View Article Online / Journal Homepage / Table of Contents for this issue
Dynamic Article Links

Chemistry Education Research and Practice

Cite this: *Chem. Educ. Res. Pract.*, 2012, **13**, 437–446

www.rsc.org/cerp

PAPER

Discovering factors that influence the decision to pursue a chemistry-related career: A comparative analysis of the experiences of non scientist adults and chemistry teachers in Greece

Katerina Salta,[b] Michael Gekos,[b] Irene Petsimeri[c] and Dionysios Koulougliotis*[a]

Received 5th May 2012, Accepted 9th June 2012
DOI: 10.1039/c2rp20053h

This study aims at identifying factors that influence students' choice not to pursue a chemistry-related career by analyzing the experiences of secondary education chemistry teachers in Greece and of Greek adults who have not pursued studies related to science. Data collection was done with the method of individual structured interviews. The comparative analysis of the answers given by 10 adults and 10 chemistry teachers, shows that there is a noteworthy agreement between the factors pointed out by the two independent groups. These factors—proposed to form an interconnected grid—are related to the following issues: the nature of school chemistry, the instructional content and context, the students' characteristics and the status of chemistry in the Greek educational system and Greek society.

Introduction

There is a continuously increasing body of research related to teaching and learning science. All over the world, science educators and researchers have expressed concerns about the outcomes of science education at school. Previous research has pointed out the lack of interest and engagement in science among high school students (George and Kaplan, 1998). Many students consider science irrelevant to their personal interests and goals and are unaware of how many jobs require this type of knowledge (Aschbacher *et al.*, 2010). Many western countries have problems with fewer and fewer adolescents, especially female, choosing to pursue careers in science (Jacobs and Simpkins, 2005). Therefore, understanding students' rationale behind a career choice has become an important research topic in science education. Several studies have been conducted in order to identify factors and influences on students' science career choices, primarily through small case studies, large quantitative datasets and through longitudinal interview and surveys. Key components that were revealed by these studies include: (a) students' attitudes, motivation, self-efficacy and academic achievement (Glynn *et al.*, 2007; Wang and Staver, 2001); (b) school influence—school environment, instructional quantity, school experiences (Britner, 2008; Christidou, 2006; Gilmartin *et al.*, 2006; Wang and Staver, 2001); (c) parental influence—parental push, socioeconomic status, home environment (Cleaves, 2005; Dalgety and Coll, 2004; Gilmartin *et al.*, 2006; Wang and Staver, 2001); (d) social influence—social encouragement, informal science program (Fadigan and Hammrich, 2004; Stake, 2006).

Students' interests, motivations, and beliefs about themselves have a far-reaching impact on their persistence and participation in science. A large body of research using the Social Cognitive Career Theory has also pointed out that interest has a large impact on career choices (Fouad and Smith, 1996; Fouad *et al.*, 2002; Lent *et al.*, 1994; Lent *et al.*, 2003). Many research studies employing the social cognitive career choice model indicate that performance (often in the form of grades received) influences self-efficacy, which in turn influences career goals and choices (Fouad and Smith, 1996; Fouad *et al.*, 2002; Lent *et al.*, 1994; Lent *et al.*, 2003). Thus, performance has a direct effect on how students perceive themselves in relation to a field such as science, and this perception influences their career choices or persistence as well as their future performance. In a recent study by Zeldin *et al.* (2008) students' self-efficacy beliefs were found to be powerful contributors to their selection of, and success in, science-related occupations.

In a study by Wang and Staver (2001), students' career aspirations were shown to be positively linked with the following three factors: (a) educational outcomes (science achievement, attitudes toward science), (b) instructional quantity (homework and schoolwork hours), and (c) home environment (parental science and academic pushes, socioeconomic status). In another study (Stake, 2006), evidence was provided for the critical role of encouragement from social agents (family, teachers, and peers) in the development of adolescents' motivation and confidence to achieve in science. Aschbacher *et al.* (2010) ascertained that few adults at home or school enthusiastically invite students to learn about science, to value scientific ways of knowing, or to pursue a

[a] *Technological Educational Institute (TEI) of Ionian Islands, Department of Environmental Technology and Ecology, 2 Calvou Sq., 29100, Zakynthos, Greece. E-mail: dkoul@teiion.gr; Fax: +30-26950-24949; Tel: +30-26950-24940*
[b] *University of Athens, Department of Chemistry, Athens, Greece*
[c] *1st Lower Secondary School of Ilioupoli, Athens, Greece*

science degree or career. Students who liked science, were good at it and showed a sense of passion and purpose towards a science career, tended to have parents or teachers, who acted as guides. Regarding the in-school factors influencing student career choice, Roberts and Wassersug's (2008) research data suggest that more hands-on high school science research programs could help increase the number of students entering and maintaining scientific careers. On the other hand, an examination of effects of science class-related variables on students' interests in a science career indicated that students' perceptions of their science class experiences are not strongly related to their science career aspirations, regardless of gender (Gilmartin *et al.*, 2006).

Chemistry has a similar problem, with a decline of students' aspirations to engage in chemistry-related careers. Using data from the Program for International Student Assessment 2006 surveys for 50 countries, Sikora and Pokropek (2012) explored gender segregation of adolescent science career plans. In all examined countries, science-oriented girls prefer employment in biology, agriculture, or health, whereas boys favour careers in computing, engineering, or mathematics. Chemistry was not a popular career choice for either boys or girls. In Greece, as well as in other countries, a decreasing number of high school students choose chemistry as a study subject every year, and the same trend appears in the number of those who follow their studies in chemistry through higher education. The percentage of students whose first choice for tertiary education is a Chemistry department is much smaller than the respective first choice percentages of Physics and Mathematics departments. Many studies have attempted to shed light on students' alienation from school chemistry, and several aspects have been identified. The public image of chemistry, the difficulties arising from the nature of school chemistry and the students' attitudes towards chemistry are some of them, and they will be briefly discussed in the next section. It is important to note that the publications referred are written recently (last decade), and they also include several studies which have been conducted by Greek researchers in the Greek school context.

Students' alienation from school chemistry

Chemistry is often considered a dangerous science. In fact, the word "chemical" has obtained a negative connotation due to the environmental pollution caused by the by-products of chemical industry and the incorrect use of chemicals. The end result is called "chemophobia", a term denoting the absurd fear for chemicals and chemistry (Kafetzopoulos *et al.*, 2006). Students also have images of scientists and chemists as 'being in white coats', using 'test tubes in labs', chemists as 'hard working', 'nerdy', 'boring', 'perfectionist' (Cleaves, 2005; Dalgety and Coll, 2004; Medhat, 2003). Such images might be perpetuated by the media, and might influence pupils' decision making (Kniveton, 2004).

Chemists generally present concepts at three levels of representation: the macroscopic, sub-microscopic, and symbolic levels (Gilbert and Treagust, 2009). Many phenomena are available to direct experience (macroscopic level), but their explanation requires knowledge of the molecular structure and the interaction between atoms, molecules, ions, *etc.* (submicroscopic level). To represent these phenomena, chemists have invented specialized symbol systems like molecular formulas, chemical equations, *etc.* (symbolic level), which help them to communicate and visualize chemistry (Hoffmann and Laszlo, 1991; Mathewson, 2005). As a result, it is a school subject that has high conceptual demands.

Students generally find that chemistry is a difficult subject (especially in comparison to other subjects). This includes perceptions of the chemistry curriculum as abstract, boring and content heavy (Cleaves, 2005; Murray and Reiss, 2005). Understanding and learning core chemistry concepts and principles is difficult and many research studies were conducted to identify the major difficulties and their key causes (Treagust *et al.*, 2000). Many of the students' difficulties in learning chemistry are directly related to the specific nature of chemistry which requires students to move from the macroscopic to the microscopic level, to use chemical symbols, and to visualize also abstract concepts such as the shape of a molecule into a two-dimensional page (Charistos *et al.*, 2003; Chittleborough and Treagust, 2000). Moreover, students have difficulties in solving chemical problems which require mathematical skills (Salta and Tzougraki, 2004). Students' difficulties are also related to the following three cognitive variables (Tsitsipis *et al.*, 2010): ability for formal operational reasoning (logical thinking), field independence (ability to identify the most important information from the general context) and convergent/divergent thinking. The most important predictive variable was shown to be the ability for logical thinking. An interesting finding of this study is the importance of divergent thinking in understanding certain chemistry concepts. Divergent thinking is closely related with language skills and ability. This brings us to another barrier to chemistry learning, the one related to the formal and abstract nature of the scientific language and the commonly used communication code in standard chemistry (and science) textbooks (Halkia and Mantzouridis, 2005; Stefani and Tsaparlis, 2009). Traditional chemistry textbooks tend to give a large emphasis in theory and use unfamiliar language that creates difficulties and discourages the average student (Halkia and Mantzouridis, 2005; Salta and Tzougraki, 2004). The difficulties in learning chemistry relate also to the rote application of concepts and algorithms (Salta and Tzougraki, 2011).

The chemistry course seems to be one of the least enjoyed among science subjects (Reiss, 2001). The extent and quality of practical activity in school chemistry is an important factor affecting students' attitudes towards chemistry. Salta and Tzougraki (2004) found that Greek students have a neutral/negative attitude regarding the interest of the chemistry course. It is noted that some of the reasons that form such an attitude are related to the content of the chemistry curriculum, the limited amount of time for chemistry lessons (one hour per week), the methods of teaching chemistry in Greek schools and the lack of laboratory experiments. In Greece, chemistry is usually taught in a theory oriented approach without hands-on activities and this practice decreases students' interest for the course. The majority of Greek students tend to recognize that chemistry knowledge is useful for interpreting aspects of everyday life, but few of them (about 4%) express the wish to study chemistry at University. It is hopeful however that most students believe that chemistry contributes to solving environmental problems and that it improves our lives. Overall, Greek students have a more positive attitude regarding the importance of chemistry and a negative/neutral attitude regarding the usefulness of the chemistry course, the difficulty and the interest. The overlying 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 (Halkia and Mantzouridis, 2005). Generally, a negative attitude toward a subject leads to lack of interest and avoidance of it when there is a choice. In contrast, a positive attitude of students towards chemistry leads to lifelong interest and continuous learning in this subject (Koren and Bar, 2009).

Yet there is still much to understand about how students perceive and pursue their chemistry interest and career options. To investigate these issues, the present study uses a multiple case study design, using retrospective interviews, to explore factors that influence students' choice not to pursue a chemistry-related career in Greece. The two samples, non scientist adults and chemistry teachers, allow us for deeper probing of key questions to better understand students' choices from different perspectives. The so far undertaken research focuses solely either on students or on adults' perceptions related to career choice. In the present study, we take into account two sources of information simultaneously, namely those of non scientist adults and of chemistry teachers. We undertake a retrospective study focusing on non scientist adults' experiences, in accordance to the proposed distinction between students' engagement with school science (which they may find fun, exciting, important, and interesting) and the percentage of students pursuing the study of science at higher level, as pointed out by Archer *et al.* (2010). We chose to examine the teachers' perceptions in an effort to make a connection between the students and adults' perspectives. Specifically, the research questions that have guided this study are the following:

• How non scientist adults describe their experiences from school chemistry?

• How secondary chemistry teachers describe students' experiences from school chemistry?

• How students' experiences influence their decision making not to pursue a chemistry-related career?

Methodology

We used a multiple case study design to examine factors that influence students' decision to choose a chemistry career through the experiences of Greek non scientist adults and secondary education chemistry teachers, with a strong emphasis on constant comparative methodology (Boeije, 2002). A case study approach is most appropriate when the phenomenon of interest has ill-defined boundaries and real-life complexity that requires multiple data sources and methods to gain an in-depth understanding (Yin, 2003). A multiple case study design has all the advantages of a single case design in capturing real-world contexts, but by repeating the procedures on multiple cases, this replication enhances the validity of the findings. We focused on the perspectives of non-scientists adult learners and secondary education chemistry teachers to investigate factors that influence students to choose a chemistry career.

Participants

Subjects were chosen for this study by using a purposeful sampling method aiming to clarify students' rationale for their choice not to pursue careers in chemistry (Rossman and Rallis, 2003). The main goal for utilizing this sampling method was to select participants that represented the variance of the experience of school chemistry based on the time and content taught. In this study, prior school experience, gender and age served as the primary criteria used for sampling participants (Table 1).

The sample consisted of 20 volunteers selected from two groups that represent different degrees of experience with chemistry education. A brief description of each group follows: The first group ("group I" or "adults") were graduates of Higher Education but with a degree not related to physical sciences (N_I = 10) and their selection was based on the following criteria: a wide range of studies and consequently a variance of school experience, gender (6 male, 4 female), wide age range (between 23 and 58 years) translating to a large variety of experience with chemistry. The second group ("group II" or "chemistry teachers") were chemistry teachers at secondary schools (N_{II} = 10) and their selection criteria were the following: variable teaching experience in secondary schools (relatively little (2), average (3), large (5), teaching experience in both public and private schools (8 and 2 respectively) in order to have an overview of the Greek educational system and finally gender (4 male, 6 female).

Data collection

The study from which the current data are drawn examined participants' perceptions of factors influencing students to choose a chemistry career using a scripted, semi-structured interview format. The aspects of chemistry career choice were identified by members of our research team through a theoretical analysis of the literature in science education as well as a review of prior work in chemistry education cited in the Introduction section. The interviews were based on a set of sequentially ordered core questions, with follow-up questions asked for clarification where needed. The questions were different for the two groups.

Table 1 Criteria for sampling of participants

Criterion (Adults)	Group I (Adults) N_I = 10	Criterion (Teachers)	Group II (Teachers) N_{II} = 10
Gender		*Gender*	
Male	6	Male	4
Female	4	Female	6
Age (years)		*School legal status*	
23–40	6	Public	8
41–58	4	Private	2
Studies		*Teaching experience (years)*	
Economist	3	Less than 5	2
Teachers	2	5–10	3
Philologists	2	More than 10	5
Health professional	1		
Mathematician	1		
Navy officer	1		

The interviews of adults included the three following thematic sections (an example question is given in parentheses):

A. The reasoning behind their career choice. (Why didn't you choose to pursue a chemistry-related career?)

B. The experience from their education in chemistry. (What are the main difficulties encountered in the chemistry course at school?)

C. The information on topics that are related to chemistry. (Can you understand the information provided by the media on issues related with chemistry?)

The questions responded by chemistry teachers included two topics as well, which are listed below (an example question is given in parentheses):

A. The experience from teaching chemistry. (What are the main difficulties you face when teaching chemistry?)

B. The interpretations for the non-selection by students to study chemistry. (Why in your opinion, many children do not select to study chemistry?)

Each participant was interviewed individually for approximately 20–30 min. The interviews were taped and transcribed. The text that resulted from transcription provided the input for the analysis process which was done in order to reconstruct the perspectives of the two groups under study. The analysis proceeded through a coding–recoding study cycle for identifying major themes (Miles and Hubermann, 1994) and through a three step approach for constant comparison (Boeije, 2002).

Data analysis

The early analysis of the interview data was inductive, allowing important themes to emerge from the data (Patton, 1990). Our inductive method was combined with a simultaneous constant comparative analysis method (Boeije, 2002), which allowed us to group answers to common questions and analyze the different perspectives of our interviewees on central issues related with the process of career choice. This process of constant comparison leads to both descriptive and explanatory categories (Lincoln and Guba, 1985). We increased the internal trustworthiness of our findings through our constant comparison and reflection on material collected (Boeije, 2002). Member-checking procedures were carried out to further ensure the trustworthiness of our interpretations as we shared emerging themes with the participants (Miles and Huberman, 1994).

In this study, analysis began by coding data after the completion of the first interview. The goal of coding is the identification of those concepts that are repeatedly present in the data, a process which ultimately leads to synthesis and to the drawing of an inference. Along with the process of focused coding, a constant comparison of data sets provided additional means for forming categories and identifying analytic distinctions. This recursive process continued until the data was "saturated", and no new categories could be developed from the collected data. In the final stage of the analysis, the constant comparative technique was used to form the synthesized description of factors influencing chemistry career choice by adults and chemistry teachers, representing a synthesis of consistent themes and categories derived from the participant's descriptions. A primary means for establishing internal validity was the triangulation of data sources that results in the formation of categories and themes grounded in the data (Boeije, 2002; Creswell and Miller, 2000).

At the start of the analysis (first step), the comparison was conducted within one single interview. In the process of open coding, every paragraph of the interview was parsed into text segments ranging in length from a single word to a paragraph. Each segment was addressed with a single meaning and labelled with an adequate code. The segments were then compared to find out what they had in common, how they differed, in what context the interviewee made the remarks and which dimensions or aspects of our subject were highlighted. The aim of this internal comparison in the context of the open coding process was to develop categories incorporating in them the appropriate codes. Moreover, by comparing different parts of an interview, the consistency of the interview as a whole was examined. All interviews of both groups were treated as described above. In the second step, the comparison was between interviews within the same group. Firstly, segments from different interviews of group I (adults) that had been labelled with the same code were compared. In many cases, some codes were combined with other codes to form a pattern or category. The interviews of chemistry teachers (group II) were analyzed in the same way as those of the adults. The final step was the comparison of the interviews from group I (adults) with those from group II (teachers) in order to enrich the information and to complete the picture already obtained by the last step.

Results

The initial analysis generated a list of provisional codes which is the beginning of the process of conceptualization. The aim of the second step of analysis was to further develop the conceptualization of our subject resulting in an extension of the amount of codes until their "saturation" (Table 2).

Four families of codes (categories) were drawn from the data (participants' comments) and they are related to the following four general issues: the nature of school chemistry, the instructional content and context, the students' characteristics and the status of chemistry. The "*Nature of school chemistry*" codes refer to statements in which the participants mentioned at least one aspect of chemistry as a source of students' difficulties. "*Instructional content and context*" codes refer to statements by the participants that are related to the teaching content and the teaching approaches. "*Students' characteristics*" codes refer to statements that reveal attitudes, beliefs and other characteristics of students as barriers to chemistry learning. Finally, "*Status of chemistry*" codes include socio-educational aspects, such as the perspective of employment (job availability). The analysis of the results for each separate category are given below.

Nature of school chemistry

Nature of school chemistry codes were assigned to utterances that refer to specific characteristics of chemistry as a learning subject, which pose difficulties/barriers to chemistry learning. The code "Abstract concepts" refers to chemistry concepts/aspects that cannot be associated with common experience in a straightforward manner. The code "Difficult concepts" refers to chemistry concepts/processes that are often too difficult to comprehend due to their intrinsic nature (*e.g.*, the concept of

Table 2 Interview codes summary. The (+/−) signs correspond to the presence/absence of the specific code from the data analysis of the respective group

Categories: Codes	Group I (Adults)	Group II (Teachers)	Description
Nature of school chemistry:			Codes refer to statements in which the participants mentioned at least one aspect of chemistry as a source of students' difficulties.
• Abstract concepts	+	+	
• Difficult concepts	+	+	
• New language	−	+	
• Difficult subject	+	+	
Instructional content and context:			Codes refer to statements related to the teaching content and the teaching approaches.
• Theory *vs.* Everyday life approach	+	+	
• Rote learning	+	+	
• Textbooks	+	+	
• Teacher's language/ability	+	+	
• Fragmentary content	−	+	
Students' characteristics:			Codes refer to statements that reveal attitudes, beliefs and other characteristics of students as barriers to chemistry study and learning.
• Interest	+	+	
• Aptitude	+	+	
• Preference	+	−	
• Self-efficacy	+	+	
• Bias or prejudice	−	+	
• Knowledge gaps	+	−	
Status of chemistry:			Codes include socio-educational aspects, such as the perspective of employment.
• Minor course	−	+	
• Allocated teaching time	+	+	
• Employment possibilities	+	+	

volume, the concept of chemical equilibrium). The code "Difficult subject" refers to how chemistry is perceived or considered as well as to the effort/hard work/persistence required for learning the subject. The code "New language" refers to the symbolic characters used for the representation of matter as well as to the formality and technical nature of the scientific language employed. Below we quote some representative participants' comments from both groups which are related to codes belonging to the "Nature of school chemistry" category. The specific assigned code is also given in parentheses. As also shown in Table 2, three out of the four identified codes are common in both groups. These common codes are the following: "Abstract concepts", "Difficult concepts" and "Difficult subject". The special language of chemistry ("New language") was also identified as a barrier to chemistry learning, however only by one of the two groups examined (Group II – Teachers).

Adults' quotations (Group I). Adult 3: - *I found Organic Chemistry to be especially difficult* ... (Difficult subject)

Adult 4: - *It* (*the chemistry course*) *was creating too many difficulties and I was getting very poor grades* ... (Difficult subject)

- *For me, it was difficult to grasp the concepts of the course* ... (Difficult concepts)

Adult 9: - *specifically when we reached the periodic table or this plum pudding model of the atom, I got really confused* (Difficult concepts, Abstract concepts)

Adult 10: - *chemistry was something that I could not perceive with my senses* ... (Abstract concepts)

Teachers' quotations (Group II). Teacher 1: - *I believe that the subject on its own* (*and physical sciences in general*) *presents difficulties* ... (Difficult subject)

- *Chemistry has this special feature relative to physics, I mean this symbolic character in which the student has to get used to* ... (New language)

- *I believe that there exist concepts which are abstract and difficult to understand fully, as for example the concept of energy which is of central importance in the physical sciences*... (Difficult concepts, Abstract concepts)

Teacher 7: ... *the difficulty of the subject is definitely an issue* ... (Difficult subject)

Teacher 8: - *First of all, chemistry is a difficult subject and requires learning a new language* ... (New language, Difficult subject)

Teacher 10: - *I believe that it* (*chemistry*) *is difficult as subject, it requires that somebody possesses good memory and logical thinking* ... (Difficult subject)

Instructional content and context

Instructional content and context codes were assigned to utterances that made reference to specific aspects of the instructional content that the two groups were following. Moreover, they referred to teaching/learning approaches and the instructional context, such as emphasis on rote learning, on teaching theoretically without practical experimentation, or by making no links between chemistry and everyday life. The code "Fragmentary content" refers to pieces of knowledge which are not well connected with each other or in which the existing connection is not adequately given either by the teacher or in the textbook. Below we quote some representative participants' comments from both groups which are related to codes belonging to the "Instructional content and context" category. The specific assigned code is also given in parentheses. As also shown in Table 2, four out of the five identified codes as barriers to chemistry study and learning are common in both groups. These common codes are the following: "Theory *vs.* Everyday life approach", "Rote learning", "Textbooks" and "Teachers' language/ability". We point out that the code "Textbooks" refers to the inadequacy of the chemistry textbooks employed, while the "Teachers' language/ability" code refers to the inadequacy of the teachers to inspire enthusiasm to the students and/or to the choice of words made by the teachers which is often not understood by the students. One code ("Fragmentary content") was identified as a barrier only by the chemistry teachers (Group II).

Adults' quotations (Group I). Adult 1: - *Experimentation was totally absent*; *everything was taught theoretically*, *on a piece of paper* . . . (Theory *vs.* Everyday life approach)

Adult 2: - *From the chemistry teachers I did not get any stimulus for following this type of study* . . . (Teacher's language/ability)

Adult 3: - *I was finding my chemistry teacher unable to transfer knowledge and very bad in general and I also did not especially like the textbook*, *it was not a good textbook* . . . (Teacher's language/ability, Textbooks)

Adult 6: - *We had to learn several things by heart* . . . (Rote learning)

Adult 7: - *We had a teacher who did not explain the concepts very well*, *he was using a very scientific language*, *and this is how problems started* . . . (Teacher's language/ability)

Teachers' quotations (Group II). Teacher 2: - *not a lot of experiments are done and in this way students perceive chemistry as a theoretical course* . . . (Theory *vs.* Everyday life approach)

- *In upper secondary school*, *textbooks present too specialized knowledge and with no connection with everyday life*, *which is of major importance in a chemistry course*. *This everyday life knowledge does not exist in the chemistry textbooks and it is not taught* (Theory *vs.* Everyday life approach, Textbooks)

Teacher 3: - *The course is taught in a manner that no connection with everyday life is shown so that it becomes more amenable to the student's experiences and interests*. . . (Theory *vs.* Everyday life approach)

- *I have realized that the kind of language a teacher uses when he is teaching is of major importance*. . . (Teacher's language/ability)

- *This is a more general problem in chemistry*; *I mean the fact that the pieces of knowledge are often not connected with each other*, *they are fragmentary* . . . (Fragmentary content)

Teacher 4: - *We should not present chemistry as pieces of knowledge that should be learnt by heart* . . . (Rote learning)

- *We should be given the possibility to bring students in contact with real chemistry*, *not the pure science of the textbooks*, *but the chemistry which is present everywhere in our daily routine* . . . (Theory *vs.* Everyday life approach)

Teacher 6: - *I believe that the chemistry course is difficult for the students because its teaching is fragmentary*, *the curriculum presents discontinuities in the transition between lower and upper secondary school* . . . (Fragmentary content)

- *we usually stick to a theoretical way of teaching chemistry*. . . (Theory *vs.* Everyday life approach)

Teacher 7: - *For sure*, *the chemistry textbooks are not very helpful* . . . (Textbooks)

- *It is important that the textbooks should be enriched with sections which show clearly the connection of the chemistry taught with everyday life activities and with students' interests*. . . (Theory *vs.* Everyday life approach, Textbooks)

Teacher 8: - *It would be interesting to do some research related to the quality of the textbooks*. *The chemistry textbooks are just terrible*, *written in a way that is unattractive and incomprehensible and which pushes students to search for private tutors* . . . (Textbooks)

Students' characteristics

Students' characteristics codes were assigned to participants utterances that identified different aspects of students as barriers to chemistry learning. The characteristics identified were the following: little or no "Interest", lack of "Aptitude", no "Preference" to the subject, little or no "Self-efficacy" in performing well in the subject, "Bias or prejudice" against the subject, "Knowledge gaps" in the subject which make it difficult to follow and understand deeply. The code "Interest" refers both to evaluative orientation towards chemistry or chemistry courses and to an emotional state aroused by specific features of a task. A different code, "Preference", was used to indicate an emotional process/function *via* which one choice is made relative to another. We adopted the code "Self-efficacy" to describe personal judgments of one's capabilities to organize and execute courses of action to attain designated goals. On the other hand, the code "Aptitude" is used to depict the potential for a specific talent or the capacity to acquire a specific skill.

Below we quote some representative participants' comments from both groups which are related to codes belonging to the "Students' characteristics" category. The specific assigned code is also given in parentheses. As also shown in Table 2, three out of the six identified codes as barriers to chemistry study and learning are common in both groups. These common codes are the following: "Interest", "Aptitude", and "Self-efficacy". The codes "Preference" and "Knowledge gaps" were noted only by Group I (Adults), while the code "Bias or prejudice" was noted only by "Group II (Teachers)".

Adults' quotations (Group I). Adult 2: - *I was attracted more by mathematics* . . . (Interest)

- *I had to learn many things on my own at home and I could not always manage that* . . . *for this reason I disliked the course* . . . (Self-efficacy, Preference)

- *I remember having many gaps related to basic chemistry principles* . . . (Knowledge gaps)

Adult 3: - *I did not have an aptitude for this course*, *I was not a good student* . . . (Aptitude)

Adult 4: - *I disliked courses such as physics*, *chemistry*, *biology* . . . (Preference)

- *Surely*, *I lacked knowledge which was prerequisite* . . . (Knowledge gaps)

Adult 5: - *I did not like the feeling of insecurity that no matter how hard I studied it was still possible I did not perform well in an exam* . . . (Self-efficacy)

Adult 7: - *When we examined the material a little more in depth*, *I was then realizing all my knowledge gaps and I did not like at all that feeling* . . . (Knowledge gaps)

- *I simply preferred to follow a profession not related with science or technology... so when I reached upper high school I chose the classical studies track* (Preference)

Teachers' quotations (Group II). Teacher 2: - *I believe very much in aptitude. There are students who have an aptitude for theoretical/classical courses and others who are more apt to science and technology courses. It is the way their mind works, it is what they really like*. (Aptitude)

Teacher 3: - *The main difficulty I encounter everyday in the classroom is that the students have no or little interest for the course* (*chemistry*)... (Interest)

Teacher 7: - *I believe that there is prejudice against the course; that it is very difficult ... and in my opinion this prejudice is much stronger than the difficulty itself...* (Prejudice)

- *Students think that the course is not related to anything that could be of interest to them; they consider it totally unrelated to their lives ...* (Interest)

- *There is a bias also from parents and the general environment, which subconsciously also affects the child in a negative way. So, when the child gets in contact with chemistry or physics in early high school, he(she) already has this preset idea that it is impossible to do well in these courses* (*due to their difficulty*) ... (Prejudice or Bias)

Teacher 10: - *while if they* (*the students*) *follow more theoretical or classical studies, they feel more confident that they can succeed since they only have to read through a book, instead of also having to solve problems, etc*. (Self-efficacy)

Status of chemistry

The "Status of chemistry" category of codes refers to factors that are related with different issues that result in the devaluation of chemistry as a course/subject/profession in the socio-economic framework. Three such codes were exported from the data analysis: "Minor course" which refers to the idea/public opinion that chemistry is a less important course relative to others offered in the school system, the little "Allocated teaching time", and "Employment" referring to the limited possibilities of finding a job or establishing a successful professional career. Among the different reasons for the low employment possibilities in chemistry in Greece, perhaps the most important ones are the lack of a flourishing chemical industry and the fact that in the Greek secondary school system chemistry is often taught by teachers of other disciplines (such as physicists or biologists). In respect to the little "Allocated teaching time", it is worth noting that in Greek lower secondary school, chemistry is first introduced in the 2nd year and it is taught for only one hour per week while all other science-related courses (Physics, Biology and Geography) are taught for two hours per week. In Greek upper secondary school, chemistry teaching time increases to two hours per week in the 1st and 2nd upper secondary school grades, while no chemistry is taught in the last (3rd) grade of upper secondary school. In addition, we need to note that the chemistry course is not a prerequisite for entrance to most science university faculties in Greece; in fact chemistry is a prerequisite course only for entering university faculties which are related with health sciences. As shown in Table 2, two out of the three identified codes of this category were found to be common in both groups ("Allocated teaching time" and "Employment") with the "Minor course" code being identified only by Group II (Teachers). Below we quote some representative participants' comments from both groups which are related to codes belonging to the "Status of chemistry" category. The specific assigned code is also given in parentheses.

Adults' quotations (Group I). Adult 9: - *The main criterion of my choice of study was the employment possibilities, and chemistry does not offer much* (*in Greece*) (Employment)

- *I remember that at secondary school, chemistry was taught only one hour per week; it was thus very hard to learn anything in depth and sustain interest for the subject ...* (Allocated teaching time)

Adult 10: - *In contrast* (*with chemistry*), *the army offered an assured future employment in the future ...* (Employment)

Teachers' quotations (Group II). Teacher 1: - *I think that there is a problem with the structure of the educational system. In upper secondary school especially, students are only interested in the few courses in which they will be examined for entering University. As a result, chemistry is considered a less important course*. (Minor course)

Teacher 3: - *One way or the other, one cannot learn many things in a course which is taught just one hour per week ...* (Allocated teaching time)

- *Children usually choose to follow studies that offer good or some employment possibility, so they usually do not choose chemistry, instead if they are good in science courses in secondary school they choose medicine ...* (Employment)

Teacher 5: - *The lack of teaching time is a major issue; I mean that we have to cover a large curriculum in a very short time period, one hour per week that is ...* (Allocated teaching time)

- *Children want to find a job, and in the last several years chemistry does not offer many employment possibilities; At least, it does not offer a job that does not require a lot of effort ...* (Employment)

Teacher 6: - *In such a short teaching time, we really do not have the possibility to actually show to the students why chemistry is an interesting and exciting science ...* (Allocated teaching time)

Teacher 7: - *The chemistry course has been pushed aside by the educational system... I mean that the students believe that a course which is taught only one hour per week is by definition inferior, less important ...* (Allocated teaching time, Minor course)

Discussion

The multiple case study analysis conducted in this work led to the identification of factors that influence students' decision not to choose a chemistry career by two different groups' perspectives; Greek non-scientists adults and Greek secondary education teachers. Four different categories of such factors were identified with each one containing several codes. The categories and respective codes which were identified to be common to both groups are depicted in Fig. 1.

At this point, it should be noted that the findings of the qualitative research conducted in this work are applicable only in the specific setting, *i.e.*, the Greek educational system and society.

However, the insights may provide assistance in the interpretation of other similar cases and encourage future research in a relatively unexplored area. Since a multiple case study approach is not easily open to cross-checking, there is the potential for selective bias. But, it is also important to note that the participants recruited in this study were highly motivated and cooperative with the research process. The reliability and validity of the reported findings have undoubtedly been strengthened due to their efforts and dedication. In this study, an effort was made to limit this potential bias by the collection of data from multiple sources (Yin, 2003). Namely, three different sources of information were employed: the experiences of non-scientist adults (Group I multiple case study), the experiences of chemistry teachers (Group II multiple case study) and the research findings available in recent relevant literature.

The comparative analysis of data from the non-scientist adults' interviews and those from the chemistry teachers' interviews produced strong concurrence on the extent and nature of factors influencing students' career choices. First, there was a high level of agreement between the two groups regarding the nature of school chemistry. Both adults and chemistry teachers recognize that chemistry is a course which poses difficulties due to its concepts which are sometimes abstract and hard to comprehend and also due to the fact that as a subject chemistry is considered difficult and requires a lot of effort, patience and perseverance. This view regarding the nature of school chemistry is also in agreement with that posed by several chemistry educators *via* research conducted solely among students (Chittleborough and Treagust, 2008; Lewis and Collins, 2001; Salta and Tzougraki, 2004).

We also found a high degree of congruence between adults and teachers in regard to the instructional content and context. The non-attractive theoretical teaching approach and textbooks, the overly technical language used by the teachers, and the emphasis on rote learning are recognized as barriers to chemistry learning and therefore as factors that influence students' decision to engage in a chemistry career, not only by the non-scientists (adults) but by the teachers as well. Several recent studies conducted among Greek secondary school students and in relation with the chemistry curriculum and the chemistry textbooks used, have indicated similar problems (Halkia and Mantzouridis, 2005; Salta and Tzougraki, 2011; Stefani and Tsaparlis, 2009).

The low level of interest for chemistry, the lack of aptitude and the lack of self-efficacy constitute a set of student characteristics which was identified as an inhibitor to students' aspirations to a chemistry-related career by both groups examined in this study. Finally, both groups pointed out the inferior status of chemistry in the educational system (little allocated teaching time) and in society (few employment possibilities). The importance of expectancy components (*i.e.* aptitude, self-efficacy), affective components (interest), and value components (*i.e.* subject value, lesson value) in facilitating and constraining learning has emerged by a comprehensive review of related studies (Pintrich, 2003).

Lent and colleagues (1994) presented a social cognitive career development model which integrates personal (self-efficacy, outcome expectations, interests, academic goals), contextual (environmental supports and barriers) and experiential (learning experiences) factors. The model proposes a relatively complex interrelationship between these factors. A career-related choice is a result of their interactions. Based on the social cognitive career development model (Lent *et al.*, 1994), the four categories of common factors identified in our study to influence students' decision not to pursue a chemistry-related career, could be viewed as forming an interconnected grid that is depicted with the connecting arrows in Fig. 1. It should be pointed out however that the connections shown are only hypothetical and they have to be tested by an independent study. Thus, based on the evidence from the present multiple case study comparative analysis, the following connections between barriers can be hypothesized:

(a) The factors related to the "Nature of school chemistry" could be amplified by the ones related with "Instructional content and context" and the "Status of chemistry". The notion is that the ineffective teaching methodology, textbook, teacher's language and learning approach ("Instructional content and context") and the little allocated teaching time ("Status of chemistry") make a "difficult" and "abstract" subject even less easily approachable.

(b) The factors related to the "Students' characteristics" could be amplified by the ones related with the "Nature of school chemistry", the "Instructional content and context" and the "status of chemistry". Here the notion is that the little allocated teaching time and the few employment possibilities ("Status of chemistry") cannot sustain students' interest

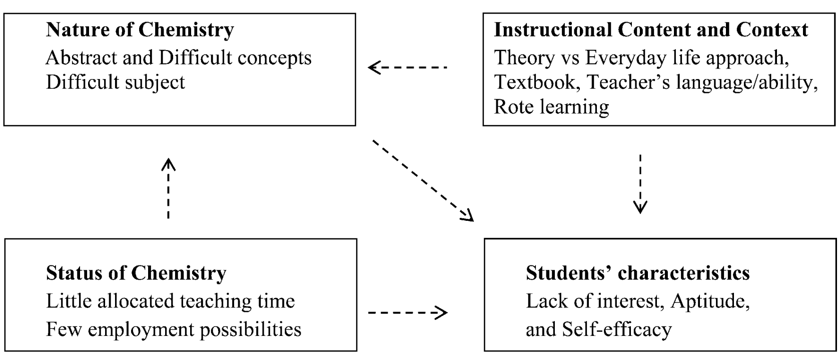

Fig. 1 Scheme of factors (organized in four categories) that influence students' choice not to pursue a chemistry-related career as identified by multiple case study analysis of the perspectives of the two groups examined in this study. The arrows show hypothesized connections between the different factor categories.

towards chemistry. In addition, the difficult and abstract concepts in combination with the perception that chemistry is a difficult subject ("Nature of school chemistry") and the ineffective teaching/learning approaches, textbooks and teachers ("Instructional content and context") are affecting negatively the students' self-efficacy and interest towards chemistry.

The resulting remarkable agreement between the views of Greek non-scientist adults and chemistry teachers regarding the barriers to chemistry learning and chemistry-related career choice could be taken as a starting reference point for the design of effective strategies to promote engagement with learning chemistry and subsequent aspiration to chemistry-related careers. The notion is that a strategy which is taking into account the factors that influence students' engagement with learning chemistry, could help educators, families, students, and others appreciate and value chemistry. At the same time, such a strategy could transform the narrow vision of the existing culture in chemical education in Greece that alienates or discourages many students from learning and enjoying chemistry.

Acknowledgements

The authors wish to thank the Lifelong Learning Program – Leonardo da Vinci Subprogram of the European Union for financial assistance.

References

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2010), "Doing" science *versus* "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity, *Sci. Educ.*, **94**, 617–639.

Aschbacher P. R., Li E. and Roth E. J., (2010), Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine, *J. Res. Sci. Teach.*, **47**, 564–582.

Britner S. L., (2008), Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes, *J. Res. Sci. Teach.*, **45**, 955–970.

Boeije H., (2002), A Purposeful Approach to the Constant Comparative Method in the Analysis of Qualitative Interviews, *Quality & Quantity*, **36**, 391–409.

Carlone H. B., (2004), The cultural production of science in reform-based physics: Girls' access, participation, and resistance, *J. Res. Sci. Teach.*, **41**, 392–414.

Charistos N. D., Teberekidis V. I., Tsipis C. A. and Sigalas M. P., (2003), Design and development of a multimedia educational tool for interactive visualization and three-dimensional perception of vibrational spectra data of molecules, *Educ. Inform. Techn.*, **8**, 369–379.

Chittleborough G. and Treagust D., (2008), Correct interpretation of chemical diagrams requires transforming from one level of representation to another, *Res. Sci. Educ.*, **38**, 463–482.

Christidou V., (2006), Greek students' science-related interests and experiences: Gender differences and correlations, *Int. J. Sci. Educ.*, **28**, 1181–1199.

Cleaves A., (2005), The formation of science choices in secondary school, *Int. J. Sci. Educ.*, **27**, 471–486.

Creswell J. W. and Miller D. L., (2000), Determining validity in qualitative inquiry, *Theory into Practice*, **39**, 124–131.

Dalgety J. and Coll R. K., (2004), The influence of normative beliefs on students' enrolment choices, *Res. Sci. Techn. Educ.*, **22**, 59–80.

Fadigan K. A. and Hammrich P. L., (2004), A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program, *J. Res. Sci. Teach.*, **41**, 835–860.

Fouad N. A. and Smith P. L., (1996), A test of a social cognitive model for middle school students: Math and science, *J. Couns. Psych.*, **43**, 338–346.

Fouad N. A., Smith P. L. and Zao K. E., (2002), Across academic domains: Extensions of the social–cognitive career model, *J. Couns. Psych.*, **49**, 164–171.

George R. and Kaplan D., (1998), A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS: 88, *Sci. Educ.*, **82**, 93–109.

Gilbert J. K. and Treagust D., (2009), Introduction: Macro, Submicro and Symbolic Representations and the Relationship between Them: Key Models in Chemical Education, in J. K. Gilbert and D. Treagust (ed.), *Multiple Representations in Chemical Education* (pp. 1–8). Dordrecht: Springer.

Gilmartin S. K., Li E. and Aschbacher P., (2006), The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students, *Journal of Women and Minorities in Science and Engineering*, **12**, 179–207.

Glynn S. M., Taasoobshirazi G. and Brickman P., (2007), Nonscience majors learning science: A theoretical model of motivation, *J. Res. Sci. Teach.*, **44**, 1088–1107.

Halkia K. and Mantzouridis D., (2005), Students' views and attitudes towards the communication code used in press articles about science, *Int. J. Sci. Educ.*, **27**, 1395–1411.

Hoffmann R. and Laszlo P., (1991), Representation in chemistry, *Angew. Chem.*, **30**, 1–16.

Jacobs J. S. and Simpkins S. D., (2005), Mapping the leaks in the math, science, and technology pipeline, *New Directions for Child and Adolescent Development*, **2005**, 3–6.

Kafetzopoulos C., Spyrellis N. and Lymperopoulou-Karaliota A., (2006), The Chemistry of Art and the Art of Chemistry, *J. Chem. Educ.*, **83**, 1484–1488.

Kniveton B. H., (2004), The influences and motivations on which students base their choice of career, *Res. Educ.*, **72**, 47–59.

Koren P. and Bar V., (2009), Pupils' image of 'the scientist' among two communities in Israel: A comparative study, *Int. J. Sci. Educ.*, **31**, 2485–2509.

Lent R. W., Brown S. D. and Hackett G., (1994), Toward a unifying social cognitive theory of career and academic interest, choice, and performance, *J. Voc. Behav.*, **45**, 79–122.

Lent R. W., Brown S. D., Schmidt J., Brenner B., Lyons H. and Treistman D., (2003), Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models, *J. Couns. Psych.*, **50**, 458–465.

Lewis B. and Collins A., (2001), Interpretive investigation of the science-related career decisions of three African-American college students, *J. Res. Sci. Teach.*, **38**, 599–621.

Lincoln Y. S. and Guba E. G., (1985), *Naturalistic inquiry*, Newbury Park, CA: Sage.

Mathewson J. H., (2005), The visual core of science: definitions and applications to education, *Int. J. Sci. Educ.*, **27**, 529–548.

Medhat S., (2003), Tapping young potential: are we investing enough in science, engineering and technology? *Educ. Sci.*, **203**, 8–11.

Miles M. B. and Huberman A. M., (1994), *Qualitative data analysis* (2nd edn), Thousand Oaks, CA: Sage.

Murray I. and Reiss M., (2005), The student review of the science curriculum, *Sch. Sci. Rev.*, **87**, 83–92.

Patton M. Q., (1990), *Qualitative evaluation and research methods*, Newbury Park, CA: Sage.

Pintrich P. R., (2003), A motivational science perspective on the role of student motivation in learning and teaching contexts, *J. Educ. Psychol.*, **95**, 667–686.

Reiss M. J., (2001), How to ensure that pupils don't lose interest in science, *Education Today*, **51**, 34–40.

Roberts L. F. and Wassersug R. J., (2008), Does doing scientific research in high school correlate with students staying in science? A half-century retrospective study, *Res. Sci. Educ.*, **39**, 251–256.

Rossman D. G. and Rallis D. S., (2003), *Learning in the field: An introduction to qualitative research*, Thousand Oaks, CA: Sage.

Salta K. and Tzougraki C., (2004), Attitudes toward Chemistry among 11th grade students in high schools in Greece, *Sci. Educ.*, **88**, 535–547.

Salta K. and Tzougraki C., (2011), Conceptual *versus* Algorithmic Problem-solving: Focusing on Problems dealing with Conservation of Matter in Chemistry, *Res. Sci. Educ.*, **41**, 587–609.

Sikora J. and Pokropek A., (2012), Gender segregation of adolescent science career plans in 50 countries, *Sci. Educ.*, **96**, 234–264.
Stake J. E., (2006), The Critical Mediating Role of Social Encouragement for Science Motivation and Confidence among High School Girls and Boys, *J. Appl. Soc. Psych.*, **36**, 1017–1045.
Stefani C. and Tsaparlis G., (2009), Students' levels of explanations, models and misconceptions in basic quantum chemistry: A phenomenographic study, *J. Res. Sci. Teach.*, **46**, 520–536.
Treagust D., Duit R. and Nieswandt M., (2000), Sources of students' difficulties in learning chemistry, *Educación Química*, **11**, 228–235.
Tsitsipis G., Stamovlasis D. and Papageorgiou G., (2010), The effect of three cognitive variables on students' understanding of the particulate nature of matter and its changes of state, *Int. J. Sci. Educ.*, **32**, 987–1016.
Wang J. and Staver J., (2001), Examining relationships between factors of science education and student career aspiration, *The Journal of Educational Research*, **94**, 312–319.
Yin R. E., (2003), *Case study research: Design and methods*, Thousand Oaks, CA: Sage.
Zeldin A. L., Britner S. L. and Pajares F., (2008), A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers, *J. Res. Sci. Teach.*, **45**, 1036–1058.