

PROMETHEAN RESPONSE OF GREEK HIGH-SCHOOL STUDENTS TO THE PROTEAN CHANGES OF THE CHEMISTRY CURRICULUM

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Abstract

The response of the Greek high-school students to the ever-changing educational program and especially their chemistry curriculum involves the adoption of the "memorize or reject" attitude rather than the assimilation of facts and laws into their scientific background. Two recent studies carried out during school years 2010-11 and 2013-14 by means of questionnaires distributed to class B and C senior high-school students in a number of Northern Greece high-schools, accidentally fell on either side of the latest modification of the Chemistry curriculum. The comparison of the overall results reveals the minimal effect of the above change on the chemical background of the students whose main purpose is to prepare adequately for the entrance examinations to University courses. The observation lies in accordance to several studies over the last four decades.

Key words: educational system, chemistry curriculum, senior high-school, Greek students

1. INTRODUCTION

Due to the growing complexity of contemporary society and its continuous dependence on pure and applied sciences in almost every aspect, teaching of Science in secondary school students gains in importance (Hodson, 1992) and much demanded is the incorporation of facts and data to the knowledge background of the young students (Armstrong 1973). Care must be, and in fact is, taken to introduce the youngsters to science in the most appropriate way such as to ensure that they will both understand and accept it, avoiding the lifelong antipathy that has often been encountered with those persons who have been introduced to science poorly or in an inappropriate manner. A condition that is essential in fulfilling is the relation of scientific aspects taught to phenomena occurring in everyday life since it is then that science actually engages with the student's beliefs which have been developed by accumulating their direct simple observations of their surroundings during their early life (Osborne & Collins, 2001). A consistent and well-designed science curriculum should aim at the conceptual development of the students drawing from the information available on their prior knowledge and constructing the appropriate models with the most convenient and sound simplifications, where required in order to achieve the best possible results (Taber 2008). Such a curriculum is expected to facilitate to a great extent the most efficient transformation of good teaching to integrated conceptual knowledge and in this way prepare the future adults for the life in their contemporary technologically advanced states (Turner 2000). Curricula are expected to be modified whenever the requirements of society for education are altered but this is not something that should occur very often and certainly not without a prior thorough evaluation. In the meantime, the effect of the current curriculum should be investigated by standard procedures such as evaluation of questionnaires with content related to disciplines upon which the teaching is based as well as direct investigation of the models developed and applied in teaching by the teachers themselves. The result should be an updated school program which is expected to include all the material and the levels of its presentation appropriate for the age of the students to whom it is addressed at every grade (Taber 2008). Consequently, the attitude of students is expected to alter resulting in an enhanced interest in the course and to a higher degree of assimilation of the scientific knowledge that is taught to them.

1.1 The Greek Educational System in Brief

At the present Greek students of ages between 12 and 18, are expected to attend consecutively the three grades of Gymnasio (freely translated as junior high-school) and three grades of Lykeio (senior high-school), before they attempt to follow an undergraduate course at some Higher level education institute through succeeding in an entrance examination. However, the system is not as simple as briefly described in the above sentence. The junior high-school level is part of the compulsory education while the senior high-school one is not. Further, the first grade of senior high-school is the last year of studies where a common curriculum is provided for every student, from then on the students are offered several options, at the moment being characterized as theoretical, technical and positive directions the last one focusing mainly on science in the form of Physics, Chemistry, Biology and Mathematics. To complicate things even more, the classes taken in senior high-school grades B and C are partitioned into “root” and “direction” ones, even for the disciplines offered exclusively in one direction, that is a student in class B attending the positive direction has two separate timetables per week for, say, 2 hours of root Physics and 2 more hours for direction Physics. Separate textbooks with differing content are provided for each of the above two example courses.

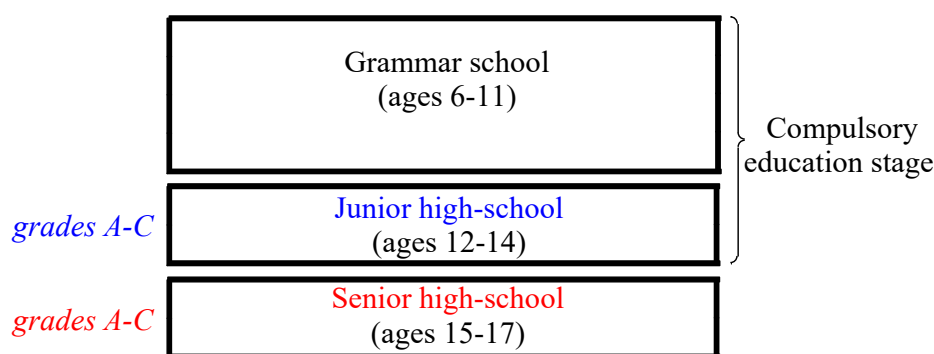


Figure 1. Outline of the Greek educational system. Common courses are provided up to grade A of senior high-school. From then on, grades B and C divided into three "directions", Theoretical, Positive (Sciences) and Technical

The uniqueness of the educational system carry on to the end of the secondary education and the final exams which determine whether a student will continue studies at High level education. The number and the content of each course that a student will be examined to as well as the relative weight of the mark he/she will receive in order to complete the full mark of the exams is determined by law which does not resemble natural or global law, in the sense that it undergoes changes frequently at a rate higher than the corresponding one for party replacement in government.

1.2 Greek High-School Chemistry Curriculum

Chemistry is taught throughout the six-year span of high-school studies, however it is apparent that it does not form part of an integrated programme for science teaching as a simple investigation of the unavoidable overlap with Biology unraveled (Karageorgiou et al 2015). Even then, the consistency of the chemistry disciplines that are programmed to be the learning target is not standard since in numerous cases, official directions are forwarded to the teachers during the school year, instructing them to modify the extent of teaching of specific topics, usually in the form of omission of entire subsections, alternation in succession of chapters and occasionally dismissal of exercises and problem solution.

Table 1. Hours per week of Chemistry classes for Greek high-schools as advised by the Ministry of Education. Numbers in parentheses correspond to additional hours per week for students attending the “positive direction”.

	Grade		
	A	B	C
Junior high-school	0	1	1
Senior high-school	2	2	(3)

A brief idea of the content presented and discussed at junior high-school is as follows:

Junior high-school grade B

Chapter 1. Introduction to Chemistry, including states of matter and physical properties of materials.

Chapter 2. From water to atom and from macro to micro-world. Topics include everyday use of water, water as solvent (including solution concentrations reported in percent per weight or volume), water pollution, mixture identification and discrimination, water dissociation, chemical reaction (in abstract form), symbols of the elements and of molecules, meaning of a chemical equation.

Chapter 3. Atmospheric air, its constitution, especially physical and chemical properties of oxygen and carbon dioxide (without reference to chemical equations), air pollution.

Chapter 4. The ground, its surface and below it, ground pollution.

Junior high-school grade C

Chapter 1. Acids. Arrhenius definition, pH scale, pH of pure water, pH of acidic solutions, pH measurement.

Chapter 2. Bases. Properties, Arrhenius definition, pH scale of bases.

Chapter 3. Neutralization.

Chapter 4. Salts. General properties, formation of a NaCl crystal.

Chapter 5. Everyday applications of acids, bases and salts. Topics include the human body, detergents, food, acid rain.

Chapter 6. The periodic table, its origin and history, identification of metals and non-metals within it, why certain elements present similar behaviour.

Chapter 7. Distinction between metals and non-metals, reaction of metals with acids, alloys.

Chapter 8. Carbon, natural and synthetic carbon polymorphs, carbon dioxide, carbonates, cement.

Chapter 9. Silicon, glass, ceramics, optical fibers, semiconductors.

Chapter 10. Hydrocarbons. General considerations, combustion, hydrocarbon fuels, air pollution and protection measures.

Chapter 11. Oil, natural gas and petrochemicals. Formation of oil, desulfurization, constitution and uses of natural gas, petrochemicals especially related to polymers, plastics and discussion of merits and drawbacks of synthetic polymers.

Chapter 12. Ethanol. Topics include fermentation process, properties of ethanol, its combustion, alcoholic drinks, physiological action of ethanol.

2. THE REPORTED STUDY

2.1 General considerations

The study was carried out by questionnaires distributed to students during a teaching hour. They were informed that it would not count as a regular test and their participation was on completely voluntary basis, in accordance with the demands of the Ministry of Education in order to issue approval for the survey. The initial sample was limited by omitting about 9 % of the answering sheets which were obviously completed at random or in a provocative way. The material reported hereby consists of the questionnaires obtained from two consecutive surveys carried out during 2010-11 and 2013-14 school years respectively. The two surveys were carried out aiming at the understanding of the general misconceptions of Greek students related to basic aspects of the Chemistry curriculum and comprised of about 1600 and 1100 questionnaires respectively. The questions were mainly multiple choice but also true-or-false questions were included (Treagust 1988; Daniel Tan & Treagust, 1999) along with a few points where some chemical formulae had to be introduced. The aspects covered included everything that is incorporated into the junior high-school chemistry educational program as well as that of the first grade of the senior high-school, i.e. atomic model and structure, chemical bond formation and properties of simple molecules, properties of electrolytes (acids, bases and salts, including the neutralization reaction), constitution and properties of solutions. Care was taken to introduce in the possible answer list misconceptions that have been shown to exist in previous elaborate studies (Kind 2004; Horton 2007).

In the meantime, between the two surveys yet another modification of the chemistry teaching program for high-schools took place in the form of omitting the acid-base-salt-oxides section, replacing it with elements of general organic chemistry in the textbook and teaching program of senior high-school grade A, with analogous implications on the overall background of the students in the years to follow. In this respect the combination of the results of the two surveys may serve as a measure of the response of the students towards the aforementioned modification although their initial planning did not have this target (Bennett 2001). It may further be used as a starting point for a thorough assessment of the chemistry course and the presentation models it employs because in the Greek educational system there is a single textbook per year of studies and therefore there is no need to perform comparative studies in order to evaluate various approaches and models utilized (Thiele & Treagust, 1995).

In order to keep factors affecting the results to a minimum we consider only the reports from schools which participated in both surveys. In this sense we hope to have eliminated factors concerning the attitude of students towards science in general and chemistry in particular. One of these factors is expected to be the socio-economic status of the family and immediate neighborhood background (Gorard & See 2009), something which we expect that cannot have changed much over a period of 3 years for people residing in a specific area. Unfortunately, Experimental schools run under the supervision of Universities are not included in the sample although they participated in both surveys since in the meantime the admittance to them has changed from random to selection and therefore the initial background of the two populations that took part in the two surveys would not be unaffected.

Unfortunately, although instructed to do so, only 343 students in the sample checked the “positive direction” box in their questionnaire, while about 300 did not check any of the provided boxes. A further complication arises from the fact that the students are allowed to alter their direction on going from the second to the third grade, a complication related to the direction change possibility renders it more difficult to verify effects of long term memory. Long term memory is expected to be present in the sample in the form of students attending grades B and C of senior high-school whereas the material of the questionnaire relates to subjects that they have been taught during junior high-school or grade A senior high-school. It has been verified that when teaching a topic is over, gradually students tend to fall back to their prior level of conception and interpretation of facts and results related to this topic, therefore revealing more accurately the degree of conceptual understanding of the topic (Taber 2004; Cokelez & Dumon 2005). Partition of the sample into boys and girls is something rather straightforward and in line with related studies carried worldwide until very recently (Cousins 2007; Zeyer & Wolf 2010) although there exists some skepticism about this distinction, a better

classification seeming to be one related to the kind of mental processes that a person utilizes in studying. However, such a partition of the present sample would be out of the question since its construction would require personal contact and a detailed discussion with every pupil participating in the test, something impossible considering their number and geographical distribution.

2.2 Description of the sample studied

The sample studied comprises of 1050 questionnaires obtained in two school years, almost evenly partitioned among them (526 and 524 for school years 2010-11 and 2013-14 respectively). The girls are considerably more than boys (589 relative to 461) and grade B students participated to a far greater extent (770 relative 280 from grade C) due to the reluctance of several teachers to “waste” the precious time of their final year students, in view of the latters’ effort to prepare for the forthcoming exams to enter Higher education. The sample is further partitioned into the various school types which are considered, namely 197 in private schools (situated in the city of Thessaloniki), 499 in schools of urban areas (i.e. towns serving as administrative centers of the Greek state prefectures) and 354 in public schools of a metropolitan centre, in this case the city of Thessaloniki with 1,5 million inhabitants. This sort of partition seemed meaningful in view of the widely accepted idea, common to both students and teachers, that the larger the city the better the educational level of its schools. The assumption is based on the system applied to the admittance of teachers to school units; in the beginning of one’s career as secondary school teacher the government proceeds with placing him/her at some remote part of the country and gradually, based on a point system to which elapsed time of service plays the major part, one finds oneself “moving” towards the urban centres, ideally finishing in one of the few large cities, one of which is Thessaloniki. Maturity and experience in the teaching process is expected to grow with time of service, however this gross model has not always been valid since it excludes factors like ageing, which slows down the initial stamina of a teacher as well as invokes long memory effects which though not discussed, are certain to appear to older teachers who have not attended an educational course for some time.

3. RESULTS OF THE STUDY

The initial step of evaluation of the results of analogous studies is the application of simple descriptive statistics such as mean values and standard deviations of sub-groups defined within the sample studied in order to verify the right or wrong assumption of the existence of such sub-groups. The results of this study are collected in Table 2.

Table 2. Descriptive statistics for the student population included in the study. The percent success column provides information about the percentage of students that would actually pass an exam with the provided questionnaire, that is achieve a mark of 10,0 or better.

School type	Sample	Average	Standard deviation	Percent success
Urban schools	499	7.05	2.49	12.8
Metropolitan schools	354	7.13	2.63	12.4
Private schools	197	5.82	2.26	5.1
Girls	589	6.74	2.54	10.2
Boys	461	6.98	2.54	12.6
Grade B	770	6.71	2.35	9.0
Grade C	280	7.21	3.00	17.5
School year 2010-11	526	6.88	2.58	11.2
School year 2013-14	524	6.81	2.51	11.3
Positive direction	343	8.39	2.62	34.4
Total	1050	6.85	2.54	11.2

The overall mean value of chemical knowledge assimilation appears to be rather poor as it reaches just about 34.3 %. The numbers reported in Table 2 refer to the 0-20 scale adopted by Greek high-schools. This observation is rather discouraging, with regard to the efforts taken, during the last three decades at least, to modify and modernize the Greek educational system especially when we compare this gross result with analogous studies carried out during the above period. Although these previous studies were performed on much smaller student populations and on more limited target schools, the common factor remains that the integration of the major chemical aspects into the chemical background of Greek students lies within the 25 – 34 % margins with a notable single exception of reaching 40 % when restricted to common household chemicals (Katsikis et al 2015). Discouraging is also the fact that the above general chemistry conception “test” would be passed only by 11.2 % of the students that participated in the survey.

These observations indicate a strong and continuous impact of the Greek society on the outcome of any educational program since the life-goal for a secondary school pupil is set to passing the exams which will “open the doors” of a higher education institute, in many cases the name, focus and perspective of the Department being irrelevant. Under this pressure, mainly from the household environment, the pupils tend to adopt behaviours that will ensure better marks in the classes and better overall marks in their exams, especially those related to the University entrance exams. It is not uncommon to come across to responses like “I have no interest in Chemistry because I will not need it when I will be studying at the Law Department”. Of course, the example of Michael Ventris is not widely known but even then, in our belief, it would not help in altering the above attitude. Ventris was a man who was a prodigy in foreign languages but learned only minimal ancient Greek and Latin at school (early in the 20th century), developed high mathematical skills and graduated from an Architecture school, cooperated in the deciphering of German military codes during World War II, only to be known and memorated as being the one to decipher the syllabus-based Linear B language and correctly interpret it as being the most early up-to-date from of Greek. This example, discussed appropriately should make it clear to people that nobody can know for sure what is going to be needed, in the form of particular knowledge about a topic, later in one’s lifetime.

In addition to the above a further observation aids our argument, in the form of the unexpectedly low achievements of the private schools. It is well known and accepted that private schools especially base their prestige largely on the high percentage of their pupils’ success and in this respect pay much

attention to their well-organized “guidance” as of how they will perform better in their exams. It is therefore either the neglect of trying to teach skills and facts other than those related to the expected forthcoming major exams by the school or the inherent tendency of the students to adopt the minimum energy pathway and concentrate only on activities that are going to help them achieve the better possible marks, and certainly a test like the one undertaken for our study is not among them.

Another notable observation is the value of the standard deviation which, in every case, is considered extremely large compared to the mean value of the distribution curves realized. This is, in our belief, another evidence for the widespread nature of pupils attitudes, from total neglect to active engaging, in practically all the considered sub-groups of the population studied. The same observation holds true also for the pupils that declare attendance of the science-oriented classes who achieve an expected larger degree of chemical aspect understanding (42.0 %) as well as a huge success percentage in the “test” (34.4 %) compared to the population average. As it can be seen from their distribution curve in Figure 2 the resulting curve is by no means typical but presents at least three distinct peaks, the higher one located around 12.5 and distinguishing this subgroup of pupils from the rest. Incidentally, an almost typical distribution curve is realized only in the case of the total sample studied.

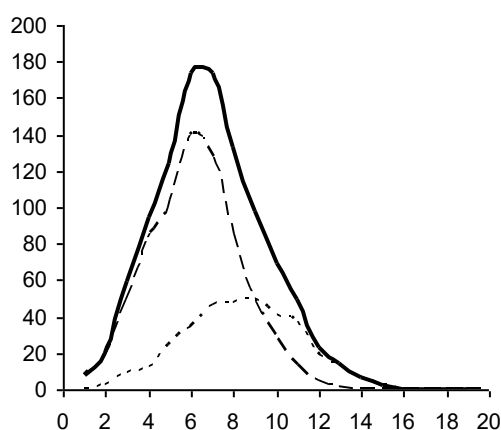


Figure 2. Distribution curve of the pupils attending the science-focused direction (dotted line) with respect to those who do not (dashed line). The continuous line represents the total population studied.

The engagement of grade C students focusing on science for their University entrance exams (87 out of 280 total), is believed to be responsible for the apparent better results of grade C over grade B students. This percentage is slightly smaller than the overall one, however since these students are giving their most in concentrating, it is most probable that they start recalling and reorganizing their previously acquired knowledge and in this respect do better than what they would a year before when they would be more relaxed. Actually, this subgroup of pupils achieved by far the best overall result with a mean of 9.91.

As in all the previous studies in Greece, there appears to be an overall similar level of understanding chemical principles between boys and girls. It is a well-established fact that at these ages girls appear more focused and more “tidy” in their study, however they appear to lack some abilities to work out mathematical operations. This is evident from the percentage of success in the entrance examinations to Universities where even in the science departments, traditionally regarded as male student playground, females constitute more than 60% of the students. However, it seems that the algorithmic skills of the boys counterbalance the above abilities of the girls. The above observations can be viewed in summary in the form of distribution curves in Figure 3.

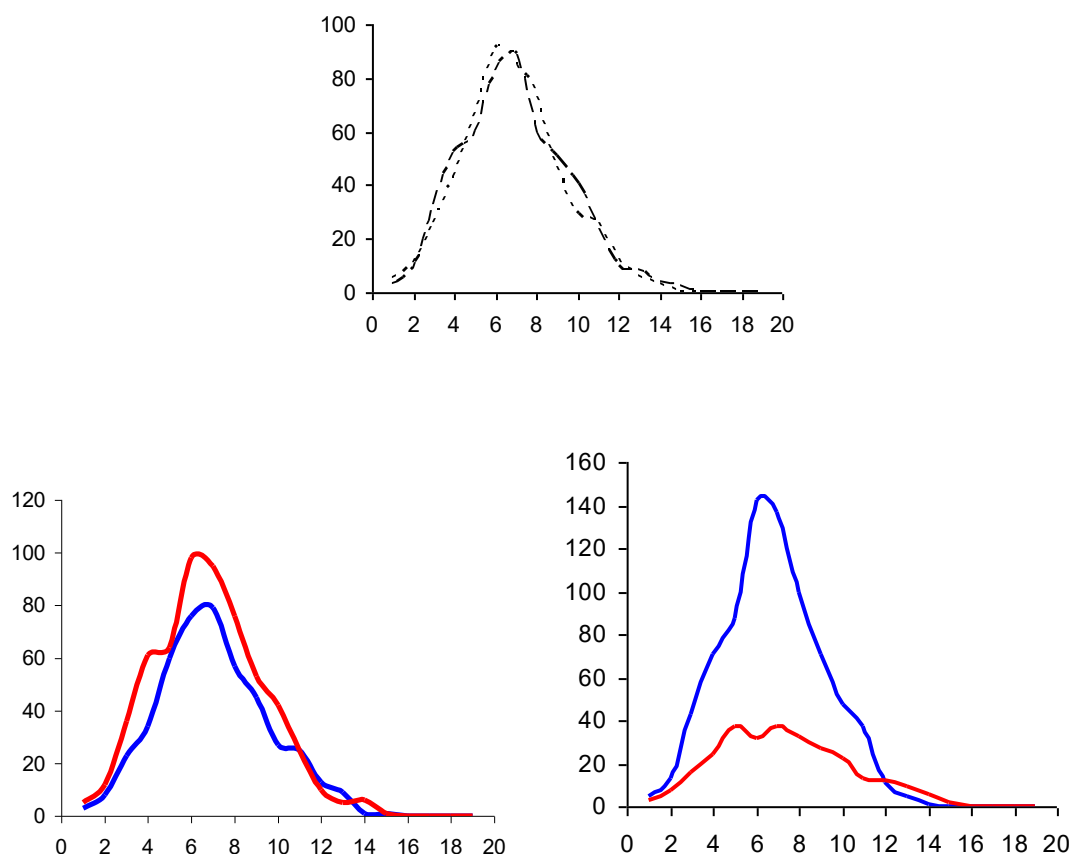


Figure 3. Distribution curves of the evaluation survey. Above, plot of the distribution of the 2010-11 survey (dashed line) versus the 2013-14 one (dotted line). Below left comparison between boys (blue line) and girls (red line) and below right comparison between grade B (blue line) and grade C (red line) students.

Post-hoc analyses are employed frequently for statistical purposes and in our case we made use of the well-documented Bonferroni correction, which, although limiting the significance of the comparisons attempted and being “conservative”, i.e. tending to overlook slight significance between groups is well suited for the treatment of the large number of unevenly distributed observations which constitute our population.

The pairwise comparisons carried out were all at a familywise error level of 95% and their findings can be expressed in the following:

Concerning school background, metropolitan and other city school units do not appear to have a statistically significant difference, however private schools appear as a distinct group of school units presenting disappointing performance probably due to the reluctance of the pupils to consider the test provided as useful or even challenging for them.

Regarding sex, the results are borderline between indicating a significant difference among boys and girls or not, while there appears to be a marginal difference between grade B and grade C students. Finally, the questionnaires of the two separate surveys do not differ providing the main grounds for the arguments proposed for the general attitude of students towards the chemical education they are provided with.

A similar treatment of the results obtained from pupils attending the positive direction follow the above observations with the notable exception that there emerges an apparent statistical difference between grade B and grade C students, which has been already discussed and attributed to the

acclimatization of the young pupils to the logic of putting every possible effort to the success in the higher education entrance examinations. It is to be noted at this point that all the answering sheets that were marked as “passed” came from this subcategory of pupils.

The most interesting feature of the study, however, was the absolute match of the two surveys, while there existed a substantial difference between them regarding the content of the senior high-school chemistry classes. The two curricula, followed during the two school years when the surveys took place are summarized in Table 3 and differ obviously by more than what could be called “a small amount”. Furthermore, since in our effort to keep the study as consistent as possible we did not introduce Organic Chemistry questions in the second questionnaire, while we eliminated ones that referred directly to acids, bases and salts, our findings are at least puzzling.

Table 3. Chemical topics taught at senior high-school grade A during the two school years of the current survey. Numbers in parentheses indicate the desired number of hours devoted to each topic. In red are marked the differences between the two curricula. School year 2010-11 is on the left column and 2013-14 on the right.

Chapter 1. Introduction (2 h) Classification of matter, solutions, solution concentrations. Chapter 2. Period table – bonds (13 h) Electronic configuration of atoms. Formation and utility of the periodic table. The chemical bond in general, factors determining the chemical reactivity of an atom. Types of chemical bonds. The language of chemistry, oxidation number, chemical formulae and introduction to nomenclature. Chapter 3. Acids-bases-salts-oxides (12 h) Electrolytic dissociation. Acids and bases. Oxides Salts Electrolytes, neutralization and everyday life. Chapter 4. Stoichiometry (13 h). Basic facts about chemical calculations, molecular mass, mol, Avogadro’s number, molecular volume. Solution concentration, dilution, mixing of solutions. Stoichiometric calculations.	Chapter 1. Introduction (3 h) Construction of matter, construction of the atom, atomic number, mass number, isotopes. Classification of matter, solutions, solution concentrations. Chapter 2. Period table – bonds (12 h) Electronic configuration of atoms. Formation and utility of the periodic table. The chemical bond in general, factors determining the chemical reactivity of an atom. Types of chemical bonds. The language of chemistry, oxidation number, chemical formulae and introduction to nomenclature. Chapter 3. Chemical reactions (5 h) Chapter 4. Stoichiometry (14 h). Basic facts about chemical calculations, molecular mass, mol, Avogadro’s number, molecular volume. Ideal gas equation. Solution concentration, dilution, mixing of solutions. Stoichiometric calculations. Chapter 5. General Organic Chemistry (6 h) Introduction, classification of organic compounds, homologous series, basic nomenclature, isomerism.
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Of course, the results we report here have been normalized to a 0-20 scale in both cases, it was expected however, that the latest survey would provide at least significantly higher overall performance since it was objectively somewhat easier to complete. In the first survey it was observed a very poor performance of the students in relation to their ability of identification an acidic or a basic substance (e.g. 11.8% did not attempt to classify ammonia as acid or base while 18.9% thought it

should be an acid, probably distracted by the large number of H atoms in the formula). In this respect the 2013-14 result should appear better since the lack of the acid-base problem was not substituted by an organic one because there was not something analogous in the first questionnaire. It seems however, that the pupils approach the whole curriculum with caution and skepticism, try to rely on long past recovered ideas and knowledge and do not attempt a rigorous and extended incorporation of new facts and ideas to their chemical background. Given the large amount of teaching carried out at senior high-school grade A on acids and bases in 2010, their performance there did not substantiate it and, in the case of the argument that this was knowledge not appropriate for their background (something that most probably was called upon in order to substitute the chapter with a different one) it did not have an important impact on the attitude of students towards chemistry. The lack of solid and clear criteria-based assessment and consequently a stable grading policy by the government in relation to the selection of high-school students that will enter University courses, renders them reluctant to enroll themselves (as well as their teachers too) into a project of understanding principles and properties but rather tends to let them utilize the well-documented memorizing process which enhances the chance of mechanically solving problems (although related to Chemistry being almost purely mathematical in nature). As a result, any reform of the educational program is not practically getting through in terms of accomplishing the alteration and probably elevation of the understanding of chemical principles by secondary education pupils (Sadler, 2005). In our opinion, this is the main reason for the stagnation observed over several decades in the degree of chemical knowledge assimilation by Greek secondary school students since the ever-changing educational program cannot operate in any of the standard philosophies accepted and adopted worldwide (Aalsvoort, 2004). In summary, one may say that the Greek society behaves as an overhead educator, instructing the teachers to adopt strategies relying on memorizing and algorithmic treatment of data rather than assimilating facts and ideas, with the furthest and most distinct target being the success of their students in the entrance examinations to the Higher Education Institutes. Secondary education students are accordingly directed into this line of attitude focusing only on what might secure their success in this single time event. Consequently, any attempt to modify the existing educational system radically or in part is confronted with a Promethean type behavior by the students who have only a single goal to achieve. The term should not be confused with any fictitious film characters or data accumulation and analysis systems; it refers to the figure in Greek mythology and in this specific case not to his cunning or skillfulness or humanitarian characteristics but to his passive acceptance of the eternal punishment that the above virtues earned him, i.e. to have his liver eaten on a daily basis by an eagle (the earliest account of the myth being stated by Hesiod the poet in his Theogony).

4. CONCLUSIONS

The assessment of the questionnaires collected provided some information about the overall assimilation of chemical knowledge by the students. The simple statistics used for the initial step are summarized in Table 2. The factors that were expected to affect the average mark achieved by the students were sex, long term memory utilization and general socio-economic background.

The overall mean value of chemical knowledge assimilation appears to be rather poor as it reaches just about 34 %. It is rather discouraging, with regard to the efforts taken, during the last three decades at least, to modify and modernize the Greek educational system especially when we compare this gross result with almost identical ones in analogous studies carried out during the above period.

Another notable feature of the data obtained is the large standard deviations especially considering the mean values to which they are related to. This is a clear indication of a wide diffusion of students likely to undertake science degrees among the mostly indifferent to science. The above mentioned complication related to the direction change possibility renders it more difficult to verify effects of long term memory since the results observed for grade B and grade C senior high-school students appear almost identical.

Boys are generally thought of as having a greater tendency than girls to follow science but some post-hoc studies revealed that at a 95% probability level these results are not statistically significant.

A striking feature of the results is that there was not observed a generally expected tendency for better grading on moving from the less privileged to the more elite schools, that is from rural areas to small cities and then to public and private schools of the large city, a consequence of the well-established urbanism movement in Greece and the expected tendency of young people from small towns to seek a better future in the form of passing the exams to enter an undergraduate course in a large city University.

More striking still is the observation that although another major reformation of the chemistry curriculum was put in effect in the meantime between the two separate studies carried out, in the form of substituting a 12-hour discussion of acids, bases and salts with a 6-hour introduction to organic chemistry plus some additional material, this did not have a detectable effect on the mean achievement of the students in the two “tests” taken. The students seem to react to the curriculum modifications in a generally passive way, resembling the mythical Prometheus who was (chained, of course) expecting the eagle to come and feast on his liver every day. It is apparent that for the last almost four decades, during which several such and among them a few more extensive reformations took place, the overall performance of the Greek high-school students in relation to the chemistry curriculum is stuck somewhere at one third of the maximum potential. The reforms applied appear to have been indifferent to the Greek secondary education students in the sense that their effect was in gross terms speaking, null. In our opinion, this calls for a consistent and thorough evaluation of the present curriculum in the form of several widely applied studies like the one reported here in order to determine the strengths and weaknesses it possesses before proceeding with the next modification.

REFERENCES

- Aalsvoort, JV 2004, ‘Logical positivism as a tool to analyse the problem of chemistry's lack of relevance in secondary school chemical education’, *International Journal of Science Education*, vol. 26, no.9, pp. 1151-1168.
- Armstrong, DM 1973, *Belief, Truth and Knowledge*. Cambridge University Press.
- Bennett, J 2001, “The development and use of an instrument to assess students' attitude to the study of chemistry”, *International Journal of Science Education*, vol. 23, no. 8, pp. 833-845.
- Cokelez, A & Dumon, A 2005, “Atom and molecule: upper secondary school French students' representations in long-term memory”, *Chemistry Education Research and Practice*, vol. 6, no. 3, pp. 119-135.
- Cousins, A 2007, ‘Gender Inclusivity in Secondary Chemistry: A study of male and female participation in secondary school chemistry’, *International Journal of Science Education*, vol. 29, no. 6, pp. 711-730.
- Daniel Tan, K-C. & Treagust, DF 1999, ‘Evaluating students' understanding of chemical bonding’, *School Science Review*, vol. 81, pp.75-83.
- Gorard, S & See, BH 2009, ‘The impact of socio-economic status on participation and attainment in science’, *Studies in Science Education*, vol. 45, no. 1, pp. 93-129.
- Hodson, D 1992, ‘In search of a meaningful relationship: an exploration of some issues relating to integration in science and science education’, *International Journal of Science Education*, vol. 14, no. 5, pp. 541–562.
- Horton C., 2007, “Student Alternative Conceptions in Chemistry”, *California Journal of Science Education*, vol. 7, no. 2, pp. 1-78.
- Karageorgiou, S, Savvidou, E, Katikaridou, P, Akrivos, PD, Katsikis, H 2015, “A Chemistry Teacher's Drama In The Greek High School With Biology As The Protagonist”, *Educational Alternatives*, vol. 15, pp. 395-403.

Katsikis, H, Savvidou, E, Schizodimou, A, Akrivos, PD, Keloglou, G 2015, "Student Misconceptions In The 21st Century. Chemistry Related Conceptions of Greek Senior High School Students", *Educational Alternatives*, vol. 15, pp. 384-394.

Kind, V 2004, *Beyond Appearances: Students' misconceptions about basic chemical ideas*, 2nd Edition, School of Education, Durham University, UK.

Osborne, J & Collins, S 2001, 'Pupils' views of the role and value of the science curriculum: a focus-group study', *International Journal of Science Education*, vol. 23, no. 5, pp. 441-467.

Sadler, DR 2005, "Interpretations of criteria-based assessment and grading in higher education", *Assessment & Evaluation in Higher Education*, vol. 30, no. 2, pp. 175-194.

Taber, KS 2004, "Learning quanta: barriers to stimulating transitions in student understanding of orbital ideas", *Science Education*, vol. 89, pp. 94-116.

Taber, KS 2008, 'Towards a Curricular Model of the Nature of Science', *Science & Education* vol. 17, pp. 179-218.

Thiele, RB & Treagust, DF 1995, "Analogies in Chemistry textbooks", *International Journal of Science Education*, vol. 17, no. 6, pp. 783-795.

Treagust, DF 1988, "Development and use of diagnostic tests to evaluate students' misconceptions in science", *International Journal of Science Education*, vol. 10, no 2, pp. 159-169.

Turner, T 2000, "The Science Curriculum: What is it for?", in J. Sears and P. Sorenson (eds.), *Issues in Science Teaching*, Routledge Falmer, London, pp. 4-15.

Zeyer, A & Wolf, S 2010, 'Is There a Relationship between Brain Type, Sex and Motivation to Learn Science?', *International Journal of Science Education*, vol. 32, no.16, pp. 2217-2233.