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Chemistry
is All Around Us

Promotion of Lifelong Learning of Scientific Subjects:

Challenges, Opportunities and Strategies

The Greek National Report

Education and Culture DG

Lifelong Learning Programme

This project has been funded with support from the European Commission.
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GREEK NATIONAL REPORT

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ABSTRACT

This work has three aims: i) present the current national situation as far as lifelong learning of physical sciences is concerned and identify (if any) the barriers to lifelong learning of these subjects iii) identify the strategies and initiatives undertaken at national and regional level for promoting lifelong learning of scientific subjects and iii) make a novel strategy proposal. The findings presented in this report are based on both literature review and on analysis of case studies conducted among adult learners and chemistry teachers. Chemistry was chosen as the specific physical science on which the overall research was focused. The barriers to lifelong learning are related to the nature of Chemistry, to the difficulties students encounter and to the attitudes students tend to have for the subject. The national and regional strategies and initiatives undertaken for promoting lifelong learning in chemistry are found in both formal and non-formal education. The organization of an Interdepartmental Masters Program targeted to teachers' training to new methodological approaches and didactical solutions, the combination of in-class (formal) activities with out-of-class (non-formal) activities, the use of alternative teaching material are some examples of such initiatives. The philosophy and aims of the established Chemistry Curriculum constitutes a major strategy. The most effective science education initiatives for promoting lifelong learning are related to Communication and Information Technology, interdisciplinary cross-thematic teaching approaches, emphasis on the students' misconceptions and difficulties and hands-on teaching approaches. The beliefs and needs of the chemistry teachers should also be taken into account. The proposed strategy involves actions aiming at helping learners to develop the ability of "learning to learn", an obligatory requirement for engaging in lifelong learning.

1. Introduction to the national situation

In the first part of this report we will briefly present the Greek education system and then we will focus on Chemistry teaching and the existing structures established to support lifelong learning of physical sciences (scientific subjects)

1.1 The Greek national education system

The organization of the National Education System is comprised of three levels: Primary, Secondary and Tertiary Education Levels. Pre-primary (nipiagogeio) and Primary School (dimotiko scholeio) form the Primary Education Level covering the ages between 4-12 years (not compulsory for 4-year olds). Secondary Education is divided in two parts: i) Lower Secondary School (Gymnasio) -a compulsory 3-year part of studies, and ii) The Upper Secondary School. Upper Secondary School provides the options of either General and Vocational Upper Secondary Schools (Geniko kai Epagelmatiko Lykeio) or Vocational Education Training Schools (EPA.S.). Duration of studies in the latter cases is 3 years (or 4 in the case of Evening General and Vocational Schools). Finally, the Higher Education Level includes Universities (Panepistimia-AEI), Technological Education Institutes (Technologika Ekpaideftika Idrymata-TEI) and The School of Fine Arts (ASKT).

Vocational Training Institutes (IEK) are not assigned to any of the previously mentioned educational levels. However, the training provided is considered Formal and they are considered to belong to the category of Post-compulsory Secondary Education. Non-typical Post-Secondary Education and Training is conducted by Colleges and Laboratories of Liberal Studies which are private institutes licensed by the Ministry of Education Lifelong Learning and Religious Affairs. Certificates and titles provided by these institutes are not equal to those granted within the framework of Post-Secondary System of Typical Education.

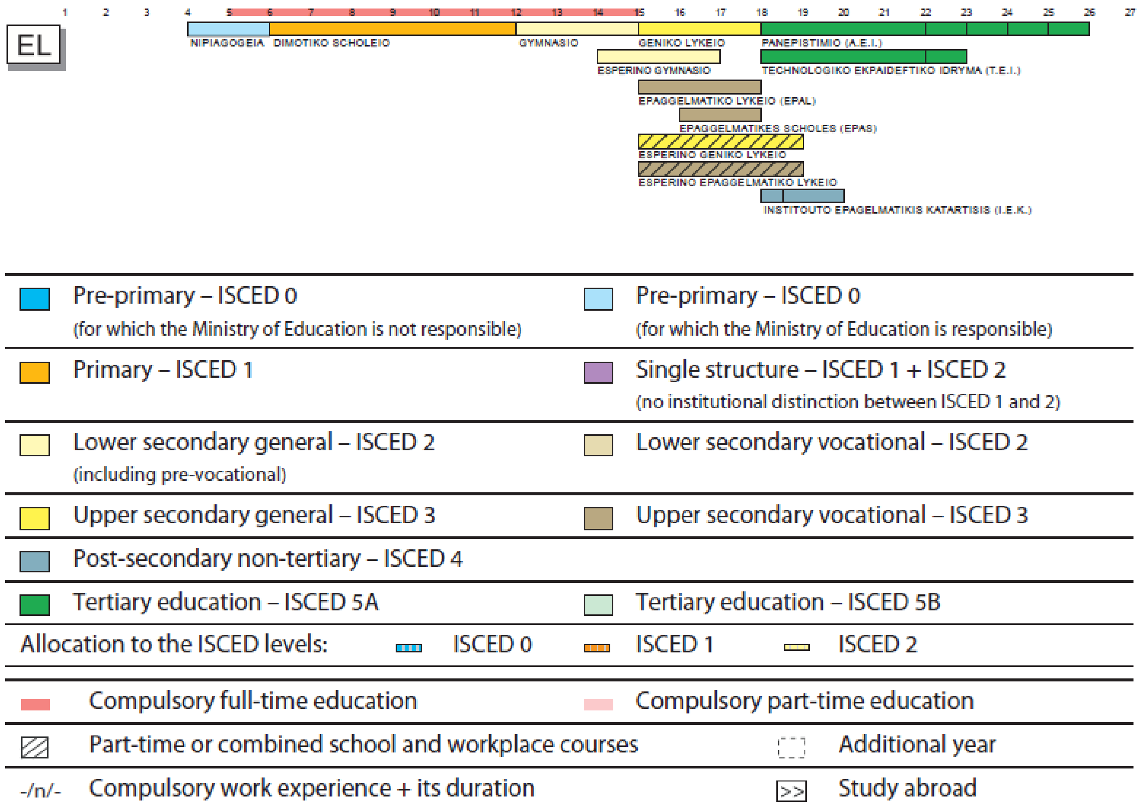

Fig. 1: The Greek Education System (*Source:* Euridice [1])

Education is compulsory between the ages of 5-15 years old, namely including Pre-primary Education, Primary Education and Lower Secondary Education. Progression from the Compulsory Secondary Education to the Upper Secondary Level is based on the overall passing grade (daily work, written tests, assignments and end-of-year written review examinations) at the end of the third year of Lower Secondary Level. A school-leaving certificate from the Upper Secondary Education Level is a prerequisite for the admission to Higher Education. Admission to the Tertiary Education Institutes is determined by the general achievement score which takes into account the final year school grades and the graduates' results in six general education and 'stream' subjects in yearly conducted National Level Examinations (Panhellenic Exams). University Tertiary Education is a State-only provided jurisdiction.

Graduates from Tertiary Education Institutes are awarded the first cycle degree (Ptychion) which leads either to employment or to continuation of studies in a higher level such as Master's (Metaptychiako Diploma Eidikefsis) or Doctorate degree (Didaktoriko Diploma).

Adults who have not completed compulsory education can follow Second Chance Schools (SDE) and be granted a qualification equivalent to the one obtained by Lower Secondary Education after successfully following a two-year duration Programme. Administratively, SDE come under the General Secretariat of Lifelong Learning (GSLLL) and in particular under the Institute of Adult Lifelong Education (IDEKE) structure.

Finally, the Hellenic Open University (EAP/ΕΑΠ) accepts Upper Secondary Level graduates and selection is made randomly by a computer-based draw. As a concept it belongs to both categories of Tertiary Education and Lifelong Learning (LLL). Degree holders have equal rights to typical Tertiary Education graduates.

In the compulsory education levels the school year lasts 9 months (September 11th to June 15th) or 175 days. Schools are open 5 days per week for a period of 35 weeks. The instructional hours depending on the grade and level are between 23 and 35 per week lasting for 40 to 50 minutes. The instructional year in the Upper Secondary Education is again 175 (35 weeks x 5 days per week) with variations in instructional hour length between Morning and Evening Schools (35' to 45').

1.2 School teaching of scientific subjects

The national curricula for primary and secondary education are developed by the Pedagogical Institute and approved by the Ministry. Science lessons, Environmental Studies, Mathematics and Geography are included in the curriculum at Primary Level. Distribution of school hours throughout the 6 years of Primary Education concerning Math and Sciences are presented in Table 1. They include a 3 hour/week Science subject in the last two grades (5th and 6th) of Primary School.

Table 1: Weekly teaching hours of Math and Science-related subjects by grade in Primary School.

		Weekly teaching hours by grade in Primary School					
	Subject	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
1	Mathematics	4	4	4	4	4	4
2	Studies of the Environment	4	4	3	3	-	-
3	Geography	-	-	-	-	2	2
4	**Science**	**-**	**-**	**-**	**-**	**3**	**3**

The above subjects –with the exception of environmental studies- also exist in the curriculum of Lower Secondary Education. Additionally, Chemistry and Biology appear for the first time as separate courses at this level. In particular, Chemistry appears for the first time as a separate subject in the second grade of the Lower Secondary Level (8th grade) (Table 2).

Table 2: Weekly teaching hours of Math and Science subjects by grade in Lower Secondary School.

		Weekly teaching hours by grade in Lower Secondary School					
		DAY			EVENING		
	Subject	**1st (7th)**	**2nd (8th)**	**3rd (9th)**	**1st (7th)**	**2nd (8th)**	**3rd (9th)**
1	Mathematics	4	4	4	4	4	4
2	Physics	-	2	2	-	2	2
3	**Chemistry**	**-**	**1**	**1**	**-**	**1**	**1**
4	Biology	2	-	2	2	-	1
5	Geography	2	2	-	1	1	-

Mathematics and Sciences are considered general education courses in the Upper Secondary Level as well. Depending on the 'stream' followed after 11th grade (Theoretical, Scientific, Technological), students follow the corresponding elective and specialization subjects. This is the key point for the detachment of many students from Chemistry since, although the subject continues to appear in both the list of compulsory subjects and that of elective subjects at 11th grade, it tends to be neglected by students who don't follow a relevant 'stream' (i.e. Scientific and partly Technological). At 12th grade it remains in the curriculum only as specialization subject for the Scientific and partly the Technological 'stream'. The distribution of hours taught in Mathematics and Science in Upper Secondary Education is presented in Table 3.

Table 3: Weekly teaching hours of Maths and Science subjects by grade in Upper Secondary School.

		Weekly teaching hours by grade in Upper Secondary School		
	GENERAL EDUCATION	**1st (10th)**	**2nd (11th)**	**3rd (12th)**
1	Algebra	2	2	-
2	Geometry	3/2	2	-
3	Physics	2/3	2	1
4	**Chemistry**	**2**	**2**	**-**
5	Biology	-	1	1
6	Mathematics and Elements of Statistics	-	-	2
	ELECTIVE SUBJECTS			

1	**Chemistry**		**-**	**2**	**-**
2	Biology		-	2	-
3	Statistics		-	-	2
4	Astronomy and Space Studies		-	2	-
	DIRECTION SUBJECTS				
1	Science Direction	Mathematics	-	3	5
2		Physics	-	2	3
3		**Chemistry**	**-**	**2**	**2**
4		Biology	-	-	2
1	Technological Direction	Mathematics	-	3	-
2		Physics	-	2	-
1	Technology Direction - Technology & Production Route	Mathematics	-	-	5
2		Physics	-	-	3
3		**Chemistry and Biochemistry**	**-**	**-**	**2**
1	Technology Direction - Information Science & Services Route	Mathematics	-	-	5
2		Physics	-	-	3

The information presented in the above two sections was taken mostly from the Euridice database ([1] – [3])

1.3 Scientific subjects in adult education

IEK provide vocational training, whether initial or supplementary; to ensure the acquisition of relevant qualifications for the trainees through the provision of scientific, technical, vocational and practical knowledge, and to facilitate the acquisition of socially and professionally useful skills so as to ensure their graduates' professional integration and their adaptation to the ever-changing needs of the labor market. According to the Organisation for Vocational Education and Training (OEEK), in 2007 there were in total 114 public and 53 private IEK. They regularly offer Vocational & Educational Training Courses in subjects strongly related to Chemistry involving a wide selection of Chemistry subjects. In particular, streams which offer Chemistry oriented vocational courses are 'Chemical Industries', 'Food & Beverage', 'Energy & Environment', and 'Applied Arts' –Table 4. [4]

Table 4: Chemistry-related specializations offered by public and private Vocational Training Institutes (IEK).

	Streams	Specializations
1	Chemical Industries	Medicine, Cosmetics and Related Products Technician
		Materials Control Technician
		Ceramic Materials Technician
		Metal Surfaces Technician
		Metalizing Technician
2	Food & Beverage	Distillery Technician
		Milk Processing Technician
3	Energy & Environment	Industrial & Work Environment Control Technician
		Pollution Control Installation Technician
4	Applied Arts	Decoration
		Decoration & Design

Second Chance Schools also involve Chemistry as part of the Science courses in the curriculum of studies. The course is taught for 2 per week. They also offer Mathematics in a 3-hour weekly basis and Environmental Studies courses for 2 hours per week. [5]

Centers for Adult Education (KEE) apart from 'Mathematics and Basic Statistics', offer several Educational Programmes related with the Environment and Sustainable Development. Many of the courses are Chemistry-related (Atmospheric Pollution, Indoor Air Pollution, Water Resources, Water Pollution, Urban Solid Waste, Waste Management, Wastewater Treatment, The Ozone Layer, Acid Rain, Greenhouse Effect, etc.). The duration of these programmes spans between 25 to 50 hours. [6]

The Center of Distance Education for Lifelong Adult Learning (KEDBMAP/ΚΕΔΒΜΑΠ) provides a distance programme in Environmental and Sustainable Development. As in the case of KEE (see above) similar Chemistry-related courses are involved in the structure of the Programme which lasts 250 hours and is provided in an annual basis starting in October for a period of about 40 weeks. [7]

The Hellenic Open University is considered part of LLL since admission to the courses is open to all Upper Secondary Level graduates regardless of achievement scores. Selection is based on a random computer-based procedure. Studies offered include an Undergraduate Course in Natural Sciences and Postgraduate Courses in 'Catalysis and Environmental Protection', 'Teaching Natural Sciences', 'Waste Management' and 'Advanced Studies in Physics'. [8]

1.4 National and Regional bodies assigned with Lifelong learning (LLL)

The established institutional framework concerning Lifelong Learning (LLL) is supported by a number of agencies and organizations. Lifelong Learning provision has mainly been devolved to the agency of the General Secretariat for Lifelong Learning (GSLLL) [9], which evolved (2008) from the previous General Secretariat for Adult Education as an advanced agency supervised by the Education Ministry and entrusted with the design and implementation of a broader spectrum of LLL – mostly informal learning – platforms with a wider impact and equitable accessibility along with its complementary executive agency, the Institute for the Continuous Education of Adults (IDEKE) [10].

The educational structures which are under the auspices of GSLLL/IDEKE and carry out LLL programmes are the following [9]: Second Chance Schools (SDE/ΣΔΕ), Centers for Adult Education (KEE), Schools for Parents, The Center of Distance Education for Lifelong Adult Learning (KEDBMAP/ΚΕΔΒΜΑΠ), Prefectural Committees for Adult Education (NELE/ΝΕΛΕ) and Vocational Training Centers (KEK).

Additionally, actions towards LLL are hosted by the Hellenic Open University [8], the Greek Manpower Employment Organisation (OAED) [11], the Organisation for Vocational Education and Training (OEEK) [4], and the Central Union of Municipalities and Communities of Greece (KEDKE). [12].

1.5 National and Regional Policies implemented to promote LLL

In alignment with the Lisbon Strategy which holds LLL as one of the main pillars against unemployment, a reform project has started seeking to overhaul the whole Greek Educational System. The reform procedure has started from LLL and Higher Education.

The establishment of an adequate institutional framework and a functional LLL network, devolving the General Secretariat of LLL as the central body for LLL provision, has simplified the administrative planning tackling fragmentation and dispersal of LLL services and agencies. Investments in the field and functional improvements have reversed the situation concerning LLL in the country in the last years, making achievable the target of participation of 12.5% of the population in LLL programmes by the end of 2010.

The particulate actions that materialise the state LLL policy can be distinguished into two complementary categories: the -general- programmes that are carried out by the General Secretariat for LLL itself and the ones implemented by the agency supervised by the Secretariat, the Institute for the Continuous Education of Adults (IDEKE/ΙΔΕΚΕ). Apart from Second Chance Schools the remaining structures (Adult Education Centres, Parents Schools, Lifelong Learning Prefectural Committees, Vocational Training Centre, Centre of Distance Lifelong Education and Training for Adults as well as the autonomous programmes of the General Secretariat for Adult Education) belong to informal education for adults.

1.6 Current national situation in Lifelong Learning

The latest general trends concerning Lifelong Learning in Europe according to Eurostat (10/06/2010) in Greece showed that Less than one third of Greece's population (17.4%) was involved in any kind of learning, formal, non-formal or informal. (Formal education corresponds to education and training in the regular system of schools, universities and colleges, non-formal education and training includes all types of taught learning activities which are not part of a formal education programme, and informal learning corresponds to self-learning which is not part of either formal or non-formal education and training, by using different methods like books, computers, learning centres or educational broadcasting). The percentages ranged from 27.2% at the 25-34 years old group age to 7.2% at the 55-64 years old group age with men slightly more active in learning activities (18.3%

males – 16.3% females). In respect of non-formal learning participation rates were generally low (4.9%), and showed very large differences among age (9.2% at the 25-34 years old group age to 1% at the 55-64 years old group age) educational levels (high educational level 13%, medium 5%, low 1%) and working status (employed 6.1%, unemployed 6.9%, inactive 1.6%). Non-formal education intensity is higher among the unemployed and inactive population (108 and 113 hours per participant correspondingly) giving a total average of 85 hours per annum regardless of sex or occupation.

As far as statistical data on Natural Sciences or Chemistry alone are concerned, these were absent from the set of data concerning the field of learning, possibly because no Science-dedicated programmes and courses were carried out. [13, 14]

2. Main obstacles to lifelong learning of scientific subjects

In this part of the report, an attempt will be done to present concisely the main reasons and causes that pose obstacles to the lifelong learning process of scientific subjects, with an emphasis on chemistry. The presentation will first involve a brief bibliographical review of the subject. It is important to note that the publications reviewed are written recently (last decade) by Greek authors who have been exploring the Greek School system and they are all connected to Chemistry learning. The barriers according to the bibliographical review are organized into three main categories: a) those related to the nature of the subject of Chemistry, b) those related to the students' difficulties with the subject and c) those related to the students' attitudes to the subject. In the second part of this presentation we will refer to the results obtained by the analysis of the case studies administered among the adult learnes.

2.1 The Nature of Chemistry

Chemistry is unique as a school subject because it possesses a triple nature: macroscopic, submicroscopic and representational (or symbolic) [15]. As a result, it is a school subject that has high conceptual demands. In addition to its multiple nature, chemistry is possibly the most visual among physical sciences. Therefore, one of the ongoing challenges in teaching chemistry is making students understand, visualize and explore the various molecular structural features [16].

2.2. Students' Difficulties

The nature of the Chemistry subject discussed above poses difficulties to Chemistry learning. According to the study of Salta and Tzougraki [17] students find difficulties in the use of chemical symbols and the application of chemistry concepts such as atom, molecule, mass, volume and mole. The application and use of chemistry concepts and symbols depends on the students' ability to transfer between macroscopic-symbolic-microscopic levels and vice versa. In the same study, it is also shown that students also have difficulties in solving chemical problems which require mathematical skills. In the study of Charistos et al. [16], it is shown that students find it difficult to visualize the shape of a molecule in a two-dimensional printed page.

Pre-existing empirical knowledge, intuitive alternative ideas and misconceptions related to several chemical phenomena often pose a major obstacle to Chemistry learning, since it has been noted that they are very persistent and very difficult to overcome. Several recent studies in Greece have explored the misconceptions/alternative ideas of students in different areas of chemistry and underlined the need for these ideas to be taken into account in the design of the teaching methodology. The specific chemistry areas/phenomena examined are the following: the dialysis of salt in water [18], the understanding of the particulate nature of matter and the phase changes [19], basic chemistry concepts related to food [20], chemical equilibrium [21], chemical aspects of photosynthesis [22] and basic quantum chemistry concepts [23]. The role of the media in creating some of these misconceptions and presenting a distorted scientific truth is also underlined [20].

Student's difficulties are also related to the following three cognitive variables [19]: 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 "technicality", formality and abstractness of the scientific language and the commonly used communication code in standard chemistry (and science) textbooks [23, 24]. Traditional chemistry textbooks tend to give a large emphasis in theory and use unattractive language that creates difficulties and discourages the average student [17, 24, 25].

2.3 Students' Attitudes

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 [26].

In the study of Salta and Tzougraki [17] it was found that students have a neutral/negative attitude regarding the interest of the chemistry course. It is noted that some of the reasons that form such attitude are related to the content of chemistry curriculum, the limited amount of chemistry lessons time (one hour per week), the methods of teaching chemistry in Greek schools and the lack of laboratory experiments. In Greece, chemistry is usually taught theoretically without hands-on activities and this practice decreases students' interest for chemistry lessons. The majority of Greek students tend to recognize that chemistry knowledge is useful for interpreting aspects of everyday life, but only few of them (about 4%) express the wish to study chemistry at University. It is hopeful however that most students believe that chemistry contributes in solving environmental problems and improves our lives. Overall, Greek students have a more positive attitude regarding the importance of chemistry and negative/neutral attitude regarding the usefulness of the chemistry course, the difficulty and the interest. The overly demanding content of the Greek chemistry curriculum has been pointed out by other researchers as well and seems to constitute an important discouraging factor for chemistry learning. It also poses major difficulties to the teachers since it leaves them very little freedom to use other teaching sources apart from the provided science textbook [24, 25].

2.4 Analysis of case studies

The case studies were conducted by interviewing 10 adults (6 men – 4 women) in a wide age range (23 to 58 years old). All 10 adults had some tertiary education degree in a subject which was not related to science. The questions posed to the adults aimed at identifying factors that cause barriers to lifelong learning of scientific subjects, with emphasis on Chemistry (Why did you decide not to continue your studies in some scientific subject, what difficulties did you face in the Chemistry course in secondary school, what do you think of the word "chemical".

The analysis of the case studies gave rise to the following results regarding the barriers to lifelong learning:

a) Teaching methodology. Chemistry is often taught very theoretically, with no lab work (or only via demonstration experiments) and with no reference to its connection with everyday life phenomena. Emphasis is given on learning many things by heart and on problem solving. Namely the interviewees mentioned the following:

"…chemistry was not easily perceived with my senses … and I was not the type of person that would sit down and learn by heart all the names of chemicals, the chemical reactions …"

"… everything was done on paper only…'

"…I liked chemistry very much… however I could not deal with the insecurity of not being able to solve a chemistry problem in an exam, no matter how hard I studied"

b) Inadequacy of the chemistry teacher. Teachers fail to create a positive atmosphere and stimulate students' curiosity for learning and enthusiasm. Certain references of the interviewees were the following:

"… we had a teacher who was too "scientific" …", "… my teacher could not communicate knowledge, he was very bad in general …", "… I believe that also from my teachers I did not get enough stimuli in order to be pushed to follow this type of studies…"

c) Too difficult textbook, with very difficult language.

"… did not like the book especially, there were other far better ones translated from English…"

d) Very demanding and heavy content of chemistry curriculum.

"… my first contact was very positive. However when I had to learn the periodic table and some models of the atom, things became too difficult…"

e) Intrinsic difficulty of chemistry concepts, necessity for a certain level of logical thinking and lack of basic knowledge, discourage students from further study. Fear for problem solving

"… had a lot of gaps in my basic knowledge … when I was trying to solve a problem, or understand a little deeper and all these gaps were coming on the surface I was feeling very discouraged and did not like it at all …"

f) Very little allocated teaching time per week (1 hour per week).

"… I remember that the course was taught only one hour per week and it was very difficult to assimilate all this information in such short time …"

The barriers to lifelong learning identified via the case studies analysis are similar to the ones identified from researchers and presented in the literature review. It is noted that most barriers brought about from the case studies are related with the ones concerning "students' attitudes" and were briefly reviewed before. Research on the factors that influence attitudes towards chemistry should be given increased importance.

3. Strategies and Initiatives developed at national and local level to promote lifelong learning of scientific subjects.

The presentation in this report will be divided into three main categories of strategies and initiatives developed at national and local level for promoting lifelong learning of scientific subjects: a) Formal educational initiatives, b) Non-formal and Informal educational initiatives and c) Educational strategies

3.1 Formal educational initiatives

The Chemistry Departments of some Greek Universities (Athens, Ioannina) have included in their undergraduate programmes elective courses in Education (pedagogics) and Methodology of Teaching Chemistry (didactics) [15].

The Chemistry Departments of three Greek Universities (Athens, Thessaloniki and Ioannina) and the Department of Chemical Engineering of the National Technical University of Athens are co-organizing an interdepartmental program of graduate studies leading to the acquisition of a Masters degree, entitled "Chemical Education and New Educational Technologies". The programme aims at providing scientific and educational training at graduate level to already serving and prospective high school chemistry teachers in Greece. The program has found a considerable response: there are approximately 150 applicants every year, of which approximately 35 are selected. Since its start in 1998 it has produced 225 diploma thesis and 70 publications. Teachers' training is related to lifelong learning since a well-trained teacher possesses the tools for making chemistry teaching more attractive and stimulate students for acquiring chemical knowledge and the scientific way of thinking. [15, 27].

All newly appointed chemistry teachers at the secondary education public system attend an obligatory training course in teaching methodologies organized by the National Ministry of Education Lifelong Learning and Religious Affairs.

3.2 Non-formal and Informal Educational initiatives

The "Association of Greek Chemists" organizes every year a two-day seminar on secondary chemical education. The seminar is attended by a large number (over 400) of chemistry teachers from all over Greece [15]. The general goal of the seminar series is to provide educational training to active secondary chemistry teachers in Greece.

The role of museums in science education has been noted by several researchers [28-30]. The conclusions of a long-term research project concerning the roles of the pupils and their teachers during a school visit to the Technology Museum of Thessaloniki (TMT) were the following [28, 29]: i) Both pupils and teachers have a strong positive attitude toward the visit to a Science and Technology museum, ii) Pupils have rather high expectations on the possible profits both at the knowledge and the emotional/fun level and these expectations seem to be confirmed, iii) Students attitudes toward science do not seem to change significantly after the visit to the museum, iv) Teachers do not usually organize thoroughly the visit to the museum and do not give significant effort to the enhancement of knowledge (meta-knowledge) after the visit. v) Teachers should attend training courses relevant to organization of out-of-school educational activities. In another recent research work [30], the authors present a novel didactic approach which incorporates the use of two educational programmes carried out at the Industrial Museum of Lavrio in the teaching of the chemistry subject "metals and metallurgy". The novel didactic approach involves redesigning of the existing museum programmes in addition to classroom actions prior to the museum visit, in order to achieve the required educational goals. The initial results of a pilot application of the novel didactic approach are also presented and they are characterized as “encouraging”. It is concluded that properly designed museum visits (educational programmes) in combination with classroom work can enhance the knowledge goal in chemistry as well as social awareness regarding the role of chemistry in the development of human civilization.

Subsequently we will focus on the brief presentation of initiatives that have been developed by four museum-structures. The first two structures are quite large: the Eugenidio Foundation located in Athens and founded in 1956 [31] and the Science Center and Technology Museum “NOESIS” located in Thessaloniki and founded in 2001 [32]. Both of these structures are non-profit foundations aiming at promoting technology culture and creating an appropriate environment for informing the public of the latest developments in science and technology. Popularization of science and dissemination of scientific knowledge to the general public are two of the main objectives of both foundations. They are achieved via exhibitions, seminars, lectures, shows (planetarium, cosmotheatre, virtual reality simulator), educational programs and experimental activities. Concentrating on issues related to Chemistry we can mention the following:

The Eugenidio Foundation organizes periodically a series of experimental interactive activities that are often related with chemistry. Two such activities took place during the last few months (November 2009 and January 2010) and were related with the application of Chemistry in Forensic Science (Chemistry in Law) and with the application of Chemistry in the kitchen. During these activities a series of five or six experiments designed to be as spectacular as possible (eg. Exploding sugar, bursting popcorn, luminol oxidation for finding non-visible blood traces) are executed in front of the public. In some cases, kids are also asked to perform experiments by working in teams. One of the permanent exhibitions of “The Eugenidio Foundation” is an Interactive Exhibition of Science and Technology in which students have the chance to learn about matter and materials by interacting with the exhibits. In a series of informal lectures entitled “the café of science” the general public has the possibility to be informed on chemistry issues that are related to everyday life activities or affecting our life in general (eg. UV irradiation and health, the role of photochemistry in environmental protection etc).

The “NOESIS” Science Center also organizes “the café of science” lecture series, experimental activities with subjects that are related to chemistry. In addition, the “NOESIS” center organizes (since 2009) 5-day summer camps (5 sessions during every summer) for children between 9 and 12 years old. In the summer camp, children (30 in each camp) are exposed to the world of science and technology via specially designed team games and activities, nature visits, showings (planetarium, documentaries), etc. The events and activities of both these structures have increasing demand among primary and lower secondary school children and their parents. The educational initiatives of both Foundations (Eugenidio and NOESIS) are attended by over 200,000 students and adults every year. The initiatives use a winner formula for scientific dissemination, for making the world of science accessible to the average person and for cultivating scientific curiosity and culture. Young children are also educated in the scientific way of thinking and the basis are set for “learning how to learn”.

The other two museum-structures we will refer to are of smaller scale, they have however strong and increasingly important local impact. These are the Lavrion Industrial and Handicrafts Museum [33] and the Milos Mining Museum [34]. The Industrial and Handicrafts Museum at Lavrion (Attica) is located in an area where mining activities and metal extraction (lead-silver) was actively taking place in the ancient times up until a few decades ago. The Museum organizes a series of educational programmes designed in specific thematic areas and following the cross-thematic approach. Some thematic areas involve chemistry themes such as metal extraction from ore and metal reactions. The programmes can be attended by a group of 30 people, they last approximately 1 hour and a half and take place every week all year round. The Mining Museum of Milos (Cyclades island) organizes annually a series of educational programs and activities aiming at increasing public awareness of the presence and use of minerals in every day life. Depending on their success some activities may go on for more than a year. Two of these activities that are related to mineral chemistry are the following: i) “All Around Us: Minerals embrace our lives”- an educational board game available in Greek and English and ii) “Minerals in our lives. Industrial minerals-our world is made of them”. This is an instructional and entertaining activity. The initiatives of the Milos Mining Museum have mainly regional impact (Cyclades island) however their impact becomes national and international during the tourist season (summer months). The educational programs are bilingual (Greek and English) and this enhances the impact of the initiative.

The Centers for Environmental Education (KPE/ΚΠΕ) are non-formal educational structures that function under the auspices of the Ministry of Education, Lifelong Learning and Religious Affairs and are funded by the EU. They aim at developing the value of environmental responsibility among young secondary school children, at providing information showing the complex interrelationship between man and its natural environment, at creating a positive attitude towards scientific knowledge related to environmental science and at cultivating the ability for inquiry about the physical world. As an example, we can refer to the Center for Environmental Education in Argyroupoli [35], which is one of the first founded in Greece in 1995. The center organizes a series of educational programs (7 active programs during 2010) which involve both classroom activities as well as field action, related with environmental themes (Water, Energy sources, atmospheric pollution, forest, landscape reconstitution, fires and natural catastrophes). Field actions related with chemistry are for example the collection of water from a local river and then performance of simple chemical tests for determining its quality, evaluation of solid waste contamination etc The Center is open during the academic year and open to organized school visits from the Athens area and the rest of the country. In the period between 1995-2009, 2650 secondary school visits (teams of 30 pupils) from all over Greece have taken place at the Center of Environmental Education of Argiroupoli, in order to participate at its educational programs. It should be noted however that these Centers (69 all over Greece) are sometimes understaffed or with personnel that is not an expert in the field.

We continue with another non-formal educational initiative functioning under the auspices of the Ministry of Education, known in Greek with the initials EKFE (ΕΚΦΕ). EKFE stands for Secondary Education Laboratory Centers for Physical Sciences [36]. The personnel working at the 44 EKFEs all over Greece (science teachers), give the opportunity to groups of secondary school children to perform chemistry experiments and aid teachers in designing and doing chemistry experiments in their own school units (either in class or in labs). They provide educational material (tests, videos, virtual lab experiments, simple chemical equipment) and also organize events related to applications of chemistry in everyday life (informal lectures). They also prepare students for participating in the chemistry Olympiad and other chemistry competitions. The activities at the EKFEs are taking place all year round (September-June). The initiative creates a positive attitude towards chemistry among the student community and cultivates creativity and general scientific skills (inquiry, discovery).

Science Fairs are also an informal educational initiative that can lead to science popularization and dissemination across a wide public. Science fairs are organized by EKFEs and sometimes by private institutions. The private secondary school “Rhodian Pedia” located in Rhodes Island organizes yearly a very successful science fair [37]. The event takes place every year on the first week of September. It is organized by the school teachers and a group of pupils and involves a series of demonstration experiments, fun activities, games in several scientific fields (chemistry, physics, biology, geography, computers, environment, etc). The event has rising success during the seven consecutive years that it is organized. The last science fair (September 2009) was attended by 250 pupils and approximately 200 parents. The event is considered already a tradition for the educational community of the island.

This section will finish by referring to the Project known as PARSEL (Popularity and Relevance of Science Education for Science Literacy) [38]. PARSEL is a European Project carried out by a consortium of 8 Universities in 7 countries (Greece, Portugal, Sweden, Denmark, Germany, Estonia, Israel) and the International Council of Associations for Science Education (UK). It lasted for a total period of 30 months (ended in March 2009). During the project, alternative teaching material was developed and tested in order to promote popularization of science and increase the level of scientific literacy. The produced alternative teaching material aimed at promoting student interest in science without alienating the teaching from the curriculum intentions.

3.3 Educational Strategies

We will refer to two main educational strategies that have been developed in order to enhance science literacy and either set the basis for lifelong learning of scientific subjects or simply encourage it. The first one is the Second Chance School (SDE/ΣΔΕ) [5]. SDEs are part of the public school system and they are intended for adults (individuals over 18 years old) who have completed the first six years of compulsory education (Dimotiko) but not the extra three compulsory years of Lower Secondary School. The graduates of Second Chance Schools are issued with a leaving certificate equivalent with the Lower Secondary School leaving Ceritificate (Gymnasium). Thus they complete the compulsory basic education and they have the chance to integrate in the job market and of course if they wish, continue to Upper Secondary School (Lyceum). Education in SDEs lasts 18 months and is organized in 25 hours weeks. Currently, there exist 57 such schools all over Greece and they are attended by approximately 5500 adult learners. Among other subjects taught, SDEs also include scientific literacy (Physics, Chemistry, Biology) in their curriculum. In other words, chemistry is not taught as a separate subject but integrated with the other physical sciences. In these schools, adult students learn modern science not with the traditional teacher-centered approach but mostly via performing simple experiments and by team work and projects. The curriculum is not pre-specified and it is tailored to the needs and specific interests of the students. It has to be noted however that according to a recent study [39] second chance schools in Greece do not seem to successfully engage their students in collaborative effective learning as they are meant to do.

A major national strategy related to the promotion of life long learning is the new inter-disciplinary cross-thematic Integrated Curriculum for Primary and Secondary Education which was established in Greece in 2003 [40]. Except of the new curriculum, the new textbooks and supplementary educational material are yet to be produced. According to the new curriculum the presentation of the material should be spiral inductive, ie from the simple to the complicated, from the easy to the difficult. The students should be encouraged to search and discover new knowledge and the teaching method should take into account the pre-existing knowledge of the students (constructivism) and connect the chemistry class with their everyday experience. Special emphasis should be given to the active involvement of the students in the performance of laboratory experiments, the analysis of the results and the subsequent “discovery” of the more general laws and principles that govern chemical phenomena. One of the main goals of the novel Curriculum is to provide students with the ability of “learning to learn”. By this term, one refers to the ability to pursue and persist in learning, to organize one’s own learning through effective management of time and information, both individually and in groups. The competence of “learning to learn” is an obligatory requirement for engaging in lifelong learning. The latter is a process starting at pre-school age and ending at post retirement age.

4. Identification of effective science education initiatives

In this part of the report we will first refer to the effective science education initiatives as they are reported in the bibliography. We will be based on research done by Greek scientists, related to chemistry teaching in the Greek educational system. Subsequently, we will refer to the findings of the case study analysis done among science teachers.

4.1 Communication and Information Technology (ICT) in Chemistry Education

ICT in chemistry education can produce a remarkable improvement in the method of teaching chemistry, significantly enhance the educational result and promote lifelong learning.

The 3D Normal Modes, is an educational tool for interactive visualization and three dimensional perception of vibrational spectra of molecules, which has been developed for helping students overcome their difficulties concerning the various molecular structural features [41].

In another study, the researchers have examined the contributions of three types of visualization (3D illustration, 3D animation, interactive 3D animation) to the learning process of science in 13- and 14-year old students [42]. The results indicate that multimedia applications with interactive 3D animation and 3D animation do increase the interest of students and render the material more appealing. The findings also suggest that the most obvious and essential benefit of static visuals (3D illustrations) is that they leave to the students the time control of learning and decrease the cognitive load.

A cartoon-style multimedia application has been developed and used to evaluate its effectiveness in supporting teaching and learning science in elementary education. The results provide evidence that the use of animated cartoons significantly increases the young students’ knowledge and understanding of specific science concepts, which are normally difficult to comprehend and often cause misconceptions [43].

A multimedia system which serves as bilingual chemistry educational tool for deaf students, including a working chemistry terminology in Greek Sign Language (GSL), has been developed in order to provide new educational opportunities to deaf students [44].

A multimedia application was developed and tested for teaching the section “Mixture separation methods” to 2nd Grade Lower secondary school pupils [45]. The application was produced in three different forms: the first included only text, static picture and narration, the second included animation, while the third included interactive 3d animation. The software (all 3 different forms) was tested to 212 students in order to check the degree at which each one of four elements (static picture, sound, animation, interactive 3d animation) attracts student's attention and thus influences the educational result. When using interactive 3d animation both the time spent at each scene and the amount of scenes watched by each pupils was much larger (statistically important difference) relative to the other two forms of the software. It is important to note that the application was developed by taking into account the principles of cognitive load theory (CLT). In this work it is pointed out that except of the respect to certain pedagogical principles, other factors that affect the successful use of a multimedia application include the pupils' previous knowledge and spatial ability as well as the choice of colors.

The main characteristics of the educational software created for teaching Chemistry in 2nd and 3rd grades of lower secondary school in Greece are presented in the work of Tzamtzis et al. [46] The software, named "The Wonderful World of Chemistry for lower secondary school", was designed by taking into account the guidelines of the new Interdisciplinary Chemistry Curriculum established in 2003 by the Greek Ministry of Education. The software is based on the principles of cognitive constructivism. The use of videos and representative photos attracts pupils' attention and stimulates their pre-existing knowledge on the subject studied. Context presentation and pupils' information on the aims of the course are done via dialogues between funny characters. Finally knowledge construction is achieved via virtual lab exercises and quizzes. The language used is simple but not simplistic. It should be noted however that there are no available hard data concerning the evaluation of the software.

A series of 10 experiments (all related with basic organic chemistry) that according to the official syllabus need to be performed by pupils in 2nd Grade upper secondary school, are presented simulated in the computer [47]. All simulations are interactive and prepared with very basic commercially available computer programmes (MSPowerpoint, MSWord, MSPaint). The result on the students' attitudes towards the subject taught was measured. It is shown that the students are attracted to learn and their interest is aroused. Their grades in tests tend to rise, showing evidence for a positive educational result. Simulated experiments can be very useful in the cases of lack of lab infrastructure or when potentially harmful/dangerous chemicals are involved. However, their use cannot and should not completely substitute real experimentation.

4.2 Non-traditional teaching methods

The use of analogies in Chemistry teaching and their effect on cognitive and affective factors of 10th and 11th grade Greek students has recently been explored [48]. Attention was paid to the structural correspondence between the analogue and the target. Regarding the analogue domain, emphasis was placed on using analogies with a strong and familiar social context. The results provide evidence for the possible usefulness of the long-term use of analogies in the teaching of chemistry. Analogies can be more effective for students with lower cognitive development. In addition, the study showed a positive affective effect to most students.

In another study [49], two teaching methods aiming at improving the learning of highly abstract and complex content of chemistry in lower secondary school have been examined. One is a method based on developmental psychology and the other is a "three-cycle" method based on the distinction of school chemistry into macroscopic, submicroscopic and representational levels. The largest positive effect was shown to be induced by the three-cycle method.

The students' attitudes towards "press science" and the possibility of transformation of such articles into novel educational materials have recently been explored [24, 50]. The teachers who volunteered in this research project ended up very content by their involvement in the production of such educational material, even though they were very reluctant at the beginning. They pointed out however that the whole process is very time and money consuming in order to be applied on a regular basis. Their dependency on the school textbook is also a major drawback. The pupils on the other hand seemed to appreciate the use of such novel educational material (press articles). Their positive attitude was basically due to the more poetic-sentimental language employed by the articles (story-telling), the more modern themes and the "livelihood" of the pictures in contrast to the "old" pictures of the typical textbooks (diagrams).

A research project conducted among 180 secondary school students in the 10th grade (15-16 years old) aimed at quantifying the higher effectiveness of the guided inquiry teaching method relative to the traditional teaching method [51]. The subject taught was the phenomenon of ionic bonding. Measurements of the test scores before and after the application of each teaching method showed that the group of students taught via guided enquiry achieved approximately 8% higher average scores relative to the control group. This difference is statistically significant. In addition, the use of the guided inquiry invoked enthusiasm among students and aroused their interest towards the chemistry concept taught. Guided inquiry can achieve increased understanding of chemistry concepts and development of critical thinking.

A recent study [52] presents the design and initial application of a Hybrid Instructional Model which integrates the positive features of web-based learning with those of the conventional classroom teaching. The results of a pilot program established at the University of Thessaloniki for teaching Molecular Symmetry are presented. The interactive activities of the web-based applications increased significantly the students' interest and understanding of the subject taught. The success rate of the final exam were very high and at the same time the students continued attending the classroom course every week. The students appreciated their independence in the learning process and the fact that they could work at their own rate. The direct accessibility and feedback from the teacher is also an element that enhanced the educational result.

The effectiveness of the application of constructivism and of inquiry to chemistry teaching via their introduction to new textbooks has recently been examined [53]. In this work, the authors attempt to make a quantitative comparison between three types of physics and chemistry lower-secondary education textbooks. The first type was the standard official physics and chemistry textbooks used in the Greek secondary educational system and which makes use of the traditional teaching method (teacher-centered and the student treated as "blank paper"). The second type was a science textbook written by American Researchers and made use of the teaching method of inquiry. The third type was a science textbook based on the theory of constructivism. The textbooks were evaluated by 34 teachers on the basis of the following five criteria: content, structure, readability, methodology and comprehension. The following eight specific lesson units were chosen for the evaluation: heat, chemical reactions, gravity, solutions, energy, electricity, mass-density, linear simple motion. Even though the sample used was marginally small for extracting safe quantitative conclusions, there are general trends pointing to the superiority of the latter two textbook types relative to the standard one in nearly all criteria.

4.3 Interdisciplinary teaching approaches

An interdisciplinary learning method based on discovery is presented in the work by Kafetzopoulos et al. [26]. Students approach "the art of chemistry" through chemistry demonstrations in the classroom and understand "the chemistry of art" by preparing colors for painting via chemical reactions. This learning method creates a learning environment which leads to a positive attitude towards chemistry and laboratory activities and as a result reduces "chemophobia". Art is used to make learning chemistry interesting and effective.

The educational package "Water in the Mediterranean" [54] has been developed in order to facilitate the educator's work in the closely related fields of Environmental Education, Education for Environment and Sustainability and Education for Sustainable Development in secondary education. The package is designed to be a flexible resource guide for the work of educators. It mainly aims at enhancing the students' understanding on major issues related to water and at introducing them in a constructive manner to the complexity and interdependence of the various economic, social and environmental factors linked with water and sustainable development. Furthermore, the material aims at the development of problem-solving and decision-making skills, in order to stimulate the responsible behavior of students and their ability to undertake action in favor of the environment and natural resources as individuals or as team members.

In another study [55], a novel method for popularizing science and increasing scientific literacy is being proposed. It involves the combination of history of science together with the study of a theatrical play and aims at pointing out the interrelation of science with a variety of topics (beyond the world and the language of science) that interest teachers and students in our days. The undergraduate students of the Department of Primary Education (future teachers) read and analyze in the classroom the play "The life of Galileo" by Bertolt Brecht. Through this study, the cultural interrelations of science and society are pointed out and especially the way science affects our perceptions of the physical world.

The recent work of Baratsi-Barakou [56] presents the design and application of an interdisciplinary approach to teaching the phenomenon of the planet overheating (known as greenhouse effect). Several previous works have shown that pupils have major misconceptions related with the causes and consequences of this effect. The teaching methodology was based on the

PBL (problem-based learning) approach and followed the model structure of the 7E's learning cycle. Three different instructional tools were employed: two experimental activities, a video with photos of Antarctica and a documentary feature. This project was put into practice in 3rd year lower-secondary school pupils (14-15 years old). The evaluation of the project showed an increased interest of the pupils to scientific issues related to real life phenomena. However, it remains difficult to overpass the descriptive level of understanding and reach to the more complex explanatory model of thinking.

4.4 Hands-on teaching approaches

The positive effect of the practical activities on students' attitudes towards Chemistry is pointed out in the interdisciplinary approach, "The Chemistry of Art and the Art of Chemistry" to which we referred to in the previous section [26].

In addition, the work of Liapi and Tsaparlis [57] explores how the hands-on work in a school chemistry lab affects the attitudes of students towards chemistry as well as the educational result. The research was conducted among 14 year old students, who were asked to perform themselves two types of chemistry laboratory experiments all related with acids and bases: a) creative experiments with themes connected to everyday life experiences (bath bubblers, toothpaste, acid rain) and b) standard chemistry experiments (acid-base neutralization, indicator color change, acid-metal reactions). The students of a control group did not perform experiments themselves but only watched the teacher-research demonstrate an experiment. The analysis of the results shows that students strongly prefer performing the chemistry experiments themselves instead of being passive attendants. Their attitude and interest towards chemistry becomes more positive and they tend to realize that the subject of chemistry is not only interesting but also useful. Students also show a strong preference for experiments that have a direct connection with everyday life.

Kampourakis et al. [58] have applied the teaching method of "problem-solving by means of experiments" in order to collect and measure the volume of gaseous carbon dioxide contained in a coca-cola bottle. This novel teaching method was applied to a group of seven 1st year undergraduate student of the Department of Primary Education, four of which had considerably less science background from secondary education. The instructional method required a lot of effort from both the instructor and the students. In the context of collaborative learning, the group tries to suggest an experimental solution that would give an answer to the problem. The group encounters many difficulties which are related to the following factors: very little previous laboratory experience, possession of declarative knowledge with very little concept understanding, lack of the concept of the particulate nature of matter. Despite the difficulties and the fact that the group does not manage to design the correct experimental apparatus, the overall method resulted in the creation of a positive attitude of the students towards science. The element of active participation in the process of knowledge (social constructivism) seems to be crucial in creating a positive atmosphere. The overlap of theory, experiment and the scientific method seems to create a perspective of an improvement of the instructional methods in science teaching.

4.5 Analysis of Case Studies conducted among chemistry teachers

Ten secondary school chemistry teachers were selected to give interviews concerning the difficulties they encounter in chemistry teaching, the reasons for which students are discouraged to study chemistry and in general be engaged in scientific subjects and the possible effective science education initiatives. The analysis of the teachers' case studies led to the following basic results:

a) Chemistry is considered a difficult subject and requires a lot of effort from the students. Its teaching should become more appealing to the students. The majority of the teachers stress the need for hands-on laboratory experimentation, which often is not possible due to the lack of equipped labs. A specific time slot every week should be allocated to laboratory activities. In this way, students feel "important", creative, their curiosity is aroused, and a positive attitude towards chemistry is cultivated. Many teachers stressed the importance of putting an effort to study the attitudes of students toward chemistry and to change them so that they do not consider it either very difficult, or very dangerous, or very unrelated to their interests.

b) Lab activities and rest of the teaching material should give special emphasis on the connection of chemistry to everyday life applications.

c) The curriculum should be redesigned. At the moment, it is quite heavy and at the same time fragmentary. A holistic, interdisciplinary approach should be followed in both the curriculum design and the chemistry teaching. In addition, the beliefs of the teachers should be taken into account in the curriculum design.

d) Chemistry textbooks should give more examples to everyday life chemistry applications and in general be more appealing (use of color, simple-but not simplistic-language).

e) Chemistry teachers should take into consideration the way students learn and understand science. Research should be encouraged in this field and its results should be disseminated across chemistry teachers.

f) A combination of traditional and non-traditional teaching methods should be employed. Use of animation, videos, photos, computer simulations.

g) Visits to research centers so that the students learn more about the latest advances in different chemistry fields that produce outcomes that are closely related with everyday life.

h) Teachers stressed the lack of job opportunities for chemistry graduates, as an important factor influencing students' choice for study. Science teaching should stress the importance of being able to understand the basics of scientific subjects and of mastering the method of the scientific analytical approach to problem solving, regardless of the profession that someone will end up practicing.

5. Identification of Best Practices

In this part of the report we will focus on identifying the best practices for enhancing lifelong learning of scientific subjects emphasizing on chemistry. We will take into account the strategies, initiatives and education actions presented in sections 3 and 4 above. It should be noted that the presentation of sections 3 and 4 has already been based on the existing field practices that have given encouraging and good results when applied. It is important to point out that in sections 3 and 4, we have already made careful selection of those practices that are supported by rigorous research results that are already published.

5.1 Best strategies and initiatives developed at national and local level

The Interdepartmental Master's Program entitled "Chemical Education and New Educational Technologies" [15, 27] has been evaluated very positively. A well-trained chemistry teacher is able to reveal to his students the wonderful world of chemistry and create a positive environment that will encourage critical thinking and inquiry.

The role of museums as non-formal educational structures can be critical in disseminating chemistry knowledge, in cultivating a positive attitude towards science and increasing the average level of chemical (and scientific) literacy. The interactive experimental activities and exhibits seem to be the ones that are more positively received by the public. The educational programs should be carefully designed by respecting pedagogical theory and should be attended simultaneously and in close connection with the traditional classroom activities, in order to achieve the most permanent educational result.

The initiatives undertaken by the Centers of Environmental Education (KPE/ΚΠΕ) can also be very useful at cultivating the ability for inquiry about the physical world. The field actions related to Chemistry (eg. Collection and simple chemical tests of water samples) provide both chemistry knowledge and at the same time develop the value of environmental responsibility among young children.

The initiatives undertaken by EKFEs (Secondary Education Laboratory Centers for Physical Sciences), if properly designed, are able to create a positive attitude towards physical sciences and cultivate general scientific skills. We note especially the contribution of EKFEs in developing easy to do experiments with very simple materials and apparatus and in organizing student competitions and fun events. However, the EKFE personnel should be in closer contact with the chemistry teachers in secondary education, in order to help him put the initiatives into practice.

The availability of alternative teaching material (like the one developed by the PARSEL project or the one that will be developed by the current project) can significantly promote student interest in science, if it is well designed. More specifically it should include material that brings up the connection of chemistry with every day life and go in parallel with the curriculum intentions.

The curriculum content and design is of critical importance. The new interdisciplinary cross-thematic Integrated Curriculum for Primary and Secondary Education (based on knowledge discovery and taking into account pre-existing knowledge) is definitely a good strategy. Its realization however is far from easy. Novel textbooks need to be produced, school laboratories need to be adequately equipped both with instruments and with personnel and more time needs to be allocated for practical experimentation.

The teaching approach and philosophy of science teaching in Second Chance Schools (collaborative learning, hands-on approach, syllabus tailored to the needs of the adult learner) constitutes a good practice in theory. However, it does not seem to be easily applicable.

5.2 Most effective science education initiatives

Experience and studies show that Communication and Information Technology (ICT) in Chemistry Education can lead to a remarkable improvement in chemistry teaching, stimulate student interest, enhance the educational result and promote lifelong learning. They should be used however as supplements and tools for achieving the ultimate education goal. This goal should be the development of critical thinking and of the ability of “learning to learn”. Experiment simulations can also be very useful, for example in the cases of lack of lab infrastructure or of potentially harmful/dangerous experiments. However, they should not completely substitute real experimentation.

The performance of chemistry experiments by the students themselves (and the least possible use of demonstration experiments) has been identified as most effective in creating positive attitudes and in achieving a more permanent educational result.

Among the non-traditional teaching methods the ones identified as most effective in promoting lifelong learning are the following: i) the use of carefully designed analogies in Chemistry teaching, ii) the “three-cycle” method based on the distinction into the macroscopic, submicroscopic and symbolic levels, iii) the use press articles which have been carefully transformed into educational material, iv) the method of guided inquiry, v) a hybrid instructional method involving both web-based and in-class learning and vi) the constructivistic methodological approach. Constructivism takes into account student previous (incorrect) knowledge and common misconceptions. It is considered very effective, however at the same time difficult to put into routine practice.

The use of science textbooks which do not follow the traditional teaching method (teacher-centered and the student treated as “blank paper”, but make use of either guided inquiry or of constructivism seems to be also an effective initiative

The interdisciplinary teaching approaches are also very effective in showing the close interconnections between different scientific fields. Many everyday life phenomena, especially those that are related with the environment, require the engagement of several different scientific disciplines for their full explanation. Examples of such approaches are Chemistry in Art and Chemistry in the Physical Environment.

6. Conclusions

The major conclusions of this report are the following:

The main obstacles to lifelong learning of scientific subjects and more specifically chemistry are related with either the nature of chemistry, or students’ difficulties, or students’ attitudes toward chemistry. Identification of these barriers is a prerequisite for the design of an effective strategy for promoting lifelong learning in scientific subject and for overcoming scientific illiteracy.

The best strategies and initiatives developed at national/local level for promoting lifelong learning involve actions in formal and non-formal education. They are also related with the philosophy/aims of the established science curriculum.

The most effective science education initiatives for promoting lifelong learning are related with the following: Communication and Information Technology in Chemistry Education, Non-traditional teaching methods, Interdisciplinary teaching approaches and hands-on teaching approaches.

A strategy proposal for the promotion of lifelong learning should be based on both the views of the students/adult learners and the teachers. It should take into account the difficulties, attitudes and needs of the first and at the same time the beliefs of the second regarding their work context.

7. Strategy Proposal

In this part of the report an attempt will be made to propose a strategy for promotion of lifelong learning of physical sciences with an emphasis on chemistry. This will be done by taking into account the findings reported above and which are based on literature review and case study analysis of adult learners and science teachers. Our proposed strategy is based on three pillars: i) Teaching methodology, ii) Non-formal educational initiatives, iii) Curriculum design.

7.1 Teaching Methodology

Chemistry teaching should take into account students' previous knowledge and misconceptions and follow the method of constructivism in order to achieve the required mental change. This requires that research on identifying these misconceptions should be encouraged.

Chemistry teaching should also take into account the specific difficulties that students encounter, as those have been identified by continued and intensive research. Chemistry is a subject that often requires high conceptual demands from the students and its difficulty discourages them from even making an effort to understand it. Teachers should not deny that Chemistry can be difficult, they should however stress to the students all possible gains they can have by investing time and effort in learning such a subject: they will end up with higher self-esteem after their successful encounter with chemistry, they will have cultivated their critical, complex, and analytical thinking and judgement, they will be able to act as responsible citizens in an constantly-changing world, they will become smarter. These gains are worth obtaining regardless of the actual profession that someone practices.

The use of novel educational tools based on ICT can provide valuable assistance to the process of making Chemistry teaching more attractive and more effective. However, it should not constitute the major teaching method, but act complimentarily.

Hands-on experimentation should be encouraged. It helps making students' attitudes more positive, it increases their interest to the subject and puts chemistry "in context", ie shows its connection with everyday life phenomena.

Non-traditional teaching methods (guided inquiry, combination of in-class and long-distance learning, articles from the press, analogies) as well as interdisciplinary teaching approaches aid in cultivating the ability of "learning to learn".

Last and most important, special emphasis should be given on teachers' training and continued education on these methodologies. Teachers' beliefs concerning their work context should seriously be taken into account by policy makers [59, 60]. Teachers should be aware of the advantages and disadvantages of each teaching approach and they should be given advice (not orders) and practical help for their implementation.

7.2 Non-formal and Informal educational initiatives

Educational programs, interactive exhibits and hands-on activities organized by science museums can be a very effective means for dissemination and popularization of scientific knowledge. However, students' attitudes towards science does not seem to change significantly after the visit to the museum. The goal of cultivating an inquiring mind is better served via a combination approach: in-class preparation for the museum visit, careful design of the activity/ies carried out at the museum, knowledge enhancement after the visit (meta-knowledge) and visit evaluation.

The educational initiatives undertaken at regional level by the Centers of Environmental Education (KPE/ΚΠΕ) and the Secondary Education Laboratory Centers for Physical Sciences (EKFEs), if properly disseminated among teachers and students, constitute an important strategy for promoting lifelong learning. The most effective initiatives are actions in the field and the possibility of setting up easy to do experiments in a school laboratory with very simple materials.

Alternative educational material produced by projects such as PARSEL [38] and our own ("Chemistry is All Around Us") constitute an effective route to the promotion of lifelong learning of scientific subjects. This material should be designed so that it is entertaining, user friendly and at the same time scientifically sound. It should include different levels of difficulty, bring out the presence of chemistry in many aspects of human life, not necessarily deny the negative results of chemistry but also point out the positive ones which are far more numerous.

7.3 Curriculum design

The length of the Chemistry syllabus and the amount of time allocated to Chemistry teaching should coincide so that it is possible for the teachers to present the material in depth and for the students to assimilate it. The content of the curriculum should give emphasis to the application of the presented principles to real life phenomena. The active student involvement in lab experimentation should be supported by lab personnel and by the allocation of a specific slot in the weekly timetable for lab work.

The Chemistry curriculum should take into account students' alternative ideas and give emphasis on interdisciplinarity. However, chemistry education needs not be integrated with other physical sciences in a sole "science" course. The presentation of the material should be spiral inductive, ie from the simple to the complicated, from the easy to the difficult. Students should be encouraged to search and discover new knowledge, to understand principles and learn the least possible by heart and most importantly to master the ability of "learning to learn".

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