific science subject which is chemistry.

Thus, the specific research questions that have guided this study can be summarized as follows:

1) How valid is the Greek version of the “Chemistry Motivation Questionnaire II” (Greek CMQ II) for measuring secondary school students’ motivation to learn chemistry?

Subsequently, if Greek CMQ II proves to be valid,

2) Which are the motivational characteristics of Greek secondary school students to learn chemistry?
3) What are the differences in motivation to learn chemistry between Greek lower and upper secondary school students?
4) What are the differences in motivation to learn chemistry between Greek male and female secondary students?

Theoretical Framework

The term “motivation” has been defined “as the attribute that ‘moves’ us to do or not do something” (Gredler, 2001 as cited in Broussard and Garrison, 2004, p. 106). In education, motivation to learn is broadly considered as “the internal state that arouses, directs, and sustains students’ behaviour” (Koballa and Glynn, 2007, p. 85). According to Brophy (1983) “motivation to learn refers to the enduring disposition of students to enjoy the process of learning and take pride in the outcomes of experience involving knowledge acquisition or skill development" (p. 200). Hence, modern theories of motivation focus mainly "on the relation of beliefs, values, and goals with action" (Eccles and Wigfield, 2002, p. 110).

Research on motivation associated with academic achievement and/or development has been conducted via different theoretical perspectives and has led to the development of an extensive motivation terminology (Murphy and Alexander, 2000). In fact, theorists have indicated the need for theoretical integration in the domain (Eccles and Wigfield, 2002). The main theoretical perspectives that have been employed in the study and conceptualization of motivation can be briefly summarized as follows.

Achievement goal theory or simply goal theory (Ames, 1992; Blumenfeld, 1992) relates students' goals to their achievement behaviour. The main idea in this perspective is the "goal orientations" that refer to students' beliefs about the purpose of engaging in achievement-related behaviour.

Self-determination theory (Deci and Ryan, 2000) postulated that an understanding of human motivation requires a consideration of innate psychological needs for competence, autonomy and relatedness. As reviewed in Deci and Ryan (2000), a social context which supports these three needs tends to enhance intrinsic motivation and facilitate the internalization of extrinsic motivation. Subsequently, enhanced motivation seems to be associated with positive affective experiences, and high-quality performance.

The theoretical concept of interest has attracted researchers' attention over the past few years (Hidi & Harackiewicz, 2001; Schiefele, 1999), and has been proposed to be connected with intrinsic motivation to learn by educational psychologists (Koballa and Glynn, 2007). A distinction between individual and situational interest is typically made. Particularly, individual interest is considered as a relatively stable orientation towards certain domains in contrast with situational interest that is an emotional state aroused by specific features of a task (Hidi and Renninger, 2006). Much research on the relation between individual interest and learning has been conducted (Renninger *et al.*, 2002; Schiefele, 1999). An important finding was the stronger relationship between interest and deep- learning than with rote learning (Schiefele, 1999).

Finally, the theoretical perspective of the social cognitive theory, originally developed by Bandura (1986) and extended by the same and other researchers (Bandura, 2001; Pajares and Schunk, 2001; Pintrich, 2003), conceptualizes the process of learning via a series of reciprocal interactions among personal, behavioural and social/environmental factors. Within the framework of social cognitive theory, Pintrich and his colleagues (1993) proposed a conceptual change model for describing students' learning and postulated that the cognitive and motivational constructs influence each other and at the same time they are influenced by the social context. In turn, both cognitive and motivational constructs are assumed to influence students' involvement with their learning and, consequently, achievement outcomes (Pintrich, 2000).

As also noted in the Introduction, the social cognitive theory conceptualizes motivation to learn as a multidimensional construct which is therefore comprised of several components (also referred in Glynn *et al*. (2011) as "types and attributes of motivation"). Many motivational components linked to learning science have been studied extensively and reviewed in Glynn and Koballa (2006), Koballa and Glynn (2007), Pintrich (2003), and Schunk *et al.* (2008). Examples of these components are intrinsic motivation, which involves the inherent satisfaction in learning science for its own sake (e.g., Eccles *et al.*, 2006); extrinsic motivation, which involves learning science as a means to a tangible end, such as a career or a grade (e.g., Mazlo *et al.*, 2002); self-determination, which refers to the control students believe they have over their learning of science (e.g., Black and Deci, 2000); and self-efficacy, which refers to students' belief that they can achieve well in science (e.g., Lawson *et al.*, 2007). The above examples of motivation components are also included in the list of 20 motivation terms proposed to be relevant to academic achievement and motivation (Murphy and Alexander, 2000). This "corpus" of terms contains motivation components associated with all four theoretical perspectives of motivation we referred to above.

In the following part of this theoretical section a brief overview of the literature on motivation to learn science with a focus on chemistry will be made. With regard to students' motivational characteristics toward a specific science domain, there is evidence that even in pre-primary school, children express some differences in their motivation toward different science disciplines (Mantzicopoulos *et al.*, 2008). Focusing on chemistry learning, there exist some studies which have attempted to examine how it may be influenced by students' motivation (Aydin and Uzuntiryaki, 2009; Black and Deci, 2000; Feng and Tuan, 2005; Juriševič *et al.*, 2008; Mazlo *et al.*, 2002; Scherer, 2013; Taasoobshirazi and Glynn, 2009; Zusho *et al.*, 2003). Black and Deci (2000) applied self-determination theory to investigate the effects of students' course-specific self-regulation and their perceptions of their instructors' autonomy support on adjustment and academic performance in a college-level organic chemistry course. Their results have shown that the students' perceived instructor autonomy support is related to positive adjustment and to increased students' autonomy as the semester progresses, which is in turn related to better performance. Zusho and his colleagues (2003) evidenced on one hand an overall decline in college students' motivational levels over time and on the other an increase in students' use of organizational and self-regulatory strategies. A diversity of trends was found which were shown to be dependent on students' achievement levels. Finally, the relation of motivation to achievement was evidenced via the identification of two motivational components, namely self-efficacy and task value, as "best predictors of final course performance even after controlling for prior achievement" (Zusho *et al.,*2003, p. 1081).

Research conducted by Juriševič and her colleagues (2008) showed that Slovene first year pre-service primary school student teachers (18.5 years old) are more or less equally motivated for chemistry as for any other subject, but their intrinsic motivation decreases as the level of abstraction increases. It has been similarly established that among the three levels of chemistry learning—namely, macroscopic, submicroscopic, and symbolic—students were the least motivated to study concepts at the symbolic level (Juriševič *et al.*, 2008). Taasoobshirazi and Glynn (2009) found that college students' self-efficacy influenced strategy use and chemistry problem solving. Students with relatively high chemistry self-efficacy tended to use a working-forward strategy and solve problems successfully while students with relatively low chemistry self-efficacy tended to use a working-backward strategy and solve the problems incorrectly. Their findings are consistent with other studies conducted on students' chemistry self-efficacy, such as those of Zusho *et al.* (2003) and Schraw *et al.* (2005). Moreover, Scherer (2013) has provided evidence for the empirical distinction between the motivation components of self-concept and self-efficacy within the domain of chemistry. By using data collected by 459 German high-school students (mean age 16.6 years), he found that students' perceptions of themselves within the academic environment (academic self-concept) are not the same with their perceptions about their ability to master given tasks or develop specific competences (academic self-efficacy) within the domain of chemistry. However, his results indicated that the two constructs affect each other.

Cultural and contextual effects in motivation to learn science and chemistry

One of the aims of social cognitive theory is exploring the influence that different contextual and cultural practices may have on students' motivation. According to Brophy (2004), the psychology of motivation that has been developed by studies in western countries is reflective of a common human condition and thus equally applicable everywhere. However, comparative research has identified interesting contrasts between nations and world regions. For example, Hufton *et al.* (2002) found that Russian adolescents showed patterns of school-related motivation that contrasted in several respects with those displayed by American and British adolescents. Particularly, Russian students tend to maintain task engagement even though their teachers are short on praise and overly persistent on correction. It is suggested that this pattern reflects a pervasive Russian cultural value on becoming an educated person.

Perhaps the most significant cultural differences have been observed between people from western nations (e.g., the United States and Western Europe) and people from East Asia (e.g., China, Korea, and Japan). Studies have shown that in the former countries people display a more individualistic attitude and their self-concepts emphasize uniqueness and independence from others. On the other hand, people from East Asia display a more collectivistic attitude with self-concepts which are interdependent (Boekaerts, 1998; Fiske *et al.*, 1998). These general differences lead to differences on more specific motivational aspects. In attributing behaviour to causes, for example, East Asians tend to make fewer references to personal dispositions but more references to situational factors than westerners do (Choi *et al.*, 1999; Krull *et al.*, 1999). Other studies have indicated that East Asians also tend to be more comfortable setting up their personal agendas by taking into account those of their families or groups. For example, East Asian (but not American) students display increased benefit perception of goal achievement when they pursue goals in order to please others (e.g. parents or friends) (Oishi and Diener, 2001). Similarly, East Asian students seem to show higher levels of intrinsic motivation relative to American students "when choices are made for them by trusted significant others" rather "than when they make the choices themselves" (Iyengar and Lepper, 1999).

Moreover, also within a specific cultural context, differences have been observed in students' motivational patterns depending on age, gender and family environment. Different grade levels present somewhat different motivational challenges because of age-related changes in students' motivational patterns. Thus, there is evidence that the enthusiastic start of schooling by most students is followed by gradual decrease on measures of intrinsic motivation, curiosity and school-related attitudes. (Gentry *et al.*, 2002; Gottfried *et al.*, 2001; Wigfield and Eccles, 2002). Potvin *et al.* (2009) suggested that the first 2 years of high school may be a critical period when students turn toward or away from a science career path; whereas Bryan *et al.* (2011) argued that for those students who turn towards a science career path the last 2 years of high school may be a critical period for motivation to learn particular areas/disciplines of science.

As students develop in our society, they are exposed to gender role socialization. Thus, certain family and social roles, occupations, personal attributes, and ways of dressing and behaving are considered primarily feminine, while others primarily masculine. Most students have certain individuals they encounter in their personal lives and in the media as role models. The behaviour expressed by the students reflects the messages they receive from their parents and peers (and even sometimes their teachers) (Li, 1999; Tenenbaum and Leaper, 2003). To the extent at which a specific school activity is associated primarily with one gender, students' attitudes and expectations are likely to be affected.

Focusing on the role of gender on students' motivation to learn science, recent research by Glynn *et al.* (2011) has provided evidence for a gender effect favouring college male students with regard to a specific motivational construct, namely self-efficacy. On the other hand, a study conducted among upper secondary school students and in a cross-cultural context which included four countries namely Malaysia, Slovenia, Switzerland, and Turkey revealed more complicated relationships between gender and motivation (Zeyer *et al*, 2013*)*.

Measuring students' motivational constructs

A motivational construct generally corresponds to a latent variable which is a presumed explanatory variable to reflect a continuum that is not directly observable (Kline, 2011). Thus a construct may be assessed only indirectly; this is achieved via measuring certain items which indicate empirically how the specific construct is conceptualized by the subject. Students' conceptualizations are important since they tend to influence their actions (McGinnis *et al.*, 2002; Scott *et al.*, 2007).

Recently, several studies have focused on developing students' motivation scales to learn science (Glynn and Koballa, 2006; Glynn *et al.*, 2009; 2011; Tuan *et al.*, 2005; Velayutham *et al.*, 2011). A Students' Motivation towards Science Learning (SMTSL) questionnaire was developed by Tuan and her colleagues (2005) and was validated with junior high school students from central Taiwan. The researchers identified six motivational constructs: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The SMTSL questionnaire has been used as a tool for measurement of change in students' learning motives after the implementation of specific activities in a chemistry course (Feng and Tuan, 2005). Recently, the SMTSL questionnaire has been adapted in the Greek language and has been used in undergraduate student teachers with reference to physics learning (Dermitzaki *et al.*, 2013). Nonetheless, the developers have annotated the conceptualization and measurement of some constructs as ambiguous and not theoretically sound (Tuan *et al.*, 2005). Another instrument, the Students' Adaptive Learning Engagement in Science questionnaire was developed by Velayutham and her colleagues (2011) based on theoretical and research underpinnings. The validation process resulted on four constructs which included goal orientation, task value, self-efficacy, and self-regulation. The researchers reported evidence for strong construct validity of the scales, by testing them on Australian lower secondary students (Velayutham *et al.*, 2011). Another scale designated as the "High School Chemistry Self-Efficacy Scale" was developed and validated by Aydin and Uzuntiryaki (2009) in order to measure Turkish high school students' self-efficacy from the perspectives of cognitive and laboratory competencies.

Glynn and his colleagues focused on those motivational components/constructs that influence self-regulatory learning to develop and validate the Science Motivation Questionnaire II (SMQ II) (Glynn and Koballa, 2006; Glynn *et al.*, 2007; 2009; 2011). According to the developers, the items of SMQ II were designed to serve as empirical indicators of components of students' motivation to learn science in college courses. The following five motivation components (scales) are included in the final version of SMQ II (Glynn *et al.*, 2011), each one comprised of 5 items, and constitute the working model of motivation in the present work as well: intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation. The scales were found to be useful in assessing the motivation of both science and non-science majors. The motivation scales of SMQ II were shown to be positively related, with intrinsic and career motivation exhibiting the strongest relation. In addition, the scales were shown to be related with students' marks, with strongest relation exhibited by self-efficacy.

The Present Study

In regard with research on motivation in school settings, most investigations have been conducted in the mathematics and science domains. Moreover, the majority of these studies have been undertaken with college students. Therefore, both from an academic as well as from a practical point of view (eg. for use in the educational policy decision making process), it is important to investigate the motivation of secondary school students to learn science and particularly chemistry. In addition, there is a need to accurately examine how the motivational constructs might be moderated by different cultural/educational contexts. The availability of valid instruments for measuring motivation is a vital necessary requirement in order to engage in such a demanding research task. Hence, we anticipate that the investigation of motivation to learn chemistry among Greek secondary school students will provide a valuable contribution to various aspects of research related with motivation. Finally, it is important to note that in Greece there has been so far no systematic study which aims directly at measuring students' motivation to learn chemistry. A measurement of upper secondary school students' attitudes toward chemistry reveals a neutral attitude regarding the interest and a negative attitude regarding the usefulness of the chemistry course to their future career. Only few students (about 4%) express the wish to study chemistry at University (Salta and Tzougraki, 2004). These neutral and negative attitudes are indices of a low motivation to study and learn chemistry (Koballa and Glynn, 2007). Taking into account the considerations noted above, we decided to investigate Greek secondary school students' motivation to learn chemistry using a translation and adaptation of SMQ II (Glynn *et al.*, 2011) in the domain of chemistry. This instrument was selected due to its psychometric features and wide usage. Particularly, SMQ II combines a number of key motivational components in a single scale consisted of five subscales, one for each construct, with strong experimental evidence for their validity (Glynn *et al.*, 2011). Questionnaire validity is an issue of central importance which is however seldom examined and/or established.

Method

The context

The interpretation of the results of a motivational study is related to the context of the existing curriculum. Thus, in this section a short description of the Greek chemistry curriculum is given. Greek secondary school includes three years of lower (junior) and three years of upper (senior) secondary school. The curricula for secondary school are structured in six grades; 7^{th}, 8^{th}, 9^{th} for lower and 10^{th}, 11^{th}, 12^{th} for upper secondary school respectively. Secondary school science curricula are centralized. All schools throughout the country must follow a particular sequence of science courses and use the same educational materials authorized by the Ministry of Education.

Table 1 demonstrates the weekly distribution of teaching hours for Science subjects in Greek secondary schools. A number of 1-hour laboratory activities are included in Science Curricula. Table 2 demonstrates the distribution of laboratory activities for Science subjects in Greek secondary school.

Table 1:Weekly distribution of teaching hours for Science subjects in Greek secondary school

	Weekly teaching hours per grade					
	Lower secondary school			Upper secondary school		
Grades	**7**	**8**	**9**	**10**	**11**	**12**
Compulsory subjects						
Biology	2	-	2	1	1	1
Chemistry	-	1	1	2	2	-
Geography	2	2	-	-	-	-
Physics	-	2	2	3	2	1
Optional subjects						
Biology	-	-	-	-	-	2
Chemistry	-	-	-	-	2	2
Physics	-	-	-	-	2	3
Total hours per grade	35	35	35	33	34	30

Table 2: Annual distribution of 1-hour laboratory activities for Science subjects in Greek secondary school

	Annual distribution of 1-hour laboratory activities per grade					
	Lower secondary school			Upper secondary school		
Grades	**7**	**8**	**9**	**10**	**11**	**12**
Compulsory subjects						
Biology	5	-	6	3	3	2
Chemistry	-	4	3	2	3	-
Physics	-	7	9	5	4	1
Optional subjects						
Biology	-	-	-	-	-	2
Chemistry	-	-	-	-	3	3
Physics	-	-	-	-	3	3
Total lab activities per grade	5	11	18	10	10-16	3-11

The subject of chemistry is obligatory in grades 8 to 11 (core chemistry courses), and optional in the 12thgrade (advanced chemistry course), depending on the direction of studies chosen by the student. At grades 8 and 9, the chemistry curriculum follows a macroscopic to microscopic approach. This approach refers to instructional methods that use examples of real-world or demonstrations to introduce chemistry topics followed by microscopic explanations using two-dimensional drawings of dots and circles to represent atoms, ions, and molecules (Gabel, 1999). At grades 10 to 12, the chemistry curriculum, both in core and advanced courses, emphasizes a linear development of chemical concepts. This refers to instructional methods that start from subjects that introduce first basic theoretical concepts of atomic theory and bonding on the microscopic level and proceed to subjects focusing on the macroscopic level (Gabel, 1999). One of the chemistry curriculum objectives is the ability of students to solve algorithmic chemistry exercises and problems.

Participants

The study was conducted in 4 urban public secondary schools located in the metropolitan area of the Greek capital, Athens. The participants were 330 secondary school students (163 males and 167 females) in grade 8 (n=146), and in grade 10 (n=184). The lower secondary school students (grade 8) were 14-15 years old and the upper secondary school students (grade 10) were 16-17 years old. Most students in the sample were of middle socioeconomic status. The students participated voluntarily without extra credit or compensation for their participation. The students and their parents were informed about the aim of this study.

Questionnaire Translation and Adaptation

The Chemistry Motivation Questionnaire II (CMQ II) is the chemistry specific SMQ II version in which the word “chemistry” is substituted for the word “science”. SMQ II was selected for the following reasons: (a) it is based on a widely accepted theoretical formulation of motivational constructs; (b) it functionalizes the motivational construct with a range of indicators, and (c) it demonstrates various psychometric properties which render it acceptable. The translation and adaptation process was conducted by taking into account the Hambleton comments on International Test Commission (ITC) guidelines for test translation and adaptation (Hambleton, 2001).

A team of three translators working independently to translate and adapt the test was used. Scoring rubrics and instructions were also translated in the Greek language. The translators have knowledge of both languages. Knowledge of the cultures, and at least general knowledge of the subject matter and testing principles, made part of the selection criteria for translators. One of translators, the second author, is a science researcher who has lived for five years in USA during his doctoral studies, and he now lives and works in Greece. Consequently, he is familiar with the source and the target culture, and the concept of interest. The second translator is a science teacher with over twenty years experience in teaching science subjects at Greek secondary school and thus he is familiar with the culture of the population that will be studied. Finally, the third translator is the first author, a chemistry educator, familiar both with the concept of interest and with literature on questionnaire development. A professional English language teacher (a native Greek with postgraduate studies in the UK) was also used as back translator.

Prior to translation, the translators met to clarify the definitions and indicators of the concepts examined by the selected questionnaire in order to promote understanding of meanings and hence facilitate translation. Each team member first made an independent translation of the questionnaire. During forward translation, the translators focused on the meaning of the items rather than on literal word-for-word translation. After individual translations were made, the team members met in order to review the translated version, discuss the discrepancies, and decide on the most appropriate translation of the items. In the next phase, the back translation from the target language into the source language was used in order to identify problems with the forward translation. The team of translators then reviewed the back translation for comparability of meaning with the target language and clarity of wording. Although Hambleton (2001) states that a back translation provides little evidence of measurement equivalence, in our case it was used to assure that the content and meaning of the original items, instructions and response categories are the same as the original. The last phase of the instrument preparation dealt with pre-testing the translated questionnaire for comprehension and cultural validity. Five 10th grade students completed the Greek version of CMQ II. The first author engaged the students in a discussion to determine clarity of the items using questions such as "What does the item mean?", and "Was this an item you felt comfortable responding?" The content of the discussion with the students was analyzed and a few necessary changes were made to items by taking into account the students' suggestions. In fact, a need of altering the wording of an item came to light. The chemistry laboratory activities in Greek high school are considered complementary without requiring both preparation of students and separate examinations or exam questions. Consequently, the second part "…*and labs*" of item 16 "*I prepare well for science tests and labs"* was considered not applicable for use in the Greek secondary school context and it was deleted. This action does not create any problem in the scoring procedure.

The end product of the translation and adaptation work is the Greek version of the Chemistry Motivation Questionnaire II (CMQ II). This version is available on line (http://www.coe.uga.edu/assets/docs/outreach/smqii/SMQII-Translations.pdf) in the form of Science Motivation Questionnaire II (Greek-SMQ II) applicable to all science disciplines. The team of translators attempted to find a balance between a literal and a culturally specific translation so that the translation and adaptation of items are appropriate for Greek secondary school students. Hence, the questionnaire in the target language was finalized and subjected to further testing of psychometric properties.

Procedure

The questionnaire was administered to students in their chemistry classes by their chemistry teacher during March and April of school year 2012–2013. Students were informed about the study and they consented to participate. Their responses to all motivation statements were assessed using a Likert-type scale ranging from 0 (never) to 4 (always).

Confirmatory factor analysis (CFA) was selected as the procedure for statistical analysis since the present study aims to test the hypothesized motivational structure/model proposed by Glynn (2011) for students' motivation to learn chemistry. In contrast to Exploratory Factor Analysis (EFA) that may be appropriate for scale development, CFA is preferred when measurement models have strong hypothesis regarding the number of latent variables in a model (Usher and Pajares, 2009). Moreover, CFA provides a rigorous test of equivalence across the groups. If the assumption of equivalence is rejected, then EFA may be employed to discover where the anomalies are in the database (Hurley *et al.,* 1997).

The factors of the model correspond to the scales of related items identified by Glynn *et al.* (2011) that were hypothesized to represent the components of students' motivation to learn chemistry. Adopting a componential model of motivation based on the social cognitive theory, we hypothesized that (a) the students' responses to the questionnaire can be predicted by the five specified components; (b) the components are related because they measure positive, mutually supporting components of the motivation. Confirmatory factor analysis was conducted using the Structural Equation Modeling (SEM) software program AMOS, Version 21.

Results

Model Specification

The five-factor model for the SMQ II proposed by Glynn and his colleagues (2011) was validated for the chemistry domain and for Greek high school students. The model included five latent (unobserved) variables (factors) : intrinsic motivation (IM), self-determination (SD), self-efficacy (SE), career motivation (CM), and grade motivation (GM). CFA was conducted in a manner that each latent variable (factor) was "observed" via its specific set of five items (measured variable indicators). Summarizing, the model to be confirmed contains 25 measured variables. Specifically, the factor intrinsic motivation (IM) predicts the students' responses to items 01, 03, 12, 17, and 19; the factor self-determination (SD) predicts the students' responses to items 05, 06, 11, 16, and 22; the factor self-efficacy (SE) predicts the students' responses to items 09, 14, 15, 18, and 21; the factor career motivation (CM) predicts the students' responses to items 07, 10, 13, 23, and 25; and the factor grade motivation (GM) predicts the students' responses to items 02, 04, 08, 20, and 24. It is also necessary to confirm that the motivational factors may be intercorrelated. Therefore, the factors were permitted to covary. Error terms were hypothesized to be uncorrelated. In each model the first item loading was constrained to 1.0 to set the scale of measurement, and no items were allowed to double load.

Model identification

A model is characterized as "identified" when "it is *theoretically* possible for the computer to derive a unique estimate of every model parameter" (Kline, 2011). For testing model identification, the first step is to count the number of data points and the number of parameters that need to be estimated. The model to be confirmed has 265 fewer parameters than data points, so the model may be identified in accordance with the required condition. Subsequently, the identifiability of the measurement portion of the model is established by examining the number of factors and measured variables as well as the error correlations and factor covariances (Kline, 2011). It is thus noted that in the testing model, there are five indicators for each factor. The errors are uncorrelated and each indicator loads on only one factor. In addition, the covariances between the factors are not zero. Therefore, this CFA model may be identified (Kline, 2011).

Model estimation

The model estimation starts with the evaluation of model fit which means the determination of how well the model explains the data. Assuming satisfactory model fit, the interpretation of the parameter estimates can take place (Kline, 2011). Multiple well-established indices and criteria were used to assess the goodness of model fit, because each given index evaluates only particular aspects of the model fit (Byrne, 2010; Kline, 2011). The analysis was conducted using maximum likelihood (ML) estimation.

The test of our hypothesis that the Chemistry Motivation Questionnaire (CMQ II) responses can be explained by five factors, yielded a χ^2 value of 569.31 with 265 degrees of freedom and a probability of less than 0.001 ($p<0.001$), thereby suggesting that the fit of the data to the hypothesized model is not entirely adequate (Byrne 2010). One of the chi squared test limitations, namely the sensitivity of χ^2 value to sample size, is a reason to consider that it may be a poor index of the quality of the fit when sample sizes are large (Hu *et al.*, 1992). The test of χ^2/df ratio was proposed to address this problem (Byrne, 2010). The obtained value of 2.15 for the χ^2/df ratio is considered a good fit of our hypothesized model to the data since it falls within the recommended range of 1.0 – 3.0 (Glynn *et al.*, 2011).

The following four additional fit indexes, which are among the most widely reported in the Structural Equation Modeling (SEM) literature, were also selected to determine model fit (Hu and Bentler, 1999; Kline, 2011): the Steiger–Lind Root Mean Square Error of Approximation (RMSEA), the Jöreskog–Sörbom Goodness of Fit Index (GFI), the Bentler Comparative Fix Index (CFI), and the Standardized Root Mean Square Residual (SRMR).

The first index, RMSEA, assesses a lack of fit of the population data to the estimated model and Hu and Bentler (1999) have suggested a value less than 0.06 as indicative of a good fit between the hypothesized model and the observed data. Moreover, MacCallum *et al.*, (1996) strongly urged the use of confidence interval in practice, suggesting a very narrow confidence interval as supporting for good precision of the RMSEA value in reflecting a model fit in the population. The RMSEA value for our hypothesized model is 0.06, with the 90% confidence interval ranging from 0.05 to 0.07. This indicates that we can be 90% confident that the true RMSEA value in the population will fall within the bounds of 0.05 and 0.07, which represents a good degree of precision (Byrne, 2010).

The second index, GFI, is an alternative to the Chi-Square test and calculates a weighted proportion of variance in the sample covariance accounted for by the estimated population covariance matrix (Tabachnick and Fidell, 2000). A GFI value of 0.90 or higher indicates a good model fit. Although the GFI value for our hypothesized model (0.88) is slightly lower than the threshold level, it is generally perceived as “acceptable” for other indices of fit (Byrne, 2010).

The third index, CFI, takes into account sample size (Byrne, 2010) and performs well even in small samples (Tabachnick and Fidell, 2000). A value greater than 0.90 is needed in order to ensure that models are accepted, with values close to 0.95 indicating superior fit (Hu and Bentler, 1999). The CFI value for our hypothesized model (0.91) is indicative of good fit.

The last index, SRMR, is a measure of the mean absolute correlation residual, the overall difference between the observed and predicted correlations. Small values of SRMR (less than 0.05) indicate good-fitting models (Byrne, 2010), however values as high as 0.08 are deemed acceptable (Hu and Bentler, 1999). The SRMR value of our hypothesized model, equal to 0.06, can be interpreted as meaning that the model explains the correlations to within an average error of 0.06 (Byrne, 2010). As mentioned above, the model chi-square is statistically significant, so the exact-fit hypothesis is rejected; however the values of the other four used fit indices indicate that our hypothesized model fits the data well, providing evidence of questionnaire construct validity.

To examine measurement invariance across different groups, successive multi-group CFAs were conducted (Vandenberg and Lance, 2000). Factorial invariance tests were done in hierarchical fashion by conducting initially the most basic form of measurement invariance that is configural invariance or equal form invariance (Model 1). If configural invariance is confirmed, this indicates that participants belonging to different groups conceptualize the constructs in the same way. A stronger form of measurement invariance is construct-level metric invariance or equal factor loadings (Model 2), which means that the unstandardized factor loadings of each indicator are equal across the groups. Metric invariance is important as a prerequisite for meaningful cross-group comparison (Cheung and Rensvold, 2002). When metric invariance is met, the suggestion is that different groups respond to the items in the same way. Subsequently, constraints to factor loadings and item intercepts are imposed in order to test for scalar or strong invariance (Model 3). Establishing scalar invariance indicates that individuals who have the same score on the latent construct would obtain the same score on the observed variable regardless of their group membership. A value of ΔCFI smaller than or equal to 0.01 indicates that the null hypothesis of invariance should not be rejected (Cheung and Rensvold, 2002) and it is indicative of model invariance.

Recall that CFAs were conducted on increasingly-restrictive hierarchical measurement models for each of the two subgroups of interest: gender and age. To assess how well the CFA models represented the data, the following criteria were used as cut-offs for good fit: CFI >0.90 (with >0.95 being ideal), RMSEA and SRMR <0.08 (with <0.05 being ideal) (Hu and Bentler, 1999). Because the measurement model showed a modestly good fit for all four subgroups namely girls, boys, lower, and upper secondary school students, (Table 3), we specified the same model for each subgroup when testing for factorial invariance.

Table 3: Summary of Goodness-of-Fit Statistics for the Chemistry Motivation Questionnaire IIMeasurement Model by Subgroup

SubgroupModel	χ^2	df	χ^2/df	CFI	RMSEA	SRMR
Girls	499.43	265	1.89	.86	.07 (.06-.08)	.07
Boys	444.16	265	1.68	.90	.06 (.05-.07)	.07
Lower Secondary	456.79	265	1.72	.84	.07 (.06-.08)	.07
Upper Secondary	474.00	265	1.79	.91	.07 (.06-.08)	.07
Total	569.31	265	2.15	.91	.06 (.05-.07)	.06

Multiple groups modeling started with testing for configural invariance. As Table 4 shows, the model gave a modestly good fit with the data supporting the configural validity across gender and different age groups. With regard to metric invariance, the results revealed that the model fits the data very well across gender and different age groups.

Table 4: Tests for Invariance of the Chemistry Motivation Questionnaire IIMeasurement Model across Gender and Age

Model	χ^2	df	χ^2/df	CFI	RMSEA (90% CI)	Model comparison	ΔCFI
Boys vs Girls							
Model 1 (no constrains)	943.588	530	1.780	.88	.049 (.044-.054)		
Model 2 (equal factor loadings)	959.826	550	1.745	.88	.048 (.043-.053)	2vs1	.000
Model 3 (equal intercepts)	976.345	565	1.728	.88	.047 (.042-.052)	3vs2	.000
Lower vs Upper Secondary							
Model 1 (no constrains)	930.788	530	1.756	.89	.048 (.043-.053)		
Model 2 (equal factor loadings)	952.122	550	1.731	.89	.047 (.042-.052)	2vs1	.000
Model 3 (equal intercepts)	972.279	565	1.721	.89	.047 (.042-.052)	3vs2	.000

Furthermore, this additional set of constraints did not lead to a meaningful drop in fit (ΔCFI =0.000) between Model 2 and Model 1, providing support for metric invariance across gender and age groups. Subsequently, scalar invariance was investigated. The overall goodness-of-fit indices and ΔCFI value between Model 3 and Model 2 across gender and age groups supported scalar invariance. Although the CFI values for all CFA models are slightly lower than the threshold level, they are generally perceived as "acceptable" for other indices of fit. Statisticians (Byrne, 2010) frequently point out that fit indexes can only describe a model's ''lack of fit" (p. 84) and that the judgment of a model's adequacy ''rests squarely on the shoulders of the researcher". With this in mind and based on the majority of the evaluated indexes, we have strong evidence that: (a) participants belonging to different groups conceptualize the constructs in the same way (configural invariance); (b) different groups respond to the items in the same way (metric invariance); (c) individuals who have the same score on the latent construct would obtain the same score on the observed variable regardless of their group membership (scalar invariance). Thus, cross-group comparisons are plausible as well.

Table 5 lists each item in the Chemistry Motivation Questionnaire II along with its standardized loading estimate for each of the five measurement factors.

Table 5: Standardized Factor Loadings

CMQ II Item Number	**Factor Loading**					**Statement**
	Total	**Boys**	**Girls**	**Lower Secondary**	**Upper Secondary**	
Factor:**Grade motivation**						
24	.78	.79	.79	.76	.77	Scoring high on chemistry tests and labs matters to me
4	.76	.69	.84	.68	.80	Getting a good chemistry grade is important to me
8	.75	.78	.71	.79	.72	It is important that I get an ''A'' in chemistry
20	.67	.66	.70	.58	.71	I think about the grade I will get in chemistry
2	.57	.52	.60	.53	.60	I like to do better than other students on chemistry tests
Factor:**Self- efficacy**						
15	.80	.82	.78	.75	.84	I believe I can master chemistry knowledge and skills
9	.79	.77	.81	.72	.83	I am confident I will do well on chemistry tests
18	.70	.77	.60	.66	.73	I believe I can earn a grade of ''A'' in chemistry
14	.64	.60	.70	.61	.66	I am confident I will do well on chemistry labs and projects
21	.56	.62	.51	.49	.62	I am sure I can understand chemistry
Factor:**Self-determination**						
22	.74	.75	.72	.69	.78	I study hard to learn chemistry
11	.70	.70	.69	.70	.71	I spend a lot of time learning chemistry
16	.60	.60	.60	.66	.56	I prepare well for chemistry tests
5	.60	.63	52	.50	.66	I put enough effort into learning chemistry

CMQ II Item Number	Factor Loading					Statement
	Total	Boys	Girls	Lower Secondary	Upper Secondary	
6	.56	.58	.49	.52	.59	I use strategies to learn chemistry well
Factor:**Career motivation**						
13	.78	.79	.75	.66	.86	Understanding chemistry will benefit me in my career
23	.78	.79	.76	.79	.80	My career will involve chemistry
25	.73	.73	.75	.73	.77	I will use chemistry problem-solving skills in my career
7	.72	.67	.72	.50	.83	Learning chemistry will help me get a good job
10	.69	.66	.76	.58	.74	Knowing chemistry will give me a career advantage
Factor:**Intrinsic motivation**						
19	.80	.78	.81	.75	.84	I enjoy learning chemistry
12	.71	.69	.72	.67	.74	Learning chemistry makes my life more meaningful
17	.67	.71	.61	.58	.73	I am curious about discoveries in chemistry
3	.66	.65	.65	.55	.75	Learning chemistry is interesting
1	.48	.55	.36	**.34**	.59	The chemistry I learn is relevant to my life

The factor loadings are estimated correlations often referred to as validity coefficients, which indicate how well a given item measures its corresponding factor. In all analyses, the standardized factor loadings were significant at the p=0.05 level and all, except one which is equal to 0.34 for the lower secondary group (shown in bold), displayed magnitude in the range between 0.86 and 0.48, and therefore exceed the factor-loading criterion of 0.35 (Tabachnick and Fidell, 2000).

The standardized correlations among the factors shown in Table 6 are considered corrected (i.e., disattenuated) for measurement error and thus may be viewed as representing the true associations among the motivation components represented by the factors.

Table 6: Standardized Factor Correlations for all groups

	Grade motivation					Self-efficacy					Self-determination					Career motivation				
	T*	B*	G*	L*	U*	T*	B*	G*	L*	U*	T*	B*	G*	L*	U*	T*	B*	G*	L*	U*
GM																				

	Grade motivation					Self-efficacy					Self-determination					Career motivation				
SE	.66	.65	.65	.59	**.77**															
SD	.56	.60	.53	.52	.60	.45	.51	.41	.40	.49										
CM	.48	.53	.40	.40	.52	.54	.66	.41	.48	.58	.37	.47	**.23**	.46	.32					
IM	.48	.47	.49	.44	.53	.57	.58	.59	.57	.58	.53	.56	.46	.53	.53	.70	.69	.69	.72	.67

Note: Minimum and maximum values are shown in bold
* T: Total, B: Boys, G: Girls, L: Lower secondary, U: Upper Secondary

The five factors showed statistically significant intercorrelations ranging in magnitude from 0.23 (between career motivation and self-determination for girls) to 0.77 (between grade motivation and self-efficacy for upper secondary students).

A thorough psychometric evaluation also includes some form of reliability evidence. The reliabilities (internal consistencies) of the subscales for the all groups, assessed by Cronbach's alphas, are presented in Table 7.

Table 7:Reliability of internal consistencies

	Reliability of internal consistencies				
	Total (n=330)	**Boys (n=163)**	**Girls (n=167)**	**Lower secondary (n=146)**	**Upper secondary (n=184)**
GM	.82	.81	.84	.79	.83
SE	.82	.84	.80	.78	.85
SD	.77	.78	.73	.75	.79
CM	.86	.85	.86	.79	.90
IM	.80	.81	.76	.71	.85
All items	.91	.92	.90	.88	.93

The values of Cronbach's alpha of the five factors ranged in magnitude from 0.71 (intrinsic motivation for lower secondary school students) to 0.90 (career motivation for upper secondary school students). According to DeVellis (2003), a coefficient above 0.80 is ‘‘very good,’’ 0.70 to 0.80 is ‘‘respectable,’’ 0.60 to 0.69 is ‘‘undesirable to minimally acceptable,’’ and below 0.60 is ‘‘unacceptable.’’ The Cronbach’s alpha values of all 25 items ranged from 0.88 (lower secondary school students) to0.93 (upper secondary school students). Analogous values of coefficients were reported by Glynn *et al.* (2011) for the scales of SMQ II.

Boys and girls as well lower and upper secondary school students were compared on their motivation components using the mean factor-based scale scores (Table 8). We adopted the factor-based scale scores instead of the estimated factor scores because the former are more easily interpreted and can also be used for comparison between studies (Glynn *et al.*, 2011). A two-way ANOVA was conducted to determine possible differences in students' mean scores on the scales of CMQ II according to age (lower secondary school and upper secondary school), gender (boys and girls), and the interaction of these variables.

The ANOVA results revealed a significant main effect of students' age on their grade motivation scores, $F(1, 326)=9.242$, $p<0.05$. Moreover, there were significant main effects of students’ gender on their self-determination scores, $F(1, 326)= 13.108$, $p<0.001$, their career motivation scores, $F(1, 326)= 6.209$, $p<0.05$, and the intrinsic motivation scores, $F(1, 326)= 15.077$, $p<0.001$. Nevertheless, no significant interactions ($p > 0.05$) were observed between age and gender for any of the students' scores on the scales of CMQ II. This actually means that the effect of the students’ age on their grade motivation scores is fairly similar for male and female students.The effect of gender on self-determination, career motivation, and intrinsic motivation scores is also similar for lower and upper secondary students.

Table 8: Descriptive statistics of CMQ II scales among boys and girls students in lower and upper secondary school.

	Lower secondary				Upper Secondary		
	Boys (n=67)	Girls (n=79)	Total (n=146)		Boys (n=96)	Girls (n=88)	Total (n=184)
Grade motivation (min=0, max=20)							
M	14.69	15.32	**15.03**		13.34	13.73	**13.53**
sd	4.01	4.06	**4.03**		4.81	4.30	**4.56**
Self-efficacy (min=0, max=20)							
M	11.90	11.71	11.80		12.81	12.53	12.68
sd	4.42	3.44	3.91		4.21	3.86	4.04
Self-determination (min=0, max=20)							
M	**9.87**	**11.30**	10.64		**9.66**	**11.28**	10.43
sd	**4.09**	**3.69**	3.93		**4.02**	**3.45**	3.84
Career motivation (min=0, max=20)							
M	**8.33**	**10.15**	9.32		8.76	9.65	9.19
sd	**4.53**	**4.21**	4.44		5.15	5.42	5.29
Intrinsic motivation (min=1, max=20)							
M	**11.08**	**13.30**	12.28		11.53	12.73	12.10
sd	**3.92**	**3.37**	3.79		4.44	3.96	4.25

Note: The results of the factors that showed statistically significant differences areshown in bold

The mean factor-based scale scores are shown in Table 8. Examination of the means in Table 8 and the results of ANOVA show that lower secondary school students have significantly higher scores on grade motivation than students in upper secondary school. In regard with gender, statistical analysis indicates the following: a) Girls in lower secondary school have significantly higher scores on self-determination, career motivation and intrinsic motivation relative to boys of the same age, b) Girls in upper secondary school have statistically significant higher score in self-determination relative to boys of the same age.

Discussion

Validity and reliability of quantitative measurements are the two most important aspects of educational research. Although the use of existing instruments is convenient, these instruments should not be used without sufficient evidence of their ability to produce valid and reliable scores in the desired context. Only if the instruments' scores are valid and reliable they can result to valid interpretations, and can lead to potentially gainful decisions for students as well as for educational researchers and policy makers. Consequently, access to valid instruments is crucial for researchers conducting quantitative research in chemistry education.

Thus the first main contribution of this work is the provision of solid experimental evidence for the validity and reliability of the SMQ II instrument, originally developed for measuring motivation among college students in USA (Glynn *et al.*, 2011), in a specific science subject (Chemistry) a different cultural context (Greece) and in students belonging to a younger age group (14-17 y) and a different educational level (secondary school). This opens the possibility for reliable measurement of students' motivation within the Greek cultural context for the first time and in addition for reliable cross-cultural comparisons of students' motivation via the use of the same valid instrument. The second main contribution of this work is the investigation of Greek secondary school students' motivation to learn chemistry for the first time.

Confirmatory Factor Analysis (CFA) was used to test the hypothesized motivational structure proposed by Glynn *et al.*(2011) for students' motivation to learn chemistry, for the Greek version of the chemistry-specific original questionnaire (Greek-CMQ II). It is important to note that CFA was employed not only in order to verify whether the original factor structure could be validated, but also in order to examine whether the measurement structure underlying motivation to learn chemistry is equivalent within the (sub)groups corresponding to gender and age. In previous studies, comparisons between group means were made based on the assumption that the measures of motivation are fully applicable within the specific groups as well. In our study, we first used multi-group CFA in order to confirm that the measures are invariant within groups and subsequently conducted comparisons between these groups (Byrne, 2010; Kline, 2011). The results of statistical analyses provided evidence supporting the construct validity of Greek CMQ-II, as well as for configural, metric and scalar invariance, thus allowing meaningful comparisons between groups. Thus the five component model of motivation consisting of grade motivation, career motivation, intrinsic motivation, self-efficacy, and self-determination was also confirmed for the Greek version of CMQ-II. The scales were positively related, consistent with the view that the components were mutually supporting. In particular, intrinsic motivation and career motivation were strongly related, suggesting that intrinsic motivation orientates students to careers that involve chemistry. Self-efficacy and grade motivation were also strongly related, supporting that self-efficacy predicts students' performance, in line with previous studies' findings (Britner, 2008; Schraw *et al.*, 2005; Taasoobshirazi and Glynn, 2009; Zusho *et al.*, 2003). Although most correlations between scales of CMQ II are similar with those of SMQ II (Glynn *et al.*, 2011), the correlations between self-efficacy and grade motivation, as well as between intrinsic motivation and grade motivation are higher. This finding might be interpreted by the main idea of self-determination theory that there is not a clear distinction between intrinsic and extrinsic types of motivation but motivated behaviours vary in the degree to which they are autonomous (intrinsically motivated) vs. controlled (career or grade motivated) (Ryan and Deci, 2000). The reliabilities (internal consistencies) of the scales of the Greek version of CMQ II for all four subgroups namely girls, boys, lower, and upper secondary school students, assessed by Cronbach's alpha values, were analogous of those reported by Glynn *et al.* (2011) for the scales of SMQ II. Particularly, the reliabilities of the scales for upper secondary school students are very similar to those reported by Glynn *et al.* (2011) for college students, suggesting the very good fitness of the scales for these ages.

Our findings suggest that the structure of CMQ II (number of factors and factor-item association) is not dependent on gender and age group. In addition, both genders and age groups have equal strengths of relations between the underlying constructs and specific scale items.

Furthermore, our findings revealed interesting statistically significant differences between specific means of the CMQ II scales across the genders and the examined age groups. More specifically, lower secondary students had higher mean score on grade motivation than upper secondary students. In the other four scales, there is no evidence for statistically significant differences between the two age groups. Previous research findings support that most students show a progressive deterioration on school-related attitudes and motivation (Gentry *et al.*, 2002; Gottfried *et al.*, 2001; Wigfield and Eccles, 2002). Our work provides similar evidence only for the motivation component related with grade motivation. Although the decline in students' motivation to learn science has been documented and is evidenced by many science teachers, studies have shown that this decline is not an attribute of adolescence, but a result of school and class context (Nolen, 2003; Vedder-Weiss and Fortus, 2011). A limitation of the present study is the fact that it is based on a cross-sectional research design. Cross-sectional samples do not accurately capture true intra-person change and preclude assessment of measurement invariance over time and as people age. A longitudinal research design is required in order to address these concerns.

In regard with differences between genders, secondary school female students exhibited higher means than male on self-determination irrespective of age group. Furthermore, the female students of the younger age group (lower secondary school) had higher means than corresponding male students on two additional motivational components: career motivation and intrinsic motivation. No significant inter-gender differences were found for the grade motivation and self-efficacy component scales. The results related with the difference between boys and girls in self-determination are in line with findings from previous studies (e.g. Cavallo *et al.*, 2004; Glynn *et al.*, 2009; 2011). However, our findings contradict those of Glynn *et al.* (2011) which indicated that men had higher self-efficacy than women, but are in line with those of Britner (2008) which indicate no gender differences in self-efficacy in physical science. Concentrating on the comparison of this work with the results of Glynn *et al.* (2011), since in both cases measurements were made via the use of equivalent instruments (SMQ II and Greek CMQ II), the documented differences concerning the inter-gender comparison of motivation could be attributed to several factors (acting separately or synergistically) such as: a) different age of students, b) different cultural context, c) different educational context, d) investigation of a specific science domain (chemistry) in our case. Research on gender differences in motivation to learn science and mathematics (Li, 1999; Tenenbaum and Leaper, 2003) points out that such differences are attributed to social influences (eg family, teachers, friends, media) rather than to natural differences between boys and girls. Such a social influence that could possibly justify the herein documented increased motivation of female lower and/or upper secondary school students relative to their male classmates with regard to self-determination, career motivation and intrinsic motivation, is the increased ratio of female vs male chemistry teachers in Greek secondary education. The large presence of female chemistry teachers in Greek secondary schools serves as a positive role model for the female students.

Elaborating more on the comparison of the total scores of our results with those of Glynn *et al*. (2011), the following main comments can be made:

i) An interesting finding of our work is related with the especially low mean factor-based scores of the career motivation scale. As seen in Table 8, the absolute values of these scores are the lowest relative to the other four motivation components and below 10 (in a scale from 0 – 20) for the whole sample (equal to 9.39/20 and 9.19/20 in the two age groups). These scores are much lower relative to the one of science majors in USA (that is equal to 15.95/20) which is not a surprising finding since the sample of the latter case involves older students who already pursue studies related with a career in science. However, the career motivation scores of the Greek students are also significantly lower relative to the corresponding score of the non-science majors in USA (equal to 11.13). Thus, the present study provides a direct measurement of the poor motivation of Greek students to pursue a chemistry related career, a fact which was inferred in the study of Salta *et al.* (2012).

ii) With regard to self-determination, the cross-cultural comparison reveals a very similar pattern with the one discussed above for career motivation. In fact, Greek secondary school students have a quite low mean absolute score in self-determination (10.64/20 and 10.43/20 in the two age groups) which is much lower from the corresponding scores of college students in USA (equal to 15.20/20 and 13.61/20 for science and non-science majors respectively). This large documented difference in self-determination between the two countries could be partly related with the different educational context of the examined student samples. A college learning environment is often more flexibly structured relative to secondary school. However, the especially low self-determination scores of Greek secondary school students could also be linked to certain features of the Greek chemistry curriculum. In fact, as recently pointed out by Greek researchers in science education (Halkia and Mantzouridis, 2005), the demanding content of the Greek chemistry curriculum poses major difficulties to the teachers since it leaves them very little freedom to use other teaching resources apart from the provided science textbook. This chemistry curriculum has to be covered in a small number of teaching hours (1 or 2 per week depending on grade, see Table 1). In addition, the possibility for hands-on experimentation is also very limited (2-4 one-hour lab experiments per year depending on grade, see Table 2). These structural characteristics of the Greek educational system are expected to have a detrimental effect on Greek secondary school students' sense of control over their learning chemistry (self-determination) as well as in the other components of motivation to learn chemistry.

iii) The total mean scores of grade motivation of college students in USA (equal to 16.96/20 and 16.11/20 for science and non-science) are much higher relative to the one of upper secondary school Greek students (equal to 13.53/20) and increased also relative to the one of Greek lower secondary school students (equal to 15.03/20). This difference could be most closely related to the different educational context of the two student samples. College students (irrespective of major) have already made a conscious choice of pursuing higher level studies for getting a tertiary degree while high school students are not in a position to make specific choices over the courses they have to study for getting their secondary education certificate.

iv) With regard to the remaining two motivation components, self-efficacy and intrinsic motivation, the mean scores displayed by the Greek secondary school students are decreased relative to college science majors but quite similar in magnitude with non-science majors in USA. The increased values for science majors are not surprising taking into account the fact that these are students who have already chosen a study path related to science. On the other hand, the display of similar self-efficacy and intrinsic motivational characteristics between students who have consciously chosen a non-science major (USA) and secondary education students (Greece) may be, among others, related to perceptions most students tend to have about the nature of the chemistry course irrespective of country of origin.

Research studies that provide novel empirical and/or theoretical content on a science education topic in a novel educational context are expected to provide significant contributions to scientific knowledge (Taber, 2012). The availability of a valid tool, such as the Greek version of Chemistry Motivation Questionnaire II, for exploring quantitatively the motivation of Greek secondary school students to learn chemistry opens several new possibilities for researchers, chemistry educators as well as educational policy makers in Greece. Its application to carefully selected student samples could provide valuable information and feedback which can be employed for increasing the effectiveness of chemistry curricula, teaching materials and teaching methodologies. Future research should be focused on identifying the elements of school culture and teacher practices which have the strongest influence on students' motivation for chemistry learning as well as their in-between interactions.

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