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Students’ Motivation to Learn Chemistry in Greece

Lifelong Learning Programme

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Abstract

Students' motivation to learn chemistry is a complex multidimensional construct. In this report, a systematic effort is made to identify and evaluate the current situation regarding students' motivation to learn chemistry in Greece. The conclusions drawn were based a) on the analysis of the experiences and comments of a group of 11 Greek chemistry teachers and 5 Greek scientific experts and b) on the analysis of the comments made by non-national teachers and scientific experts in relation with Greek national teaching resources and publications uploaded on the "Chemistry is All Around Network" portal. The experiences of the Greek teachers/experts were explored in the course of three workshop activities by using the constant comparative method. The comments of the Greek teachers/experts were related to non-national teaching resources available also in the above mentioned portal. The results of the undertaken work gave specific insight into the following three aspects regarding the national situation on students' motivation to learn chemistry: a) the main existing student motivational constructs, b) the obstacles affecting students' interest towards chemistry and c) the successful practices in motivating students to engage in chemistry learning.

1. Introduction to the National Situation

Primary education in Greece begins at the age of 6, it lasts 6 years and it is compulsory for all students. Secondary education comprises the compulsory attendance of 3 years in Gymnasio (lower secondary education) and is a prerequisite for enrolling and attending general or vocational upper secondary schools. The second tier of secondary education lasts also for 3 years, constitutes the non-compulsory upper secondary education and comprises general secondary education (including Geniko Lykeio/General Lyceum) and vocational secondary education (including Epaggelmatiko Lykeio/Vocational Lykeio and Epaggelmatiki Scholi/Vocational School). In General and Vocational Lykeio, pupils enrol at the age of 15 while in Vocational School at the age of 16.

Higher education constitutes the last level of the educational system and comprises the University and Technological sectors. The University sector includes Universities, Technical Universities, and the School of Fine Arts. The Technological sector includes the Technological Education Institutions (TEIs), and the School of Pedagogical and Technological Education (ASPETE).

The Greek educational system is governed by national laws and legislative acts (decrees, ministerial decisions). The general responsibility for education lies with the Ministry Education and Religious, Culture and Athletics Affairs.

Primary and Secondary Education curricula and timetables are drawn up by the Pedagogic Institute which, in turn, submits them to the Ministry of Education and Religious, Culture and Athletics Affairs for approval. They are implemented in all schools nationwide. Current Primary Education Curricula fall under the integrated philosophy of the Interdisciplinary Single Curriculum Framework for Compulsory Education (DEPPS). The interdisciplinary approach defines the structure of autonomous subjects' teaching on the basis of a balanced horizontal and vertical distribution of the teaching material and promotes cognitive subjects' interconnection as well as basic concepts' global analysis.

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1.1 Scientific Subjects in Primary Education

Primary Education has a six- year duration and includes 1st, 2nd, 3rd, 4th, 5th and 6th grades. Curricula for each subject are organized into six (6) levels (each of them corresponding to one (1) out of six (6) Primary School grades) or into fewer levels depending on the subject. Science and Geography curricula are organized into two (2) levels (5th and 6th grade). Moreover, several science topics are included in the subject "Study of the Environment" that is organized into four (4) levels (1st, 2nd, 3rd, and 4th grade). Curricula specify the reasons for which the relevant subject is taught, the educational objectives, the thematic units, while indicative activities and interdisciplinary projects are introduced. Table 1 demonstrates teaching hours distribution for Science related subjects in Primary School according to the relevant Ministerial Decision (Government Gazette F.12/773/77094/C1/ 1139/Issue. B'/23-8-2006).

Table 1. Weekly teaching hours distribution for Science related subjects in Primary School

A/O	Subjects	Weekly teaching hours per grade					
		GRADES					
		1st	2nd	3rd	4th	5th	6th
1.	Study of the Environment	4	4	3	3	-	-
2.	Geography	-	-	-	-	2	2
3.	Sciences	-	-	-	-	3	3
4.	Interdisciplinary & Creative Activities Flexible Zone	3	3	3	3	2	2
5.	New Technologies - Computer Science	2	2	2	2	2	2
	TOTAL HOURS	31	31	34	34	36	36

Curricula are compulsory for all teachers in regard with the teaching material content and distribution in the six (6) primary school grades. In the Flexible Zone, cross-thematic teacher initiative programmes are developed. In the 1st grade, one Flexible Zone teaching hour will be dedicated to activities pertaining to Health Education, in the 2nd grade it will be dedicated to activities pertaining to Eating Habits issues, in the 3rd grade, to activities pertaining to Traffic Education and in the 4th grade to Environmental Education. Most of the activities include Science related topics.

1.2 Scientific Subjects in Secondary Education

Secondary Education in Greece is divided in two cycles: compulsory Secondary Education (lower secondary school) and non-compulsory Secondary Education (different types of upper secondary schools).

<u>Lower Secondary Schools</u>

The curricula for lower secondary school are structured in three levels with each level corresponding to each one of its three grades (7th, 8th, and 9th). Table 2 demonstrates teaching hours distribution for Science subjects in Lower Secondary Schools.

Table 2. Weekly teaching hours distribution for Science subjects in Lower Secondary School

	SUBJECTS	Weekly teaching hours per grade		
		GRADES		
		7th	8th	9th
1	Geography	2	2	-
2	Biology	2	-	2
3	Physics	-	2	2
4	Chemistry	-	1	1
	Total Hours per Class	35	35	35

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In addition to the curriculum, innovative actions have been introduced in Secondary Education, such as Health Education, Youth Entrepreneurship, Environmental Education, Flexible Zone of Innovative Actions, Cultural Programmes, School Vocational Orientation, by applying the respective programmes. Most of them incorporate Science related topics.

Upper Secondary Schools

The 10th Grade of the General Upper Secondary School, being an orientation class, includes General Education subjects of 32-hour duration weekly and one elective subject, of 2 hours per week. The 11th and 12th Grades of Upper Secondary School include 2 categories of classes: General Education and Direction Subjects. General Education subjects are taught 25 hours per week in the 11th grade and 17 hours per week in the 12th grade. Direction subjects are divided in two categories:

a) Compulsory subjects for all pupils, taught for 7-8 hours per week in grade 11 and 12 hours in grade 12.

b) Elective subjects, out of which pupils can choose 2 in grade 11 and 1 in grade 12. There are three directions offered: Theoretical, Exact Sciences and Technological. In grade 12, the Technological Direction includes 2 cycles (A Cycle: Technology and Production; B Cycle: Information Technology and Services). Table 3 demonstrates teaching hours distribution for Science subjects in Upper Secondary Schools.

Table 3. Weekly teaching hours distribution for Science subjects' in Upper Secondary School

SUBJECTS		Weekly teaching hours per grade		
		GRADES		
		10th	11th	12th
GENERAL				
Physics		3	2	1
Chemistry		2	2	-
Biology		1	1	1
Project		2	2	-
ELECTIVE				
Biology		-	2	-
Chemistry		-	2	-
Astronomy		-	2	-
DIRECTIONS				
Exact Sciences	Physics	-	2	3
	Chemistry	-	2	2
	Biology	-	-	2
Technological	Physics	-	2	3
A Cycle	Chemistry/Biochemistry	-	-	2
	Electrology	-	-	2
	Total Hours per Class	**34**	**34-35**	**30**

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A lot of effort is also invested in the direction of laboratory teaching for subjects of Sciences in all Lower and Upper Secondary Education Schools. For this purpose, a number of laboratory activities are included in Science Curricula. Table 4 demonstrates laboratory activities distribution for Science subjects in Lower and Upper Secondary Schools.

Table 4. Laboratory activities distribution for Science subjects in Lower and Upper Secondary Schools

SUBJECTS		Number of laboratory activities per grade					
		GRADES					
		7th	8th	9th	10th	11th	12th
GENERAL							
Physics		-	7	9	5	4	1
Chemistry		-	4	3	2	3	-
Biology		5	-	6	3	3	2
ELECTIVE							
Biology		-	-	-	-	2	-
Chemistry		-	-	-	-	2	-
DIRECTIONS							
Exact Sciences	Physics	-	-	-	-	3	3
	Chemistry	-	-	-	-	3	3
	Biology	-	-	-	-	-	2
Total Laboratory Activities per Class		**5**	**11**	**18**	**10**	**16-20**	**11**

2. Setting up of the Network

In order to set up a functional Network, we used a specific strategy for the selection of teachers and scientific experts.

In respect with the teacher selection we note the following: The network should involve a minimum of ten teachers (in at least five different schools) with at least one of them in primary education. The secondary school teachers should have a science degree (preferably chemistry or some other closely related discipline such as biology, physics, chemical engineering, geography, geology) and have taught chemistry in secondary education. We were interested in recruiting teachers possessing different levels of teaching experience in order to obtain a more spherical and objective overview. Effort was also made in order to include a balanced representation of both genders. A geographical/demographic criterion was used as well, namely we made an effort to include schools from different areas of Greece both geographically as well as from a demographic point of view (ie schools in richer/middle class/poorer areas).

In respect with the scientific experts, we made an effort to include experts of both genders and from different types of academic institutions, ie Universities, Technological Educational Institutes and Research Centres. Obviously, their scientific expertise and experience should be closely related with some chemistry discipline.

In all cases, before making final decisions, the teachers and experts were given a detailed oral description of the Project aims and their expected role in it. We made an effort to approach and recruit teachers and experts that gave us evidence (via their biographical information and/or their personality characteristics) that they are willing to actively participate in the project and make further use of the results reached by it in their professional lives. Good reading skills of the English language were a prerequisite for all participants.

The network that was finally set up had the following characteristics:

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A total of 10 schools (2 primary schools and 8 secondary education schools) joined the “Chemistry is All Around Network” represented by a total of 12 teachers (3 primary school teachers and 9 secondary school teachers). All school units belonged to the public school system. Six out of the ten schools are located in the Athens Metropolitan area, three in the islands (Zakynthos, Mykonos, Aegina) and one in inland Greece (Voiotia). The 8 secondary schools involved in the network belong to upper secondary education with 7 of them being General (“Geniko Lykeio”) and one of Vocational (“Epaggelmatiko Lykeio”-“EPA.L.”) type. It is important to note that the majority of the respective teachers (60%) also have experience in teaching chemistry in lower secondary education (“Gymnasio”). In addition, to these 10 schools two additional schools have already joined the Network as Associated Schools (one lower secondary school (“Gymnasio” and one upper secondary vocational school (“EPAL”). The School Network set up process will be continued during the project lifetime via the gradual involvement of more associated schools. The 10 schools comprising the main network (ie leaving out the associated schools) have an average of 240 ± 75 students (Min. 160 – Max 450). This corresponds to the typical size of a school unit (either primary or secondary) in the Greek public education system.
We continue by giving more specific information on the teachers’ characteristics: 8 schools joined via the participation of one teacher and 2 schools via 2 teachers each. Both genders are represented among the teachers (5 females and 7 males). It is important to note that all 9 secondary school teachers have different levels of experience in chemistry teaching and in addition that all of them hold a Bachelors degree in Chemistry, except of one who is a holder of a degree in Chemical Engineering. In addition, 6 out of the 9 secondary school teachers hold a Masters degree in Chemistry Education with one of them also holding a Ph.D. degree in the same field. In regard with the three primary school teachers, all of them hold a Bachelors degree in Education, they all have experience in science teaching at primary school level and a special personal interest in science learning and teaching. Finally, regarding the number of students and classes taught we note the following: all secondary school teachers devote their teaching time primarily in chemistry teaching at their respective schools (over 80% of their working hours) and their classes consist of at least 20 students. The primary school teachers devote their working hours teaching all required subjects (Math, Science, Languages, History etc) as is the rule that applies in the Greek school public system. The classes in the primary school consist of at least 20 pupils. The names of all schools and teachers with relative details are already uploaded on the Project Portal.
In respect with the scientific experts, we note the following: A total of five experts from five different institutions joined the Chemistry is All Around Network. Both genders are represented (2 females and 3 males). All experts a Ph.D. degree in a subdiscipline of chemistry (biological, physical, inorganic, biophysical, environmental chemistry) and hold academic positions in three different types of tertiary education institutions. Namely, two of them serve as teaching/research staff at Technological Educational Institutes, two serve as teaching/research staff at Universities and one is a researcher in a National Research Centre. All Institutions are state-owned. All scientific experts are strongly interested in the educational role of their work and enthusiastic regarding the specific project.
Finally we make a note on the quality and functionality of the network. Judging from the successful organization of the first workshop on “Students’ motivation to learn Chemistry” and the high quality of the comments uploaded by all teachers and experts, the network set up has been successful.

3. Main Obstacles to Students’ Motivation to learn Chemistry

In this part of the report we will describe the main motivations for students to study scientific subjects and chemistry in particular, the main obstacles that affect the interest of the students towards scientific subjects emphasizing on chemistry and finally the most successful experiences in motivating students. The presented description will be based on three sources of information: the reviewed national publications and existing data, the comments posted by non national teachers/experts to the national publications and paper and finally the comments posted by national teachers/experts to non national publications and papers. In this way, this part of the report will be divided into three main parts in reference to the three different information sources.

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3.1 Reviewed National Publications and Data

By taking into account the reviewed national publications and existing data, we present and shortly discuss the following main motivations for students to study scientific subjects and chemistry in particular.

According to the study of Salta and Tzougraki [1], Greek upper secondary school students present a neutral attitude regarding the interest of the chemistry course 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.

A gender-related connection has been identified in respect with students' motivation towards different scientific subjects [2, 3]. In this way [3], girls show more interest towards subjects related to human biology, health and fitness while boys are significantly more interested than girls in learning about threatening aspects of science and technology as well as the social dimensions of science and technology. Apart from the gender-related differences, the same study [3] showed that boys and girls have similar interests towards the subjects "Astronomy, space and the sky", "Light, sound, their perception and reproduction", and "Plants and animals".

The study of Halkia and Mantzouridis [2], explored the students' preferences for articles in the press and it showed a large difference between boys and girls. Namely, science is one of the most favoured subjects that boys choose to read (second among nine), while for girls it is one of the least favoured subjects (seventh among nine). In relation with the science areas, the same study [2], showed that students seem to prefer subjects connected with contemporary technological discoveries and computers. They are also attracted by the subjects referring to cosmology and astronomy. It is interesting to note that chemistry is missing in all of the above mentioned subjects. Subjects like "health", "fitness", "plants and animals", "human biology" involve chemistry knowledge, however they are not perceived as such by the students.

Another important finding of the previous study [2] is that the narrative elements found in popularized science articles attract students' interest and motivate them towards further reading. The use of emotional/"poetic" language with a lot of metaphors and analogies is preferred by the students, who tend to avoid science articles that present their data in a rigorous scientific way.

In the study of Sarantopoulos and Tsaparlis [4], the Greek students' distribution into the four motivational styles proposed by Adar [5] was found to be the following: 45.9% of the students fell into "the curious" category ie those who preferred freedom in learning and discovering; who enjoyed open-ended tasks and found rigid instructions irksome; 31.8% of students were classified as "conscientious" ie those who preferred an expository method of teaching and learning; who felt secure only when given clear objectives and precise instructions; who set out to please the teacher and to meet the expectations of the home; who were assiduous about examination preparation and hard work; 19.3% fell into the category "social", ie those who were very sociable and group conscious; who preferred to study with friends and to discuss problems; who were so involved in social events that time for consistent studying tended to be limited and last-minute and only 3% belonged to the "achiever" category ie one who had a distinct preference for an expository method of teaching and learning; who enjoyed the challenge of competing with others for top marks; who disliked being held back by slow learners. This study implies that the majority of students tend to fall into the "curious" and the "conscientious" motivational styles and it is one of the few research efforts aiming at measuring Greek secondary school students motivation for learning chemistry.

The role of the teacher in student motivation is pointed out in the work of Vosniadou [6]. It is pointed out teachers can help students become more motivated learners by their behaviour and the statements they make. They should use encouraging statements that reflect an honest evaluation of learner performance. In the same work, teachers are suggested to recognize student accomplishments, to help students believe in themselves and set realistic goals, to provide feedback to learners about the strategies they use and instruction on to how to improve them.

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By taking into account the reviewed national publications and existing data, we present below the main obstacles identified to affect the interest of the students towards scientific studies and chemistry in particular.
In the study of Salta and Tzougraki [1], the following issues are raised: Students find difficulties in the use of chemical symbols and the application of chemistry concepts (for example atom, molecule, mass, volume and mole). The application and use of chemistry concepts and symbols depends on the students’ ability to transfer from the macroscopic to the symbolic level and from the symbolic to the microscopic level and vice versa. Students’ attitudes regarding the difficulty of chemistry lessons are also related to their abilities in solving chemical problems which require mathematical skills. The above obstacles are related to the nature of chemistry as a science.
Certain obstacles that are related to the instructional content and context have also been proposed to influence student motivation to engage in science learning [1 - 3, 7]. This type of obstacles are the following: the curriculum context and the abstract rigorous language employed in the textbooks, the tendency to adopt a theoretical teaching approach with very limited hands-on practical activities and without pointing the connections of the material taught with everyday life experiences and phenomena, the emphasis on rote learning, the teacher’s inability to attract students’ attention.
Specific students’ characteristics have been implied to influence their decision not to pursue a chemistry-related career [7]. These include the lack of aptitude, interest and self-efficacy. Self-efficacy is a motivational construct which was defined as “beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments” [8] and which has been found to be the best predictor of grades in an introductory college chemistry course, even after controlling for prior achievement [9].
Finally, a category of factors related to the status of chemistry in the Greek educational system and Greek society have also been proposed to influence students’ decision not to pursue a chemistry-related career [7]. They include the little allocated teaching time and the limited employment possibilities. These factors could also be viewed as obstacles to student motivation to engage in chemistry learning.
By taking into account the reviewed national publications and existing data, we present below the most successful practices in motivating students to engage in chemistry and science learning in general.
The most successful practices can be divided into three main categories as outlined recently [10]: teaching approaches, educational tools, non-formal educational material and activities.
The successful teaching approaches are related with laboratory instruction [11-13], interdisciplinary teaching approaches [14-17], and other approaches such as the use of analogies with a strong social content [4].
The term “educational tools” refers to information and communications technology (ICT) based applications. There have been studies which show that different types of educational software and multimedia application are connected with a rise in student interest and motivation toward chemistry [18, 19].
The practice “non-formal educational material and activities” refers to museum visits [20], science fairs [21] press science [2] and out-of school experiences [3] that are relevant to the students’ interests. The type of language employed in popularized science articles of the press seems to stimulate students' interest and motivate them towards further reading [2]. In addition, significant correlations were identified between the topics of students’ interest and their out-of-school experiences [3].

3.2 Analysis of comments posted to national publications and paper

In this section of the report, we will comment on the main student motivations, the obstacles that affect students’ interest towards chemistry (and science in general) and the successful practices in motivating students by analyzing the comments posted to the national publications and the paper, by non-national teachers and scientific experts.

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We will start with the paper entitled “Students’ motivation to learn chemistry: The Greek case”, which received a total of seven comments. We will specifically focus on these comments that bring out some new issues and points of view which were not mentioned in the previous section of this report.
In respect with the obstacles that affect students’ interest, the comments seem to corroborate the opinion that chemistry is perceived as one of the more difficult science subjects. However, the little allocated teaching time does not seem to be necessarily relevant with the lack of motivation. In the Irish example, chemistry remains a less favorable subject among students, even though “adequate teaching time is allocated at all levels”. The lack of career opportunities seems to be relevant in other countries as well (Belgium, Turkey). However, in other cases (Ireland) where there are plenty of career opportunities, the problem seems to be the “lack of knowledge and awareness amongst students regarding job opportunities available to students as a result of studying chemistry at second and third level”. Establishment of “contacts with the “community” (for instance the industry or university research units) could reveal career opportunities for students”, as pointed out by another comment. The use of inappropriate teaching approaches (not enough experimentation, no relevance with everyday life experiences) is pointed out as an obstacle in several comments. Special reference is made to the need of the establishment of the inquiry-based teaching approach.
In respect with the successful practices in enhancing student motivation, it is interesting to note that two independent comments (Belgium, Ireland) refer to the difficulty of implementing the interdisciplinary teaching approach. The non-national teachers/experts have pointed out that “interdisciplinarity seems more complex to implement”, that “this kind of approach and supervision would require a new organisation of the science courses and of the programmes” and that “with the ever increasing demands on teachers within their own departments it is difficult to see how teachers would have the time or opportunity to liaise closely with teachers of other disciplines”. In addition, even though the use of ICT in education is generally aspired, its practical use and implementation can be problematic in some cases and it does not necessarily guarantee a successful result in respect with motivation. As noted in one of the comments “It is apparent that teachers have embraced the digital era. Despite this greater awareness, obtaining resources can be a time consuming and sometimes fruitless exercise”. In fact, this is an issue that was also pointed out by the Greek teachers and experts who participated in the first workshop (see below). In respect with “hand-on activities and experimentation” several comments point out the necessity to reorganize curricula and set rules for the number of students per class in order to engage in active experimentation and stimulate students’ interest. In the case of Ireland, it is commented that “this approach is already incorporated at junior and senior chemistry level”. The fact that the level of student motivation to engage in chemistry learning is rather mediocre is in accordance with the generally aspired view that motivation is a complex multidimensional construct influenced by many parameters simultaneously.
We will continue with the analysis of the comments posted on three national publications and specifically in the ones numbered [1], [3] and [6] in the “References” section. The importance of informal learning and of the need for integrating teaching topics and students’ experiences and interest is pointed out in the comments, as a practice that could be successful in enhancing students’ motivation. In respect with the obstacles affecting students’ interest, the comments corroborate the view that students find it difficult to transfer from the microscopic to the macroscopic level and vice versa. In addition, it is agreed that the required mathematical skills also pose difficulties to the students.

3.3 Analysis of comments posted to non-national publications and papers

In this section we will make an effort to analyze the comments made by Greek teachers to non-national publications and papers. A total of 21 comments were posted. Nine of these comments correspond to nine different non-national papers and twelve correspond to 10 different non-national publications. All comments contain very detailed descriptions. We will present only the main results emerging in respect with students’ interest and motivation by referring separately to the papers and publications.
The comments on the non-national papers gave the following general picture regarding students’ motivation to engage in chemistry learning.

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In respect with the different aspects of student motivation (motivational constructs) the main points that emerge from the analysis of the non-national papers are the following: a) The image, perception and public awareness of chemistry in society. Chemistry is either perceived as a "negative" science or scientists are perceived as "crazy", as people who "don't know what people need", as "possible saviors", etc. Students are not aware of the usefulness of chemistry in their everyday lives. In addition, unlike other physical sciences "chemistry lacks champions, role models and grand challenges to inspire students". b) The crucial role of the teacher in sustaining students' motivation and his/her own as well. A characteristic quote is the following: "A stressed, not well-trained, not well-paid teacher cannot be constantly enthusiastic about his/her work and also transfer this enthusiasm to the students, in the context of affective motivation" c) The personal needs of the students which should be taken into account for all student "types" (from the very weak to the very bright ones). d) The possibility of a rewarding professional career.

In respect with the main obstacles that affect students' interest towards scientific subjects and chemistry in particular, the main points that emerge from the analysis of the non-national papers are the following: a) Lack of logical reasoning and ability in mathematics (student characteristics). b) Perception of chemistry as a difficult course in which the possibilities of performing well are very small (low level of self-efficacy). c) Nature of chemistry (abstract concepts which also create misconceptions), d) Instructional content and context ("obscure" textbook content, not well designed curriculum which does not give emphasis on developing the students' critical ability , unattractive teaching methods with little use of experiments or with uninteresting experiments, teacher's personality and ability to inspire enthusiasm or applying non-traditional teaching methods on an everyday basis, demanding evaluation and outdated assessment system), e) the existence of gender related stereotypes ("Girls do not perform as well in science as boys do"), f) devaluation of the chemistry course in the educational system (few teaching hours, non-required course for entering the majority of science related faculties) and in society.

In respect with the successful experiences in motivating students, the main points that emerge from the analysis of the non-national papers are the following: a) Teaching approaches (experimentation, acquisition of practical knowledge with everyday life applications, student-centred approach with emphasis on inquiry, group discussion and collaborative learning, use of ICT, alternative approaches involving the use of cinema, or theatrical play). It is important to note that the comments raise the issue that more detailed research is required in order to accurately quantify the extent at which each teaching approach actually increases motivation and in addition to identify the factors that influence the successful implementation of these novel approaches. b) Changes in the curriculum design (inclusion of more experiments, presentation of chemistry as an integral part of human life, more careful student evaluation). The importance of continuous technical support for successful realisation of the curriculum is pointed out. c) Initiatives for improving the social image of chemistry and for popularizing chemistry (eg. "Hearts and Minds", "Popuch", science communication programs between higher institutions and schools). Some comments raise the issue of the sustainability of these initiatives due to the lack of funding. In addition, it is pointed out that these initiatives are positive but that they do not usually produce a permanent change in attitude.

The comments on the non-national publications gave the following general picture regarding students' motivation to engage in chemistry learning.

In respect with the different aspects of student motivation the main points that emerge from the analysis of the non-national publications are the following: a) Interest and relevance. Students cannot have interest in something that is seen as detached from reality. Both those aspects of motivation are very important and need to be promoted simultaneously. Students often ask the question "Why are we studying this?". and need to understand the usefulness of chemistry in order to get motivated. The incorporation of the triad "Science – Technology – Society" in the teaching praxis is also connected with these two motivational constructs. b) Development of student autonomy. This motivational construct is connected with the independent laboratory activity and inquiry-based learning. c) Differentiation for students with special educational needs. d) The critical role of the teacher who has to develop the ability

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to understand the mental processes followed by the student, acquire flexibility and thorough knowledge of the phenomena.
In respect with the main obstacles that affect students' interest towards scientific subjects and chemistry in particular, the main points that emerge from the analysis of the non-national publications are the following: a) The problem of language b) The lack of formal operational reasoning by a large percentage of students. This seems to be related with the students' modern way of life (internet, TV, social media) which tends to make them lazier for engaging in the discovery of knowledge via experimentation. c) Lack of the required mathematical skills d) Abstract and difficult concepts discourage students in a very early phase of the learning process. Students are thus characterized by low self-efficacy. The perception of chemistry being a difficult subject is also relevant with low self-efficacy. e) Not well-designed chemistry curricula which do not include issues that deal with everyday life applications. f) Examination-driven syllabus. Old-fashioned centralized assessment system. g) Use of traditional teaching approach with emphasis on theory and involvement of little experimentation. h) The class "atmosphere" created by the perceptions of the students for the practices of their teachers. Unmotivated, insufficient, not well-trained teachers. i) The image of a scientist as a boring "nerd" who lives in a parallel universe, the negative image of chemistry in the media (often associated with pollution), the lack of important role models and j) the lack of career opportunities.
In respect with the successful experiences in motivating students, the main points that emerge from the analysis of the non-national publications are the following: a) Innovative teaching initiatives that aim to cultivate the interest and bring out the relevance at the same time, such as the PARSEL project. Instruction needs to be embedded inside a student-developed need-to-know situation. Context-based learning: "instead of worrying about content at the micro-level students should all know and be informed about chemistry in the real world" b) Use of the most recent findings of educational research (how children learn, etc) in the teaching practice in order not to get stuck to unproductive teaching methods. A teaching approach based on the program CASE (Cognitive Acceleration in Science Education) is mentioned. c) Incorporation of authentic research environments in the teaching practice d) Taking into account the Information Load. By measuring carefully the amount of information we expect students to retain at a given time we could reduce the stress on their working minds and memories. Of course, this variable is integrally related with the applied teaching methodology and the corresponding curriculum. e) Hands-on experience in and out of school (eg. Science fairs, museum visits). f) Creating a positive image of chemistry and of scientists through the media. Undertaking science communication initiatives (eg. "Researchers in Residence", "Express Yourself Conferences").

4. Analysis of Teaching Resources

In this part of the report we will first make a short description of the innovative resources and materials to teach chemistry identified at national level. In the description, we will make reference to the possible ways that these resources can enhance attractiveness and effectiveness of chemistry teaching, by taking into account the initial comments/reviews posted by the Greek team members upon uploading. Subsequently, we will attempt to draw conclusions on how teaching resources (national and non-national) can enhance student motivation to engage in chemistry learning by taking into account two additional sources of information: i) the comments posted by non-national teachers/experts to the Greek teaching resources and ii). the comments posted by Greek teachers/experts to non-national teaching resources

4.1 Description of uploaded national teaching resources

Several ICT-based national teaching resources were identified. In order to select the 20 most suitable ones, we used the following criteria: a) educational value, b) functionality, c) easiness of use and d) minimum system requirements for successful execution. Special emphasis was given on the fourth criterion since experience shows that teachers (and students) are strongly discouraged to use a teaching resource that takes a lot of time to download and/or requires special additional programs or system characteristics.

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All 20 selected national teaching resources were critically and adequately reviewed in order to provide a detailed yet concise explanation of their contents and applicability in class. The guidelines that had been set in the 1st Partners' Meeting were strictly followed.
Among the 20 teaching resources, 16 are available only in the Greek language, 3 are in English and 1 is available in both Greek and English.
In regard with the target group of the teaching resources, we note that 16 of them are aimed to Lower Secondary School students, 16 to Upper Secondary school and 2 are suitable for primary school.
In regard with the level of chemistry knowledge, we note that the majority (14 out of 20) of the teaching resources require a basic/medium level of knowledge (namely 1 is characterized as "basic", 12 as "basic/medium" and 1 as "medium"). The remaining 6 teaching resources are characterized as either "Medium/Advanced" (3) or "Advanced" (3).
The selected Greek national teaching resources fall into the following subject areas: Fundamental Chemistry (19), Life Chemistry(10), Environmental Chemistry (9), Materials Science (9), Food Science (7), Health Science (6), Industrial Chemistry (6) and History of Chemistry (5).
The selected Greek National teaching resources fall into the following typologies: Website/Portal (8), Downloadable Material (8), Online Course (5), Downloadable Software (4) and Experimental Demonstrations (1).
Finally, the selected teaching resources employed the following pedagogical approaches: Experiential learning (10), Problem Solving (10), Self learning (10), Peer Education (7), Cooperative learning (6) and Modelling (5).

4.2 Analysis of comments posted to national teaching resources

A total of 14 comments were posted to 8 different national teaching resources by non-national teachers and experts. The national teaching resources that received comments were the following (the amount of comments are shown in parenthesis):

- Chemistry at Home (4)
- 3D Mol Sym (3)
- Parsel (2)
- Chemical Compound of the Month (1)
- EKFE Chania (1)
- Green Chemistry (1)
- 3D Normal Modes (1)
- juniorLAB (1)

By analysing these comments, the following possible ways with which these teaching resources can enhance the attractiveness and effectiveness of chemistry teaching are identified. Some characteristic quotes which substantiate the points made, are given in parenthesis:
a) The connection with everyday life experiences ("…contents contain appreciable and significant references to the chemistry in everyday life and thus very close to the real contexts of students" for "Chemistry at Home"; "…all the topics in chemistry are offered starting from daily matters" for "PARSEL"; "…The students' interest to study chemistry is increased by showing its numerous connections to and application in our daily routines" for "Green Chemistry"; "…students feel more captivated and enjoy learning topics associated themselves, the issues of everyday life, considering factors that promote interdisciplinarity and modern applications, which are transferable to the fruitful functioning in society" for "PARSEL")
b) The language employed ("…The language used is a fine tuned one. Readers do not get bored with millions of confusing terminological elements…" for "Chemistry at Home"; "…and the language is simple" for "Chemical Compound of the Month")
c) Easiness to use or apply in class ("…This resource should interest students, as it's easy to use, quick and clear' for "3DMolSym"; "..The chemistry student can reach the program easily and download it their

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computer" for "3DNormalModes"; "…proposals for laboratory activities are well detailed and easily reproducible in a school without a well equipped laboratory…" for "Chemistry at Home")
d) Connection of theory with practice ("…The practical orientation of the materials is extremely useful as it overcomes a major obstacle of contemporary education, i.e. students' inability to relate theory to practice**"** for "Green Chemistry"; **"…**the activities are very operational and experimental, with engaging and easy to make experiments… the methodological approach, just because it is very operational, can capture students' attention" for "EKFE Chania")
e) Self-learning and Interactivity ("…This feature of the program encourage the student to self-learning and rises the motivation for learning the chemistry" for "3DNormalModes"; "…By providing high interactivity, the simulation allows an individual use, at home," for "juniorLAB"; "…It allows students to work at their own pace and encourages initiating and learning independently" for "Chemistry at Home"; "…This teaching resource.. provides opportunities like self-learning and self-evaluation" for "3DMolSym")
f) Aesthetics ("…The presence of poster presentations that combine colour depiction and text stimulate the students and increase their cognitive interests" for "Green Chemistry"; "…The resource can help students learn significantly thanks to the well-structured graphics…" for "Chemistry at Home")
g) Interesting and well-structured content ("…The information provided is abundant, the topics covered are interesting and sometimes very appealing" for "Chemical Compound of the Month"; "…The materials are easy to understand, ingenuous and introduce various topics with attractive content" for "Green Chemistry"; "…At a graphical level, this resource is very well designed, very intuitive…" for "juniorLAB"; "…it is also very well-equipped in terms of content" for "3DMolSym")
h) Cooperative learning ("…the tools can be used to increase the interest of students (because) they propose cooperative work, so (that) students have an active role…" for "PARSEL").
i) Useful tools ("…it may motivate students to solve exercises, due to the clues/help tools available" for "Chemistry at Home"; "Students will benefit from using software to visualise molecules in 3D" for "3DMolSym")

4.3 Analysis of comments posted to non-national teaching resources

A total of 13 comments to 13 different non-national teaching resources were posted by 12 different Greek teachers and scientific experts (8 teachers – 4 experts). The non-national teaching resources that received comments were the following:

- Chemistry for Junior Certificate Science (Ireland)
- World of Chemistry (Ireland)
- The Periodic Table of Videos (Ireland)
- Chemistry and water treatment (Ireland)
- Chemistry for Juniors: Sci-spy (Ireland)
- Materials for Special Uses (Italy)
- Food Education (Italy)
- Che cos'è la Chimica? What is Chemistry? (Italy)
- A Química das coisas –The Chemistry of Things (Portugal)
- Virtual Chemistry Experiments (Portugal)
- Study and discover Chemistry! (Bulgaria)
- General Chemistry Laboratory (Bulgaria)
- Science Kids – Chemistry (Czech Republic)

By analysing these comments, the following possible ways with which these teaching resources can enhance the attractiveness and effectiveness of chemistry teaching are identified. Some characteristic quotes which substantiate the points made, are given in parenthesi

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- The connection with everyday life experiences ("…This extremely helpful website contains analyzed issues from almost every aspect of everyday's interest(s), according to the science of Chemistry" for "The Chemistry of Things"; "…By presenting certain connections between food and health issues, the site can motivate young readers to ask themselves questions such as "Why do I have to eat well and choose the right foods?" for "Food Education"; "…The site does present chemistry from the point of view of its numerous applications in everyday life" for "Chemistry for Juniors – Sci-spy"; "...Another important issue is that the resource deals with a subject which is related with the everyday life experiences of the students (water resources)" for "Chemistry and Water Treatment"; "...The series successfully promotes the significance of Chemistry as a tool for improving the quality of life" for "World of Chemistry"; "…The sections related with Metals and Polymers contain fun to do activities which bring out the connection of chemistry with several everyday life materials and experiences. Some of them could also be very enjoyable to perform even away from school" for "Materials for Special uses")
- b) The language employed ("…The material is presented in an easy to follow way" for "Food Education"; "…the information given in the factsheet contains a lot of chemistry by completely avoiding symbols", for "Chemistry for Juniors – Sci-spy"; "...(it contains) the correct language that can actually help students to understand better and faster" for "Chemistry and Water Treatment"; "...the fundamental Chemical concepts are presented in a simple, easy to understand, manner" for "World of Chemistry")
- c) Easiness to use or apply in class ("…He (the teacher) is given a variety of resources and ways to approach a certain subject with just a click of the mouse!" for "Chemistry for Junior Certificate Science"; "…It proposes very nice and easy to perform experiments" for "Chemistry for Juniors – Sci-spy"; "...I find it very important that once you click on the resource, it is pretty much straightforward what needs to be done. No special downloading is required and the resource does what it also say, ie it gives a "stimulus to engage" for "Chemistry and water treatment"; "…The applets are easy to run and parameters can be clearly distinguished from each other so that the student understands the phenomenon or the experimental results with no difficulty" for "Virtual Chemistry Experiments"; "…the activities they propose are quite interesting and can be relatively easily performed in a school laboratory or even at home without the need of advanced safety precaution or difficult to find chemicals" for "Materials for special uses")
- d) Different points of view/Social Image of Chemistry/Interdisciplinarity ("…it is a convenient opportunity for extended discussion and interest increase" for "The Chemistry of Things"; "…the webpage is a very useful site which gives teachers the possibility to employ new interesting teaching methods for approaching the subject of nutrition from many different points of view" for "Food Education"; "...This teaching resource contains also the element of interdisciplinarity: it combines chemistry, physics and systems' engineering" for "Chemistry and Water Treatment"; "...The combination of the four separate subsections "Introduction" – "Activities" – "Exercises" – "Relevant Links" in each teaching section gives the possibility to all types of users to approach the subject under study from different angles" for "Materials for special uses"; "...Its main purpose is to attract the students' interest and show how important is the role of chemistry in areas such as science, environment, art, industry and life. Using several examples, there is an attempt of absolving the term "chemical" of something negative, which is falsely used by the media as something that implies hazard and aggressiveness" for "What is Chemistry")
- e) Self-learning and Interactivity ("...the site becomes pleasurable by offering to student the possibility to engage in an interactive game called "future city"…" for "Study and discover Chemistry"; "…and links to fantastic interactive on line experiments" for "Chemistry for Junior Certificate Science"; "..The site contains interactive games that can increase motivation to learn by providing positive feedback" for "Food Education"; "…The student could start by knowing nothing on the subject, read the factsheet, watch the video and then take an interactive quiz" for "Chemistry for Juniors – Sci-spy"; "...it also incorporates a nice interactive "game" on the water filtration which really invites the average student to engage in it" for "Chemistry and Water

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Treatment"; "...One can also take into consideration that Chem Lab offers to the students the possibility of learning on their own needed time leading to a better assimilation of the upcoming experiment" for "General Chemistry Laboratory")

- f) Aesthetics ("...It contains the right amount of text and the right amount and quality of colour, animation and sound" for "Chemistry for Juniors: Sci-spy"; "...The resource contains nice illustrations" for "Chemistry and Water Treatment")
- g) Interesting and well-structured content ("...Every issue (of the ones described here) is illustrated with the use of an inspired video which contains (in most of them) clever selection of possible "in deep" cases!" for "The Chemistry of Things"; "…The videos are quite short and really interesting to watch. I especially appreciated the fact that the interactive quiz also contains an explanation for the correctness of the answer", for "Chemistry for Juniors – Sci-spy"; "..the subject of water use and treatment in space is also a subject that does excite the curiosity of every average person and of a young student even more" for "Chemistry and Water Treatment"; "...the first two sections (Metals and Polymers) can actually help students understand better and faster because they do contain a lot of useful information in a limited space and in the context of nice activities and interactive exercises" for "Materials for Special Uses")
- h) Paradigm/role model (''... I liked very much the fact that the people in the videos seem to really enjoy doing the experiments, especially the ones which are more spectacular", "…By watching these videos, it is realized that anybody can be involved in lab work and enjoy the experience" for "The Periodic Table of Videos")
- Useful tools ("...It contains a series of pleasant activities, videos, experiments, quizzes and games. I found especially interesting the games section of the webpage, since children have the opportunity to learn by playing." for "Science Kids – Chemistry"; "...students can learn faster since proper visualization can drastically enhance learning" for "The Periodic Table of Videos")

5. Workshop

The workshop on "Students' Motivation to learn Chemistry" took place in September 2012 and it was designed in such a way that it would encourage the interaction between chemistry teachers and scientific experts. There were a total of 16 participants, of which 11 were teachers and 5 were experts. The participants were divided into 4 groups of 4 persons each. In each group there was at least one scientific expert. The group members were given a specific topic related to students' motivation to think on and express their views. At the beginning, they were left free to interact with each other (within the group) for a specific amount of time (ca 20 min). Subsequently, a representative from each group gave a short (5-8 min) presentation of the main conclusions that each group had reached in respect to each discussion topic. There were three main discussion topics: a) Evaluation of the contents of the "Chemistry is All Around Network" database (Papers – Publications – Teaching Resources), b) Analysis of the current situation in Greece in relation to "Students' motivation to learn chemistry" via the personal experiences of the participants and c) Proposals for overcoming the problem of the lack of student motivation to learn chemistry.
The interaction between chemistry teachers and scientific experts was achieved in an efficient manner. Both points of view were presented but most importantly some common final conclusions were reached. Different possibilities of how the gap between the academic and educational sector could be bridged were examined and discussed. This process involves on one hand teachers' constant training and on the other upgrading of the educational role of the academic world.
The main results of the workshop on "Students' motivation to learn chemistry" are presented below.

A. In the first part of the workshop, the participants discussed the papers, the publications, and the teaching resources of the database. The discussion involved all sources they had written comments on, but also sources they had looked into without producing a written comment.
The participants felt that from the sources they examined, the most important factors that could affect the motivation of students to learn and study chemistry, were the following:

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- the content of chemistry courses: students want to learn about things which are related with their everyday life and experiences,
- the personality of the teacher,
- the curriculum design (teaching methods and strategies),
- the job opportunities and the potential for a successful professional career.

The Irish example was found to be very interesting: Student motivation towards chemistry was not found to increase despite the increased funding in infrastructure. This paradox was attributed to a not-well designed educational system that undermines the chemistry course for entering tertiary education institutions.
The workshop participants pointed out that some publications' reviews were written in the national languages of the respective countries with no translation possibility in English. In addition, in some of the papers the translation in English was a Google translation which usually makes very little sense.
Several of the teaching resources in the portal were really very interesting and useful for the teacher, and they could increase motivation. Special reference was made to "The periodic table of videos" (Ireland), "Food Education" (Italy), "The Chemistry of things" (Portugal) and "Chemistry for Junior Certificate Science", an Irish site which is integrating the whole chemistry curriculum of lower secondary school providing teaching material and useful links. However, the participants noted that they also stepped into resources that were too difficult to use because they needed downloading too much material which was not always functioning and of course this can be very discouraging for motivation. Some resources were pay-per-view and this is considered to be a negative aspect as well. In regard with the national resources uploaded on the site, the participants felt that most of them were easy to use in an efficient manner in order to stimulate student interest (eg. the site www.chemview.gr, "The Wonderful world of Chemistry", the sites of EKFE Rethymnou and EKFE Chanion). It is interesting to note that the majority of the chemistry teachers were already familiar with the existence of the Greek teaching resources.
An important conclusion that was reached is that "acting like magicians" in order to attract students' interest has its limitations. It can be a good starting point but it is simply not enough for maintaining motivation.

B In the second part of the workshop, there was a discussion analyzing the current situation on students' motivation in Greece via the personal experiences of the participating teachers and experts. The main results reached were the following:
In primary school, children do not come with preconceived ideas and the teacher may have the possibility to affect their interests in a large degree. However, the word "chemistry" is never mentioned in the curriculum even though the pupils are taught different chemical phenomena (like for example the water cycle). This makes the subject of chemistry very unfamiliar to the pupils who will subsequently become secondary school students.
In lower secondary education, the motivation of students can be more easily influenced because they are still quite far from taking decisions about their professional future and from preparing for the national exams for entering higher education institutions. The students who are in upper secondary school (16-18 years old) have usually chosen an orientation. Chemistry is a prerequisite only for health and medicine. The students who do not have this orientation are already psychologically very distant from chemistry and it is very hard to get motivated to learn anything related to it. It was also noted that especially in upper secondary school, students are very often interested only in their grades. This poses a major obstacle for creating intrinsic motivation to learn.
The participants felt that the teacher is a central figure in the process of student motivation. The teacher can exert a large influence on the students by constant encouragement, by convincing them that they can do well in chemistry. Especially in the young ages (up to 15-16 years) the teacher can largely influence motivation via his personality, personal paradigm and teaching approach. However, in several

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cases, teachers themselves have very low expectations from their students and they are not interested in motivating them.
Students at University have different motives than secondary school students. University students either start with strong intrinsic motivation to learn or they tend to develop it as the years go by. However, there are few students who feel they entered a faculty that was not their first choice and they are not really motivated to learn. In general, University students tend to have a higher degree of self-regulation. This means that they have the ability to set goals and do their best to achieve them.
According to the experiences of the participants, family plays an important role in the creation and development of motives to learn. The family environment can cultivate a specific learning culture and value system and help the child develop special interests. Finally, it has recently been noted that the economic crisis of the last few years in Greece has made students more responsible and more apt to develop their own motivation to learn.

C. In the last major part of the workshop, the participants discussed possible solutions for overcoming the problem of lack of student motivation to learn chemistry
All experts and teachers agreed that it is necessary for students to get informed and understand what chemistry is about. The fact that chemistry, unlike other sciences, does not have a specific catchphrase for describing its content makes it quite unfamiliar to the average person. Moreover, students' self-efficacy and self-regulation should be built up.
For this purpose, the curriculum should be designed so that it advances the general level of knowledge. It should be enriched with new interest themes. More time is needed for active participation of the students in the educational process especially via lab work. In addition, it is useful that teachers also make use of the historical aspect of chemistry so that students get an idea of how scientific knowledge has evolved.
Teachers need to be given the possibility for constant training. They need to get informed on the latest advancements of chemistry and on the most recent findings in educational research. Finally, a systematic connection between Universities and secondary schools would facilitate both the professional development of chemistry teachers and the students' motivation to learn chemistry

6. Conclusions

By taking into account four different sources of information, namely comments to national and non-national publications, comments to national and non-national papers, comments to national and non-national teaching resources and workshop on students' motivation to learn chemistry, the following major conclusions can be drawn.

In respect with the main student motivations to engage in chemistry learning and the motivational constructs, the main conclusions are given in the following:

- Interest and Relevance – Personal needs. Students cannot have interest in something that is seen as detached and irrelevant to their everyday life reality.
- The communication code (narrative elements, emotional/poetic language)
- Development of student autonomy (self-determination)
- Self-efficacy (perception of own ability to perform well)
- Self-regulation (student ability to set goals and perform all necessary actions for reaching them)
- The family environment which can cultivate a specific learning culture and value system
- Teacher's personality, flexibility and ability to understand the mental processes followed by the student.
- The false image of chemistry and of scientists. Awareness of the usefulness of chemistry.
- The possibility of a rewarding professional career
- Some gender-related connections have been identified in respect with students' motivation toward different scientific subjects.

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In respect with the obstacles that affect students' interest towards chemistry (and science in general) the main conclusions are the following:

- Obstacles related to the Nature of Chemistry (chemical symbols, abstract concepts, microscopic-macroscopic-symbolic levels, molecule visualization etc)
- Obstacles related to students' characteristics (lack of interest, aptitude and self-efficacy, lack of logical reasoning and ability in mathematics, perception of chemistry as a difficult subject)
- Obstacles related to instructional content and context (theoretical teaching approach, "obscure" textbooks and rigorous scientific language, rote learning, teacher's lack of motivation, teacher's inadequacy and insufficient training, examination-driven syllabus, curriculum context which is not interesting and relevant to the student's experiences)
- Low status of chemistry in the Greek educational system and society. Negative image of chemistry in society, lack of important role models and of a catchphrase expressing "what chemistry is about".
- The existence of gender related stereotypes.
- In respect with the most successful practices and experiences in motivating students to engage in chemistry (and science) learning, one should make the important note that experience shows that there is not a simple recipe/remedy to the problem. Students' motivation is indeed a multidimensional construct which is influenced by many parameters simultaneously. The following list gives some practices and experiences which under certain circumstances can be proven to be successful in enhancing student motivation:
- Initiatives for improving the social image of chemistry and for popularizing chemistry. However, such initiatives cannot easily produce a permanent change of attitude
- Innovative teaching initiatives that aim to cultivate the interest and bring out the social relevance at the same time. Context-based learning (PARSEL)
- Teaching approaches related to laboratory instruction and educational tools related to ICT based applications. It is noted however, that ICT based applications have to be easy to implement and use, otherwise obtaining them can end up to be a fruitless effort.
- Teaching approaches giving emphasis to cooperative learning and student-centered giving emphasis to guided inquiry. Major prerequisite: experienced, well-trained and motivated teachers.
- Certain types of appropriately designed non-formal educational material and activities such as museum visits, science fairs, press science and out-of-school activities
- Taking into account the information load in the teaching praxis.
- Finally, in respect with the possible ways that the teaching resources used, can enhance attractiveness and effectiveness of chemistry teaching the following main conclusions are drawn:
- The connection with everyday life experiences, b) Connection of theory with practice, c) The language employed, d) Easiness to use or apply in class, e) Self learning and interactivity, f) Cooperative learning, g) Different points of view/Social Image of Chemistry/Interdisciplinarity, h) Aesthetics, i) Interesting and well-structured content, j) Paradigm/role model and k) Availability of useful tools

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