ENVIRONMENT: A NEW PEDAGOGICAL APPROACH TO GENERAL CHEMISTRY COURSES - REPORT OF A PEDAGOGICAL EXPERIMENT

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ABSTRACT

An alternative approach to the teaching of General Chemistry at university first year level is presented. The new pedagogical approach is based on environmental issues, featuring chemical first principles. As no environmental-oriented general chemistry textbook is available, different sources (e.g. popular science magazines) were used. The new pedagogical approach was applied to 3 (first year) classes at the Pontifical Catholic University of Rio de Janeiro. A fourth class which followed the conventional course was used for comparison. The assessments were made by questionnaire, answered by the students at the end of the course.

Keywords*general chemistry course, environment, new pedagogy.*

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INTRODUCTION

The discipline of General Chemistry is part of the Brazilian Ministry of Education undergraduate minimum curriculum and is offered at the Pontifical Catholic University of Rio de Janeiro (PUC-RJ) leading to a university degree in Engineering, Physics, Mathematics and Computer Science. It is also the first discipline taught in both Chemical Engineering and Industrial Chemistry. A single General Chemistry syllabus is adopted and according to current university rules, the students are assessed in the same ways. When the discipline is taught students haven't opted for their majors. And they share classes with other students whose interests are diverse and divergent. The overwhelming majority of them, with perhaps the exception of chemistry students, have contact with chemistry only once in their academic life. And it is minute, if not negligible, those who choose a chemistry related discipline as an elective.

The Physics and Mathematics basic disciplines are recognized by the students "as hard" and constitute unavoidable pre-requisites to take their majors. Not surprisingly, students' efforts are concentrated on basic Physics and Math to the detriment of General Chemistry.

The situations described above and the bad image which pervades the teaching of chemistry at high school favor the student's lack of interest in the course. But this is not limited to the students. The Department of Chemistry itself, which is responsible for the teaching of the discipline, and is nationally recognized for its research activities, is unwilling to participate more actively in the course. Deeply involved in their research work, most of the faculty's creative energy is diverted away from their teaching activities and obligations. Moreover, the faculty's background is essentially technical. Very few lecturers have teaching qualifications and have no previous experience in research on education; though this is not mandatory for the lecturer's good performance. "Chalk and Talk" classes occupy most of the time that teachers spent with students. And, in general, the lecturer's teaching performance counts for nothing, since there is no consensus on how he or she should be evaluated and ascend in the career. This is in sharp contrast with the lecturer's own research (or administrative) career where rules and criteria for ascent and prestige are well known.

Finally, one issue which transcends the history of faculty and student concerns is the student/teacher ratio in the first year at the university. Generally, this ratio is pedagogically unfavorable. However, lab classes should be considered separately: all 600 freshmen enrolled in Experimental Chemistry each year are divided into groups of three and, experiments inspired by those suggested in the book of Cotton, Lynch and Macedo(1), are carried out fortnightly. The experimental course seeks, as far as possible, to follow the theoretical one. And it is interesting to note that the student's satisfaction and involvement in Experimental Chemistry is much greater than in General Chemistry, which come as no surprise for those who are sensitive to educational issues.

To increase the students' and faculty's involvement in the discipline of General Chemistry, a new pedagogical approach, based on environmental issues, was suggested and later implemented without changing the original syllabus. The aim of the present paper is to describe this pedagogical experiment, its context and the results obtained.

MATERIAL AND METHODOLOGY

Ever since the Earth Environmental Summit (ECO '92), held in Rio de Janeiro in 1992, environmental issues have been given more attention in the media. Given its use as a source of news on television, radio, and in the newspapers, the environment has certainly caught the public's attention, especially young people. But it would be premature to speak of environmental awareness as opposed to environmental popularity. Taking into account the several intersections between Chemistry and the Environmental Sciences, it was decided to approach the teaching of the General Chemistry course from a different point of view, i.e., presenting and discussing chemical first principles within a framework of environmental issues. It was noticed that the existing general chemistry textbooks approach environmental issues rather vaguely and incompletely. And none of the translations of foreign books treats important Brazilian issues. The bibliography of textbooks in Portuguese is even more restricted and limited. For this reason, we opted for adaptations and translations of texts of different sources. Table I shows the structure of the new course and the association of the main texts used with the programmatic content of the course. The left column lists (in bold type) the environmental texts adopted, the central column the environmental topics and the right column the topics of the original syllabus with respective chapters of the textbook. The adapted texts were typed or copied in order to form a single set of notes. Other material was added to these texts published (mainly) by the Brazilian popular science magazine "Ciência Hoje" which was also suggested as further reading.

Transparencies and photocopies of transparencies were annexed to the notes which resulted from assembling the texts in order to minimize the amount of copying from the blackboard. The students were always encouraged to have the material with them. We also suggested, as a reference for the chemical first principles, the book of J. B. Russel[23], which was bought by the majority of the students. Thus they had at their disposal both a textbook for the first principles and a booklet containing the environmental issues dealt with in the course. And the lecturer's duty was to bridge the gap between the two.

Given the excessive number of students per class (up to 80 students), the course was inevitably based on "chalk and talk" classes. The new environmentally - oriented course was taught to 3 classes (in fact 6, paired off into three groups) by 3 different lecturers. A fourth lecturer, taught the conventional course and adopted the conventional textbook (that of J. B. Russel). All lecturers were equally experienced, i.e., all of them have taught general chemistry for an uninterrupted period of 5 years.

In both types of classes the traditional assessments (written examinations) were carried out following the criteria adopted by the coordination who determines that three partial and one final assessments should be applied during the semester. Naturally, the new environmentally-oriented classes had to have a different type of assessment and, therefore, the percentage of failure and the overall average were not taken into account when both types of classes were compared.

The didactic material used in the 3 main classes was exactly the same. At the end of the term, during the third partial examination, a questionnaire (a copy of wich appears in the appendix) was submitted to the students to assess the course. The questionnaire was divided into 7 modules as follows:

(I) the general character of the course.

(II) the lecturer's teaching performance

(III) the relationship between lecturer and student.

(IV) the adequacy of assessment.

(V) the quality of the supporting material employed in classroom.

(VI) supporting personnel (auxiliaries)

(VII) the quality of lab classes.

The aim of dividing the classes into two categories was to identify, if possible, variables other than those related to the experiment whose assessment was fundamentally made by the first, fourth and fifth modules of the questionnaire.

RESULTS AND DISCUSSION

All students present in the third partial examination answered the questionnaire. And each item of it has received a grading from 1 to 5. The score for each item, per class, along with the corresponding number of students are displayed in table 2 where class C is the one which followed the conventional course. The score is calculated by dividing the total number of points obtained in each item by the maximum value attainable, i.e., **5n** where **n** is the total number of students who answered the questionnaire. In table 2, this ratio is multiplied by 100, expressing the percentage reached with respect to the maximum value attainable.

Before discussing the results obtained, it is essential to clarify some aspects of the items of the questionnaire and their classification. The items from 1 to **7** are included in the same module I because they contain the same aspects that the new pedagogical approach was looking for, i.e., a better learning process. Items from 8 to 12 (modules II and III) refer to the quality of the individual lecturers. Items from 13 to 15 (module IV) seek the students' opinion relative to the examinations' fauness. Items from 16 to 20 (module V) refer to the quality of the teaching material used which was limited to a textbook in the case of the conventional class. Items 21 to 23 (module VI) concern external issues, such as tutorials taught by graduate students, which are foreign to both course and lecturer. Finally items from 24 to 28 (module VII) seek to verify the influence of lab classes on the students' learning process since they were divided into small groups and taught by different lecturers unfamiliar with the pedagogical experiment that was taking place in the classrooms.

The analysis of the results of the questionnaire infers very interesting formulations. With respect to the module I, we noted that the scores obtained from questions 1 and 2 concerning the course organization correlate very well with those obtained in module II which refer to the lecturers' performance. The same correlations (r_1 = 0,96, r_2 = 0,94 and r_3 = 0,85) are not observed in questions 4,5 and 6 (r_4 = 0,45, r_5 = 0,31 and r_6 = 0,35). Here the letter **r** represents the correlation coefficient and the subscript refers to an item of the questionnaire. Higher marks obtained classes are those who correlate the course with actual issues and real situations. However, there was no agreement among students whether environmental issues would affect their careers (question 4, r_4 = 0,45). This question sought to find out the weight that the students' environmental consciousness, awaken during the course of their academic life, would have in their professional life; which seemed in our opinion to have remained unanswered. This observation have led us to believe that there is a dissociation between the student's vision as a citizen (sensitive to environmental issues) and the student's vision as a professional (characterized by pragmatism) and it becomes more acute among students of engineering. And contrary to what we sought, no benefit was gained in their learning process by adopting this new pedagogical approach (question 7). However, there is a strong correlation (r_7 = 0,93) with the lecturer's performance. It has become quite clear that the lecturer's didactic performance plays the main role in the student's learning process. Much more than the new pedagogical approach adopted.

All the analysis carried out would not be significantly changed if module II (lecturer's didactic performance) were added to question 12 (the one that deals with lecturer's relationship with the students). The lecturer's performance and his relationship with the students were intimately correlated (r = 0,92) showing that, at least for freshmen classes, these qualities seem to be undifferentiated.

The assessment of such a new course brought about several difficulties. Perhaps the greatest of them all was to find out essentially simple applications and at the same time not to lose sight of the world's industrial society reality. The characteristics of the new (general chemistry) course and the necessity to comply with the original syllabus have led to long and less direct questions in the assessments.

Written examination revisions are carried out by an auxiliary team and not by the lecturer. And the item of the questionnaire (question 15) dealing with it should not be associated with module II. The material taught (question 13) was more simpler in the conventional course (75 points) than in the new one. This can be explained by the difficulties already mentioned before. It is interesting to note that items 13 and 14 (module IV) relate significantly well with the mean of the scores of module II (r_{13} = 0,93 and r_{14} = 0,73) showing the influence of lecturer's didactic performance on how the students face the evaluation.

The textbook (module V) where the chemistry basic concepts are expounded was adopted in all 4 classes. Thus one should not expect substantial differences in the assessment made (question 16): In fact, these did not occur. Items 17 and 18 concern the texts which were distributed to complement the textbook while questions 19 and 20 refer to the transparencies displayed in the classroom and whose copies were previously handed over to minimize the students' copy work. It should be noted that although the material used was the same, in some cases the assessments were very different. In fact, the technical quality of the material left a lot to be desired given the lack of infrastructure to support the experiment. All items in module V correlate well with those of the module II (didactic performance). This seems to indicate that the intrinsic quality of the didactic material was second to none when compared with the lecturer's skill in using it.

The inquiry which refers to module VI (tutorials taught by gradulate students and monitors) received the same mark in all classes. It is interesting to note that students were sensitive to tutorials (item 22) whose content dealt with conventional rather than environmental aspects of the course, and whose supporting personnel was not trained for the pedagogical experiment. This fact perhaps explains the low mark received in item 23 in the environmentally-oriented classes. The low mark in item 22 may reflect the poor didactic performance of graduate students and monitors and the students' discontent with tutorials which covered only a part of the material taught.

As mentioned before, lab classes were not modified. They were designed to meet the conventional course requirements. As they are taught by other lecturers, correlations with module II were meaningless. And as there were no assessments of lab instructors, one cannot say whether the systematically low mark of class A and the systematically high mark of class C in this module is accounted for by the difference between lecturers and instructors performance. It is, however, coherent that the highest mark was obtained by lab classes in the conventional rather than in the new course. Still referring to other items in the same module; one can wonder about a possible greater animosity among students of class A towards chemistry. And no one can say whether it is the cause or effect for the low mark given by this class on other items to other modules.

CONCLUSIONS

The results have shown that the new pedagogical approach adopted to tackle general chemistry teaching problems at university first year level was successful. However, there was no significant difference between the learning process and the meaning of chemistry as a science might have in the student's future career when the old and new approaches were compared. The lecturer's teaching performance had far more influence in the students' learning process than previously thought. And it is possible that the awareness of environmental issues might positively affect the exercise of their future careers. In the authors' understanding better results could be reached if more investments were applied. However, additional institutional funds are not easily obtainable for this type of experiment. Other aspects of the implementation of the experiment such as the quality of the didactic material left something to be desired. And the use of computational resources should be taken into account but only introduced if necessary.

The bibliography in this field is very rich but not a single volume was found which met the course profile. That meant a great effort of assembling and adapting of existing material which can doubtless be improved. New chemistry introductory texts (though in English), adopting a similar approach, have recently appeared in the market.

The good acceptance of lab classes is a sign that they should be adapted to the course profile. This is also a way of minimizing the excessive "chalk and talk" character of the course.

The great difficulty still lies in the assessment of the course. The basic chemistry knowledge and its relation to environmental issues should be better checked. The size of classes should be adapted to the new pedagogical approach adopted in order to make the course more interactive. And the supporting personnel (graduate students, monitors and instructors) should be trained in the spirit of the new pedagogical approach.

In the authors' opinion the results are encouraging and the experiment should be taken further according to the recommendations set out above. The authors are also encouraged by other pedagogical experiments carried out recently along the same line.(25,26)

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UNIT I: INTRODUCTION

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
The Framework of Ecology[3]	Presentation Objectives Basic Principles Levels of Organization Ecosystems	Matter Pure Substances and Mixtures Elements and Compounds Atoms and Molecules (R, 2.2 and 2.3)
The Amazon and the Earth's climate[4]	Trofic Chains Cycles Ecological Equilibrium Pollution-Generalities Concentration Degradation x Recovering Consequences	
Nucleosynthesis of the Elements[5]	Origin of the Elements Nucleo synthesis of the Elements Interstellar Atoms and	The Atom: The Divisible Atom; Atomic Weight; Electrons in Atoms (R, 5.1, 5.2 and 5.3)

	Molecules	Chemical Periodicity: the periodical law, periodical properties (R. chapter 7)
The Development of the Earth[6]	The Development of the Earth Formation of the Earth Loss of gaseous elements Differentiation of elements Formation of the minerals The evolution of the atmosphere Formation of the oceans Aspects of life's origin	Chemical Periodicity: the periodical law, periodical properties (R. chapter 7)

UNIT II: THE ATMOSPHERE

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
The Atmosphere(7)	Structure, Properties and Composition of the Atmosphere Atmospheric Photochemistry	Ideal Gases: Gas-laws (R,4.1, 4.2 and 4.3): Avogadro's Hypothesis (R,4.4)
The Ozone Layer: A threatened filter[8]	Atmospheric Pollution A little bit of history Main pollutants and their sources (cycles) Thermal Inversion Local effects	Chemical Equilibrium Homogeneous (R, 15.1 and 15.2)
A Threatened Planet[9]	Global effects Greenhouse effect The ozone hole	Chemistry Kinetics: reaction velocities and mechanisms (R, 14.1 and 14.2)
The Greenhouse Effect[10]	Acid Rain Pollution control	Activation Energy (R. pp 445/6)
Rain Acidity[11]	"End of the Pipe" New Processes	Reaction Mechanisms (R, 14.5) Catalysis (R, 14.6)

UNIT III: THE HYDROSPHERE

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
The Hydrosphere(11)	Water: Physical and Chemical Properties Water Resources: The	Chemical Bond: covalent bond (R, 8.2 and 8.3)

	water cycle Water Treatment and Purification	molecular geometry (R, 9.2) hydrogen bond (R, 9.4)
Artificial Eutophization: the lakes disease(12)	Water Pollution Sewer: organic matter and detergents (eutrophization)	Solutions: mixtures, types of solutions, concentration and solubility: Colligative Properties, electrolytes (R, 12.1 up to 12.6)
The Gold Mining Threat(13)	Industrial Effluents: thermal pollution, acid drainage, havy metals Rural Effluents: agrotoxics Pollution Control (Water treatment)	Aqueous Solutions Equilibrium: acid and basis (R, 16.1 and 16.4) and solubility (R, 17.1 and 17.2)

UNIT IV: ENERGY

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
Human Production of Energy as a Proces in the Biosphere(15)	Energy Cycle on Earth Energy Cycle on the Biosphere Energy for Human Activities Consumption: Evolution, atual situation and perspectives Common sources of energy	Chemical Thermodynamics (Chp.18) 1st Law: thermochemistry 2nd Law: free energy, work and equilibrium Organic Chemistry
Coal:energy without pollution (16) Fossil Fuels (17)	Coal Composition and origin Form and utilization its usefulness/perpectives Environmental impact	Carbon Peculiarities: structures and bonds Organic functions: structure and reactivity (R, 23.1 up to 23.4)
Alternative sources of Energy (18)	Petroleum Composition Origin Use and Perspectives Environmental impact	Nuclear Processes Radioactivity: desintegration Kinetics; nuclear reactions; Nuclear fission and fusion (R, 24.1 up to 24.5)
On Nuclear Energy's Future	Fission reactors Working principle and types its usefulness and limitations of use/perspectives environmental impact Alternative source of energy Nuclear Fusion Solar Energy	Electrochemistry Galvanic cells Standard potentials, Free energy and equilibrium (R, 19.1, 19.3 and 19.4)

	Wind Energy Biomass Electrochemistry Increasing the Efficiency of Energy Utilization Storage Distribution Energy-saving	

UNIT V: THE LITOSPHERE

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
The Litosphere (20)	Minerals Composition of the Earth's crust Reserves and consumption Tendencies General Principles of Metals Processing	Ideal Liquids and Ideal Solids The crystalline lattice; ionic solids; molecular solids - Van der Waals forces; Covalent solids; metallic solids Lattice energy; Liquids (R, 10.3, 10.4, 10.5, 10.6)
New Strategies of Manufacturing(21)	Steel Manufacturing: processing manufacturing requirements environmental impact Gold Mining: alterntives to current gold mining extraction Soils: structure and origin of soils nutrients and cycles ionic exchange, pH and availability use of soil and its effects erosion, deforestation, desertification contamination/solid waste alternative techniques to the use of soils	

UNIT VI: PERPECTIVES

BIBLIOGRAPHY	ENVIRONMENTAL TOPICS	BASIC TOPICS
Perspectives (22)	Environmental catastrophe vs	

	Radicals changes A Reformist's Vision

TABLE 1 STRUCTURE OF THE PEDAGOGICAL EXPERIMENT

		SCORE PER CLASS			
MODULES	**CLASS ITEM**	**A**	**B**	**C**	**D**
I	1	52	74	75	62
	2	61	75	90	73
	3	53	58	66	63
	4	41	58	45	41
	5	70	81	54	72
	6	64	83	65	74
	7	36	54	66	60
II	8	36	59	65	59
	9	45	61	64	58
	10	39	58	68	58
	11	57	71	72	56
III	12	47	74	83	65
IV	13	50	61	75	62
	14	50	81	66	72
	15	51	61	71	55
V	16	61	74	74	69
	17	58	71	-	73
	18	62	71	-	72
	19	57	69	-	61
	20	50	70	-	57
VI	21	38	68	75	38
	22	40	40	68	45
	23	39	46	69	52
VII	24	50	75	77	62
	25	66	73	82	73
	26	64	72	77	75
	27	55	60	77	69
	28	48	66	76	64

Class A, 68 students; class B, 31 students; class C, 44 students; class D, 26 students.

TABLE 2 SCORES REACHED, PER ITEM, FOR THE DIFFERENT CLASSES INVOLVED IN THE PEDAGOGICAL EXPERIMENT.

	Modules	
Item Minimum		Grading

1 2 3 4 5 Grading Maximum							
	1. Aims: Are they clearly specified?	Minimum					Maximum
	2. Was the proposed syllabus taught?	Minimum					Maximum
	3. Was the syllabus content taught adequate to class duration?	Little					Fully
I	4. Does the discipline have any meaning to your future career ?	No					Fully
	5. Is the discipline important for the understanding of real problems?	No					Fully
	6. Has the discipline established a link between Chemical concepts and real situations?	No					Fully
	7. Has the approach adopted helped in the learning of Chemistry?	No					Fully
	8. Were concepts clearly presents?	No					Fully
	9. Were interdisciplinary relations clearly shown?	No					Fully
II	10. Were theoretical concepts clearly coupled with tutorials and real situations?	No					Fully
	11. Use of graphics, diagrams and texts	Very poor					Quite good
III	12. Relationship with lecturer in classroom.	Very bad					Quite good
	13. Were examination questions adequate to syllabus content?	No					Fully
IV	14. Written examinations duration	Insuf.					Sufficient
	15. written examination revision	Insuf.					Sufficient
	16. Textbook	Very poor					Quite good

	17. Were supporting texts clear?	Very poor						Quite good
V	18. Did supporting texts have technical quality?	Very poor						Quite good
	19. Was supporting didactic material clear?	Very poor						Quite good
	20. Did supporting didactic material have technical quality?	Very poor						Quite good
	21. Size of classes	Excessive						Adequate
VI	22. Were tutorials clearly presented?	Very poor						Quite good
	23. Were tutorials sufficient in number?	Insuf.						Adequate
	24. Were classes well organized?	Minimum						Maximum
	25. Were equipment and material taught adequate?	Minimum						Maximum
VII	26. Were equipment and material taught sufficient in number?	Minimum						Maximum
	27. Was the assessment adequate?	No						Fully
	28. Did classes help in the perception of the material taught?	No						Fully

APPENDIX. QUESTIONNAIRE MODEL ANSWERED BY THE STUDENTS FOR THE ASSESSMENT OF THE DISCIPLINE.

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