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CONTENTS

THE PERIODIC TABLE OF THE ELEMENTS; PATTERNS AND LAWS AND SCIENCE EDUCATION

Reading and reviewing the publication 'The Periodic Table: a very short introduction' by Eric R Scerri (Goodwin, 2012) and another his book about PT (Orlik, 2010), have raised a number of questions and issues in our minds that that we hope will be appreciated and shared with our readers. On the basis of the number of popular accounts of the elements and the periodic table that have been published recently, Dr Scerri makes the statement (p6) "… the appeal of the elements in the public imagination has now truly arrived". This we felt might be a somewhat optimistic view but it raises the further questions as to what the public can reasonably be expected to know about elements and the periodic table – and the same question can be asked about any fundamental concept in science, arts, humanities or any other aspect of human culture. Perhaps 'the public' does not mean everyone?

It is certainly a fact that much accessible and attractively presented information about the elements in the periodic table is readily available on the internet see for instance http://www.rsc.org/periodic-table and http://www.periodicvideos.com/ . The first of these is an interactive version of the periodic table (the visual elements) set up by the Royal Society of Chemistry and the second is a set of videos produced by Brady Harana and a team led by Prof Martyn Poliakoff at the University of Nottingham (UK). It is reported that the videos have had had over 13 million views and Poliakoff is reported (Wikipedia) to be excited with the success of the videos, stating "With a few hours of work, I have lectured to more students than I have reached in my entire career." Unfortunately, in spite of the quality and popularity of such resources it is not possible to probe the learning or understanding of the viewers. The material is widely used by chemistry teachers in schools so clearly they find it to be effective and it is interesting to speculate as to how many visitors to such web-sites are 'sent' there by their teachers. There seems to be no way of answering this.

However, returning to the question as to what people 'should' know about elements and the periodic table we must take into account the background and cultural context of individuals since this will affect the value they will place upon different subjects of study and their motivation to take an interest in a subject and make the effort to develop and maintain their own understanding and competence in the subject. So it would be quite inappropriate to suggest that everyone should have the same understandings of the elements and the periodic table, or even that all chemists should have the same depth of understanding.

Perhaps we should not expect anyone who has not gone through a formal secondary school education necessarily to be aware of elements in the chemistry sense or to have heard of the periodic table? Where there is a published National Curriculum this should fairly closely define the words to be used and understood. For example in the UK Science National Curriculum for students aged 14-16 currently states that students should be able to "*explain the properties of typical ionic, covalent and metallic substances in terms of models based on chemical bonding and use symbolic representation of these models in three-dimensional form, diagrams and equations; carry out a more detailed study of a range of metals and non-metals and their compounds, and investigate the different ways in which they can be classified as metallic, ionic, covalent molecular or giant covalent; understand simple trends in the properties of elements within groups and across periods of the Periodic Table; understand that there are limitations to different systems of classification, for example, oxide classification in terms of acid/base behaviour."* http://www.deni.gov.uk/scie_ks4_dbl.pdf . If you are not based in the UK it would be interesting to compare this with what *you* are expected to know.

The above represents the best we could expect from students leaving the compulsory stage of education in UK schools unless they have been inspired to read beyond the formal requirements of school. One problem is that schools are nowadays so concerned about examination grades that they rarely encourage students to take their interests or allow questions outside the strict confines of the examination specifications. These specifications tend to narrow down the interpretation of topic in terms of what might be examined and thus restrict the questions and approaches that are seen to be legitimate. For example the section that covers "*Elements in the same group in the periodic table have the same number of electrons in their highest energy level (outer electrons) and this gives them similar chemical properties* (see www.aqa.org.uk subject > science > chemistry) is constrained by the following advice "*Knowledge is limited to the reactions of Group 1 elements with water and oxygen. Candidates are* **not** *required to know of trends within each group in the periodic table, but should be aware of similarities between the elements within a group*." There seems to be little emphasis on the development of ideas about the atomic theory and the PT or even the *evidence* which leads us to have confidence in their validity.

Only a small proportion of students choose to take their chemistry studies beyond age 16 and even fewer take the subject to graduate level. Even then, formal courses rarely include significant focus on the history and philosophy of chemical *ideas* the focus lies towards learning the facts and skills although, as in the earlier courses these are often constrained and limited to aspects that are likely to be examined.

Unfortunately the focus on 'passing examinations' rather than 'understanding and engaging in science' seems to provide a somewhat boring experience for a majority of students – and for many of their teachers. Perhaps we need to shift the balance of schooling – especially in the later years – towards helping our students to find the areas of science (or perhaps of the rest of the curriculum) that *really* interest them and to which they are prepared to commit a substantial amount of cognitive and emotional effort and time. Even science teachers need the opportunity to develop scientific interests personally and these may not always have direct connection with the content of courses they teach. However, it seems to us to be a major waste if such interests and enthusiasms cannot be shared to some extent with their students. Such a shift is probably more significant for educational practice than for educational ideals since it has long been argued that formal education is to prepare students for *life,* to become *independent learners* and *useful citizens.*

Where does that leave the Periodic Table – certainly central to basic science / chemistry courses, but not necessarily the focus for our *deep critical thinking* (even if we are chemists) unless it becomes central to our personal and professional interests. Perhaps we may be forgiven for leaving lanthanum and all the lanthanides in the same box in group 3 of the Periodic Table on the grounds that all are (more or less) tri-valent metals? Also we could be excused for not having considered previously whether it is lanthanum or lutetium that *should* be placed in group 3. (see review p. 92) This is only one example from the almost limitless range of possible areas of study and clearly it is not possible for anyone' however clever, to become a skilled expert in more than a few.

As quoted by Adee (2012) it is estimated that it takes an investment of about 10,000 hours to become an expert and fully skilled in a particular aspect of a subject be it a sport, mastering a musical instrument or skill in surgery (and presumably also aspects of chemistry). Such an investment of time is possible only for a few areas of study in a lifetime and only then if the individual has sufficiently passionate commitment and long-term interest to sustain the hard work involved. It may be that not everyone has the ability, opportunity or aspiration to become a recognised expert, but surely we can hope that everyone can find some area of human achievement in which they can gain real personal satisfaction? However, it is only people with real expert knowledge and skills who are able to contribute to the maintenance and extension of humanity's skill base in science, literature, art, music, sport, technology, medicine, environment etc., and possibly earn a living working in an area that they find personally enjoyable and satisfying.

Thinking, reflecting deeply with self-awareness and a growing perception of our responsibility for our continued existence seems to be a uniquely human facility. Surely our education system should aspire to encourage students to realise their maximum humane potential and to discover their own particular responsibility and commitment to this enterprise.

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"Nerves made of iron" - electrochemical model experiments on the excitation of nerve fibre

"Nervios hechos de hierro" - modelos experimentales electroquímicos de estimulación en fibras nerviosas

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Abstract

One of the great "wonders" of the human organism as well as the animal organism is the information transmission through the excitation line of nerves. Due to the great importance of nerve conduction, this is an inherent part of the science classroom. The structure and function of the nervous system however are topics of high abstraction. The number of neurons, the speed of nerve conduction and especially the mechanism of the excitation line are topics which are difficult to teach even at undergraduate level. On top of this, the experimental use of neurophysiological procedures of excitable membranes requires not only a large amount of time but also an enormous effort to install equipment. These are reasons why this is rarely practiced in schools.

In this context the authors have developed an impressive and novel model system, which has now found its way into many German educational books.

This model system consists of a pure iron rod (model of nerve fibre), which is dipped in a hydrogen peroxide solution. Under suitable conditions the iron rod will react to activating influences like a nerve reacts to excitation impulses.

Key words: *nerve impulse conduction, passivity of metals, model experiment, electrochemistry*

Resumen:

Una de las grandes "maravillas" del organismo humano así como del organismo animal, es la transmisión de información a través de la línea de estimulación de los nervios. Debido a su gran importancia, forma parte inherente de las clases de ciencia. No obstante, la estructura y la función del sistema nervioso son temas de un alto nivel de abstracción. El número de neuronas, la velocidad de la conducción nerviosa, y, particularmente, el mecanicismo de la línea de estimulación, son contenidos difíciles de enseñar. Además, la compilación experimental de procedimientos neurofisiológicos de membranas nerviosas no sólo requiere mucho tiempo, sino también enormes esfuerzos para instalar los instrumentos. Por estas dos razones, generalmente no se practica en la escuela.

En este contexto, los autores han desarrollado un sistema modelo original y fascinante que mientras tanto ha sido integrado en muchos libros educativos alemanes.

Este sistema modelo consiste en una barra de acero puro (modelo de fibra nerviosa) que se sumerge en una solución de peróxido de hidrógeno. En condiciones adecuadas, la barra de acero reaccionará a factores activadores tal como un nervio respondería a impulsos estimulantes.

Palabras clave: *conducción de impulsos nerviosos, pasividad de metales, modelo experimental, electroquímica*

INTRODUCTION

One of the great "wonders" of the human organism as well as the animal organism is the information transmission through the excitation line of nerves.

The clarification of the underlying conduction mechanisms of real membranes as also of model systems is not only interesting when looked at from the biological point of view but is also an integral part of the theory of the constructive process to interpret such phenomena as spatiotemporal processes.

In 1843 E. Du Bois-Reymond first provided evidence that the excitation as well as the propagation of a nerve impulse is connected with electrical processes (Du Bois-Reymond, 1843). In 1850 H. von Helmholtz took the first measurements to determine the speed of impulse propagation (von Helmholtz, 1895). In 1872 the physiologist L. Hermann formulated that the propagation mechanism is based on local streams, which flow from an excited point to neighbouring sections (Hermann, 1872). The fundamental idea of his theory in today's "Ion theory of excitation" which was justified by Bernstein in 1902 and expanded by Hodgkin and Huxley in 1952, has been maintained (Hodgkin and Huxley, 1952).

Due to the great importance of neurophysiology, this is an inherent part in the science classroom. The structure and function of the nervous system however are topics of high abstraction. The number of neurons, the speed of nerve conduction and especially the mechanism of the excitation line are topics which are difficult to teach. On top of that, the experimental compilation of neurophysiological procedures of excitable membranes requires not only a large amount of time but also an enormous effort to install equipment. These are reasons why this is rarely practiced in schools.

Therefore a visual demonstration of the electrophysiological sequences during excitation and transmission of signals would be helpful for teachers.

This article provides first a short overview of the known models, which simulate nerve excitation and impulse propagation. This is followed by a detailed description of our novel model system to simulate the nerve propagation.

Our model system consists of a pure iron rod (model of nerve fibre), which is dipped in a hydrogen peroxide solution acidified by sulfuric acid. Under suitable conditions the iron rod will react to activating influences like a nerve reacts to excitation impulses. So not only continuous impulse propagation but also *saltatory* impulse propagation can be displayed with this model system.

The basic neurophysiological principles of the excitation and nerve propagation can be found in relevant text-books, for example (Campbell and Reece, 2002).

Our model system can be used in teaching biology in school as a qualitative demonstration, because the chemistry of the processes would be too advanced for most school students (especially in biology classes). Also it is suitable as an experimental exercise for undergraduates.

In Germany this model system is often taught in chemistry courses for graduates in the context of topics as passivity of metals, corrosion and galvanic cells.

MODEL SYSTEMS OF EXCITATION AND OF TRANSMISSION OF SIGNALS

The three types of models found in the didactic literature can be divided into three groups:

- Mechanical models
- Electronic models
- Electrochemical models

Mechanical models

One example for the mechanical models is the domino effect model (Poenicke, 1985). In this model the area of the dendrites and the cell body is symbolised with tracks (fig. 1). On one end of the tracks a (mechanical) chain is built up, for example a row of dominos. This shows the nerve fibre in its static condition. A ball which is situated on the tracks, simulates the excitation level of the perikaryon: The more you lift the tracks the further the ball will roll which means the stronger the excitation of the cell body is. Due to the slight s-shaped tracks the ball doesn't roll unstoppably with every "depolarisation" of the first stone. Instead the tracks have to be lifted up to a certain level in order to start the chain reaction (below threshold and above threshold). 9-

A repolarisation in the model can only be achieved by repositioning the stones.

In the model experiment for the saltatory conduction the dominos are only standing in the area of the Ranvier's nodes, each stone is equivalent to one node. Between the dominos there are two plastic straws which lie on columns made of two lego bricks. If the ball hits the first domino, this one will then fall against the plastic straw which will be pushed forward and then causes the next domino to fall over and so on. In this way analogue to the saltatory impulse propagation larger distances can be bridged. Further mechanical models are for example the vacuum lifting tool model and the coil spring model (Maier, 1984, Bauer, 1987).

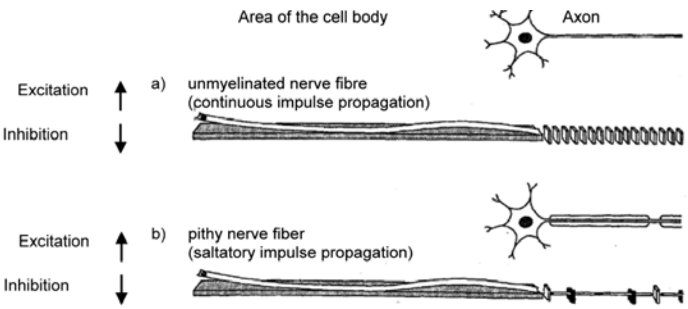

Fig. 1: Models of nerve cells with unmyelinated and pithy nerve fibre, developed from (Poenicke, 1985)

Electronic model

This is a model that is offered by many different companies which produce teaching aids. The front panels mostly show the scheme of a nerve cell with neuron and dendrites. In the inner part of the metal box unrecognisable electronics are built in. Sometimes such neuron simulators contain a photo receptor which works as a light-sensory-cell and is indicated as a synapse on the front panels. When approaching the photo receptor with a source of light (stroboscope or a torch) a sequence of illuminating diodes show whether the irritation is below or above threshold. Only when the illumination is above threshold an excitation is simulated in the "nerve cell" which can be measured with change of potential.

Electrochemical model

It was *W. Ostwald* who had pointed out the similarities of the activation broadening on passive iron wire in concentrated nitric acid and the impulse propagation in living nerves. Research of Lillie showed a set of analogies, by what the system received the name „*Ostwald-Lillie* model of the impulse propagation" (Beinert, 1941, Lillie, 1920 and 1925). Fig. 2 shows the historical test arrangement. With this model one of the characteristics of pure iron is exploited. When pure iron is in acid oxidizing solutions it becomes 'passive' when the surface becomes covered with a coherent, protective oxide film. The results of the tests of Ostwald and Lillie are difficult to reproduce. Moreover during the active state of the iron a large amount of poisonous gaseous nitrogen oxides develops and a repassivation can't always take place so that the reaction can get out of hand.

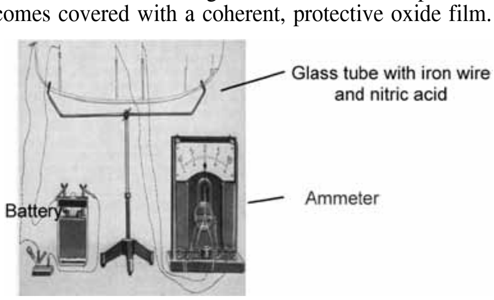

Fig. 2: The *Ostwald-Lillie*-Model (Schütz, 1972)

The following new demonstrations can be considered to be a further development of the Ostwald-Lillie-Models.

Experiment 1 – Simulation of the continuing impulse propagation

A solution of 97,5 mL distilled water, 27,5 mL sulfuric acid solution, $c(H_2SO_4) = 1$ mol/L, and 38 mL hydrogen peroxide solution, $w(H_2O_2) = 30$ % (stabilised), should be prepared (Take appropriate safety precautions). The water can be added from a measuring cylinder, but for the sulfuric acid solution and the hydrogen peroxide solution a graduated pipette should be used. The degreased and well sanded down pure iron rod (length approx. 30 cm; Ø = 3,2 mm; a suitable rod is available from Goodfellow: http://www.goodfellow.com, Artikel-No.: FE007920). Always wear clean plastic/rubber gloves when handling the rod to avoid contaminating the surface with oil or grease from the skin. The rod is put into the experiment container and filled with the solution until the iron rod is completely covered with it (solution depth approx. 3 cm). Now one end is briefly touched with a zinc electrode (0,5-1 s) (fig. 3).

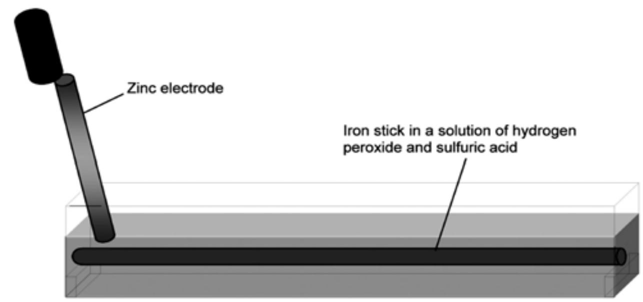

Fig. 3: Experiment for simulating continuing impulse propagation

RESULTS AND DISCUSSION

When the iron rod is placed into the solution a strong gas evolution can be observed for a few seconds on the metal surface. However, after a few seconds the iron looks unreactive and metallic despite being in an acid medium. Contact with the zinc electrode causes gas development on the iron which – based on the area of contact –transmits wave-like over the whole surface of the iron rod. Just after the wave reaches the end of the rod the gas development stops.
Notice:

- If at first the wave does not run completely along the iron rod, the rod should be removed from the solution and its surface carefully sanded down again.
- If the gas production does not stop more hydrogen peroxide should to be added drop by drop, while keeping the solution stirred. This case occurs especially then when the supply bottle of the hydrogen peroxide solution has not been kept in the fridge (Hydrogen peroxide decomposes in heat) and consequently the concentration has sunk below w = 30 %. If necessary take the iron rod out and sand it down again.
- If the iron rod stays in a passive state, a few drops of sulfuric acid need to be given to the solution while keeping it stirred. If necessary take the iron rod out and sand it down again.

After being dipped in the solution the starting gas production shows that the iron rod is in an active state which means that the metal dissolves by producing hydrogen:

$$Fe \rightarrow Fe^{2+} + 2\,e^-$$
$$2\,H^+ + 2e^- \rightarrow H_2$$

However, the gas development is so intense that it can't be completely explained by this process. In fact there is also a production of oxygen which results from the Fe^{2+}-catalysed decomposition of hydrogen peroxide on the iron surface:

$$2\,H_2O_2 \rightarrow 2\,H_2O + O_2$$

At the same time the oxidizing effect (electron removal) of the hydrogen peroxide leads to a positive charge on the iron rod:

$$H_2O_2 + 2\,H^+ + 2\,e^- \rightarrow 2\,H_2O$$

When this reaches a certain potential (the passivation potential E_p), the iron rod will encase itself in a coherent iron oxide layer.

$$2\,Fe + 3\,H_2O \rightarrow Fe_2O_3 + 6\,H^+ + 6\,e^-$$

The oxide layer is impermeable to the molecules and ions and inhibits the iron dissolving and also its own formation (autoinhibition). For this reason the oxide film remains extremely thin and the metal keeps its typical appearance. The decomposition reaction of hydrogen peroxide comes to an end: The metal is passivated.

The short contact with the zinc electrode leads to the transfer of electrons from the zinc electrode, whose resting potential in this solution lies at around –0.62 V, to the passive iron (resting potential approximately +0.6 V). This electron transfer causes a reduction of the iron oxide layer in the area of contact (fig. 4):

$$Zn \rightarrow Zn^{2+} + 2\,e^-$$
$$Fe_2O_3 + 6\,H^+ + 2\,e^- \rightarrow 2\,Fe^{2+} + 3\,H_2O$$

Therefore a small part of the surface of the iron rod is returned to its active state, which means that the elemental iron which has been protected by the oxide film is now in direct contact with the electrolyte (fig. 4), while the rest of the surface is still passivated.

$$Zn \rightarrow Zn^{2+} + 2\,e^-$$
$$Fe_2O_3 + 6\,H^+ + 2\,e^- \rightarrow 2\,Fe^{2+} + 3\,H_2O$$

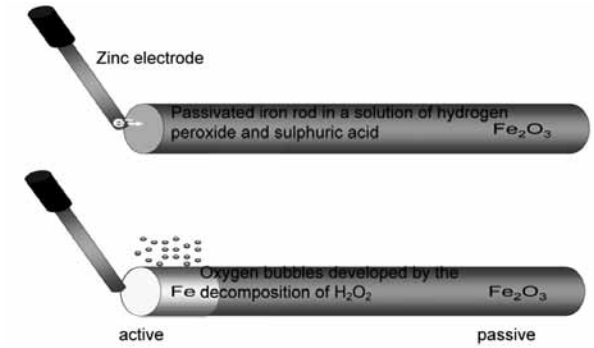

Fig. 4: Reactions at the contact zone zinc/passivated iron

On the metal surface a local element has now emerged which now causes the wavelike propagation of activation: If a part of the surface is activated the bordering passive area will, due to the minor potential difference, allows local currents to flow whose reducing force breaks up the passiveness at this point (fig. 5).

Local anode (active iron surface):

$$Fe \rightarrow Fe^{2+} + 2\,e^-$$

Local cathode (passive iron surface):

$$Fe_2O_3 + 6\,H^+ + 2\,e^- \rightarrow 2\,Fe^{2+} + 3\,H_2O$$

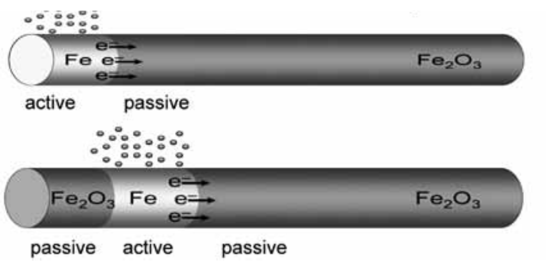

Fig. 5: Propagation of the activation zone by occuring local currents between active and passive areas of the iron rod

By observing the ascending gas bubbles that occur after activation, the movement of the potential wave can readily be followed visually. Although the activation zone as well as the action potential on a nerve-fibre strictly speaking do not move: In fact, in both cases, it is the electrical impulses which are transmitted and constantly newly generated due to local electric circuits along the nerve fibre or, in this case, the iron rod.

The model system shows the characteristics of the reversible change of state. Just after the formation of the gas the iron rod is repassivated by the oxidising force of the hydrogen peroxide.

A further accordance of the model is that the activation moves to both sides when the contact point between the iron rod and the zinc electrode is located in the middle of the iron rod. The same behaviour causes an impulse which is set on an axon by the help of an irritation electrode. Normally action potentials will emerge in organisms but only on the point where the nerve fiber arises from the nerve cell (axon hillock) and moves towards the end of the axon.

The significant matches between model system and nerve fibre are summarised as follows (tab. 1):

1. Experiment 2 – Simulation of the saltatory conduction

The carefully sanded down iron rod (compare experiment 1) is taped every 5-6 mm with a fabric tape with a width of 20 mm to provide alternating sections of 'open' and insulated rod (Fig 6).

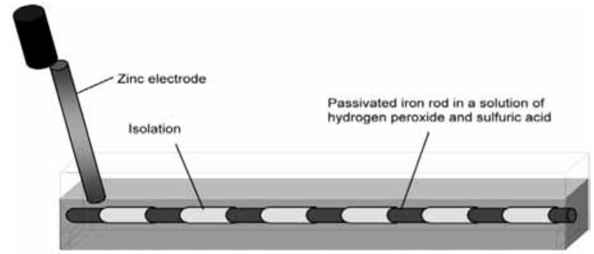

Fig. 6: Experiment set-up to simulate saltatory impulse propagation

Table 1: Accordance between the model and real system

NERVE CELL	MODEL
Resting membrane potential	Potential of the passive iron
Depolarisation	Electron supply through contact with the zinc electrode
Action potential	Change of potential of iron on activation
Excitation	Activation
Marginal potential differences between excited and nonexcited areas of the cell membrane induce local streams, which cause the propagation of an action potential.	Marginal potential differences on the border between active and passive iron surface induce local streams, which cause the propagation of an activity zone.
After an excitation the initial state is returned (repolarisation)	After an activation the original state is returned. The oxide film is regenerated through the oxidating force of the hydrogen peroxide solution.

After this the iron rod is laid in the experiment container, which contains an electrolyte of 97,5 mL distilled water, 27,5 mL sulfuric acid solution, $c(H_2SO_4)$ = 1 mol/L and about 33 mL of the hydrogen peroxide solution, $w(H_2O_2)$ = 30% (stabilised). Now a non-isolated area on one end of the iron rod is touched by a zinc electrode for about 1 second (fig. 6).

RESULTS AND DISCUSSION

If an iron rod is dipped in the solution, gas production can be observed in the non-isolated area which comes to an end quite quickly. The mechanism of the passivation of the exposed iron surface is described above (exp. 1). The contact to the zinc electrode causes a further gas development which spreads out like a wave from the contact point of both metals over the exposed areas of the iron surface while the isolated areas don't show any reaction at all. It is clear to see that the wave reaches the end of the rod considerably faster than in experiment 1. Finally the iron rod goes back to its passive state. This appearance can be generated repeatedly. With each new demonstration session it is necessary to remove the entire fabric tape and to completely sand it down again before re-insulating sections of the rod. Please bear in mind the advice given in experiment 1.

The mechanism of the transmission is the reason for the higher speed of the potential wave. The encountering with the zinc electrode leads to a local reduction of the iron oxide layer and to the occurrence of local currents. The excitation of neighbouring areas are caused.

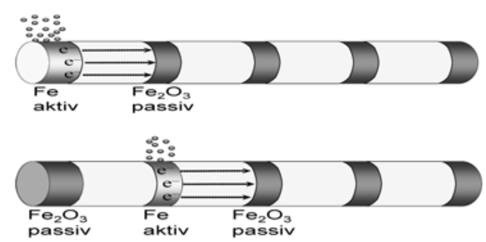

Fig. 7: Mechanism of the discontinuing propagation of activation

If the activation wave is achieving the first insulated sector the propagation of the electrical impulse to the next not insulated sector isn't slowed down by the time consuming reduction of the oxide layer. Therefore the propagation is carried out with much higher speed. (Fig. 7). At the next open section the degradation of the surface layer starts again, caused by the local current. Therefore the propagation of the activation occurs just like the saltatory excitation from one nerve constriction (Ranvier's node) to the next one. Table 1 can be extended as in Table 2:

Experiment 3 – A model experiment of information transmission by neurotransmitter

The procedure matches experiment 1 with the following change: The zinc electrode does not touch the iron rod, instead a few drops of sodium chloride solution, c(NaCl) = 1 mol/L, are added to one end of the experiment container (fig. 8) – no stirring.

Table 2: Accordance between the model and real system

NERVE CELL	MODEL
With the saltatory impulse propagation the excitation "jumps" over the isolating Schwann cells from node to node.	With the discontinuous activation the broadened activity zone "jumps" over the isolating glue strip from one node to the next.
The excitation propagates with high speed because the time-consuming unloading of the axon membrane only takes place on the nodes.	The activation zone propagates with high speed because the time-consuming reduction of the iron oxide film only takes place on the nodes.

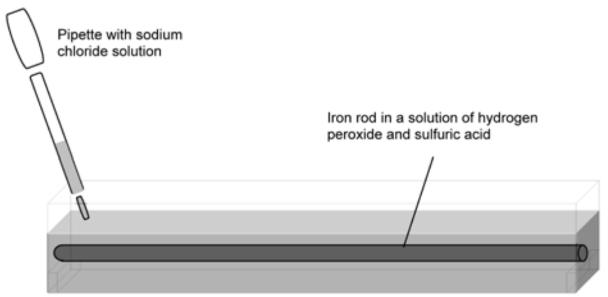

Fig. 8: Experiment to simulate the synaptic excitation transmission

RESULTS AND DISCUSSION

At that end, where the sodium chloride solution was added an activation wave is running across the rod that used to be passive after approximately 30 seconds. The first few cm of the iron rod remain in the active state, while the rest of the surface is run through by potential waves.

The activation of the iron rod is caused by the presence of the chloride ions. As soon as they are diffused to the rod in a large amount their corrosive effect causes the decompositon of the oxide film:

$$Fe_2O_3 + 4\,Cl^- + 11\,H_2O \rightarrow 2\,[FeCl_2(H_2O)_4]^+ + 6\,OH^-$$

The partial reduction of the surface layer by the chloride ions triggers an activity wave.

In comparison to the neurophysiological procedures on the synapse, where the neurotransmitters are split by an enzyme after just a short time and this prevents a constant excitation (e.g. acetylcholine through acetylcholinesterase), the chloride ions in the model experiment are not degraded. The entire repassivation of the iron, as for example after the short contact with a zinc electrode, is inhibited by the permanent presence of the chloride ions at the beginning of the rod so that this area remains in a continuing active state. This constant excitation provokes the rhythmic release of potential waves.

Table 3: Accordance between the model and real system

nerve Cell	Model
The transmission of a signal on the synapse is caused by neurotransmitter which react depolarisating on the post synaptic membrane and eventually leads to the release of an action potential.	Release of an activation wave by chloride ions which decompose the iron oxide layer.

CONCLUSIONS

In this article a new electrochemical model system has been introduced, which features numerous analogies to the neurophysiological procedures during the development and transmission of excitation on real nerve fibres.

Numerous teaching experiences have shown that this model is very motivating for students. The experiments are carried out in group work and functioned excellently. Especially the propagation of the activation wave impressed the students. During experimental phase the students discovered an analogy to the impulse propagation on nerves. One could hear comments like *„that is just like the impulse propagation in the nervous system, it is above threshold;...".* In a fruitful classroom communication the similarities and differences between the model system and the procedures on the neuron can be discussed. The most thrilling part for the pupils was to recognise the connection of this model system with another subject.

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The evaluation of combinatorial abilities of high school students in the context of chemistry

La evaluación de las habillidades combinatorias de los estudiantes en la escuela secundaria en el contexto de la química

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Abstract

Various chemistry lesson contents can be used for enhancing and evaluating combinatorial abilities. This paper explores use of the term mixture, an essential term for learning and understanding chemistry, as a tool for evaluating combinatorial abilities. 47 First year high school students (15 year olds) were the subjects in this study. An investigative instrument with four tasks (definition question, conceptual questions - analysis of pictorial representations, analysis/interpretation of data and prediction of outcomes) and one experiment (for individual work of students) was created. The tasks examined the definition of the term mixture and understanding of the terms pure matter, homogeneous mixture, heterogeneous mixture and solubility. In addition, the task evaluated the combinatorial abilities based on the various solubility information gathered. The students gathered solubility information by dissolution of two nickel salts in water or ethanol and by dissolving ethanol in water. In order to recognize how different information derived from experiments affects combinatorial ability the solubility of $NiCl_2$•$6H_2O$ was tested by one group of the students and the solubility of $NiSO_4$•$7H_2O$ by the other. The following question was used for the evaluation of combinatorial ability: "How many homogeneous mixtures can be made from ethanol, water and nickel salt you used in your experiments?" The results showed only 10.6% of students solved the problem successfully, leading to the conclusion that the students involved in the study generally lacked combinatorial ability. The possible effect of different information available on students' combinatorial ability could have not been evaluated.

Key words: *formal thinking, combinatorial ability, mixture, solubility, experiment, analysis of pictorial representations*

Resumen

En el proceso de la enseñanza/aprendizaje de la química, el desarrollo y la evaluación de las capacidades combinatorias se pueden realizar en varios contenidos. En esta ponencia, la capacidad de combinar está considerada en el término mixtura, que es imprescindible para el aprendizaje y entendimiento de la química. La investigación fue hecha en la muestra de 47 estudiantes del primer año de escuela secundaria (15 años de edad), divididos en dos grupos por la elección casual. Para las necesidades de la investigación fue compuesto el instrumento que abarcó cuatro tareas diferentes (la cuestión de definición, las cuestiones conceptuales – el análisis de las representaciones pictóricas, análisis e interpretación de los datos y la predicción de los resultados) y un experimento (para el trabajo individual de los estudiantes). Con las tareas se examinó la definición del término mixtura y entendimiento de los términos materia pura, mixtura homogénea, mixtura heterogénea y solubilidad, y también la habilidad combinatoria fue evaluada a base de la información de solubilidad. Los estudiantes llegaron hasta las informaciones de la solubilidad mediante el experimento de disolución de dos sales de níquel en alcohol etílico y agua, y disolución de alcohol etílico en agua. Para entender la influencia de informaciones diferentes en las capacidades combinatorias de estudiantes, un grupo de ellos examinó la solubilidad de $NiCl_2$x $6H_2O$, y otro $NiSO_4$x $7H_2O$. La capacidad combinatoria fue evaluada con la tarea: "¿Cuántas mixturas homogéneas se pueden producir si se tienen en disposición el alcohol etílico, agua y sal de níquel cuya solubilidad habíais investigado?" Los resultados de la investigación muestran que sólo 10.6% de los estudiantes solucionó el problema, lo que llevó a la conclusión de que estudiantes que participaron en la investigación generalmente no tienen desarrolladas las habilidades combinatorias. En consecuencia, la conclusión sobre la influencia potencial de las informaciones diferentes en la capacidad combinatoria de los estudiantes no podía ser evaluada.

Palabras clave: *Pensamiento formal, la capacidad de combinar, la mixtura, la solubilidad, el experimento, el análisis de las representaciones pictóricas*

INTRODUCTION

Combinatorial problems are a part of math courses. A typical combinatorial problem given to students would be: *How many possible combinations (without repeating the elements) one can make from the elements A, B, C and D?* For solving such problems a refined thought process – formal thinking – must be applied. According to Piaget and Inhelder (1958, p. 107) „*...formation of propositional logic, which itself marks the appearance of formal thought, depends on the establishment of a combinatorial system (...) which is manifested in the subjects' potential ability to link a set of base associations or correspondences with each other in all possible ways so as to draw from them the relationships of implication, disjunction, exclusion, etc.* ". In solving combinatorial problems the difference between formal and preformal thinker is that the formal thinker would find all possible combinations, whereas the preformal thinker would list only a limited number e.g. AB, AC, AD and ABCD, e.g. (McDevitt and Ormrod, 2002). According to Piaget the development of formal thinking begins around ages 11-12 and around ages 14 and 15 its development is completed and consolidated (Moshman, 2005). However, many researches showed students at ages 14-15 cannot solve problems requiring formal thinking (Byrnes, 2003; Kuhn and Franklin, 2008). Also, Piaget's claims about certain periods when everybody reaches formal operations have been widely criticized. In addition to the research about metacognition and the environmental effect on cognitive development there is a renewed interest about students' ability to solve well known Piaget's problems (Kuhn and Franklin, 2008).

Evaluation and development of combinatorial abilities can be achieved through teaching/learning of chemistry. The term *mixture* can be used for that purpose. That term has a great importance for the learning of entire chemistry and it is listed as a "chemical axiom" by Taber (2002).

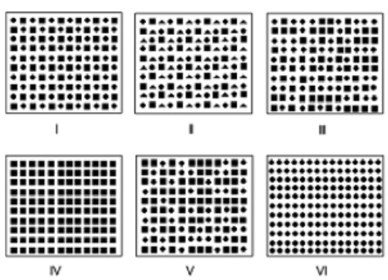
The purpose of our research was to use the term mixture to evaluate combinatorial abilities of 15 year old students (high school freshmen).The premise of the research was that students understand terms *pure matter, homogeneous and heterogeneous mixture and solubility* because those terms were taught in the middle school. However, some previous studies showed various misconceptions in understanding of those terms (Sanger, 2000; Taber, 2002; Stains and Talanquer, 2007). Therefore, we also checked if the students understood those terms as a prerequisite for assessing combinatorial abilities. With the same goal in mind, we also investigated what is the effect, if any, of different outcomes from the same experiment (with different solutes) on students' combinatorial abilities.

METHODS

The research goal was achieved through an instrument containing four tasks. The first task was a definition question (Smith et al, 2010) testing if students knew how to define the term mixture. The second task (Figure 1) was a conceptual question requiring students' „*analysis of pictorial representations*" (Smith et al, 2010; p. 149). That part of the learning process includes analysis of schematic images giving students the opportunity to test their mental understanding of the term. The ability to solve such problems, i.e. translation from one context to another, is considered to be possible if a certain level of understanding exists (Bloom, 1956; Marzano and Kendall, 2007). Therefore, the task two was used to test the understanding of the answer to the task one and understanding of the terms homogeneous and heterogeneous mixture. The importance of the „*analysis of pictorial representations*" problem is in the fact that students have to separate only the information which is relevant and clearly points to the essence of the term mixture form various information available from the pictures. The images IV and VI contain just one geometric shape each, compared to the other images which contain two or three different geometric shapes. In this case, the analysis calls for connecting the information about various geometric shapes and its implicit relation to the definition of the term mixture. It should be noted that the meaning of the geometric shapes was not given in the task two although it is generally provided as a part of black and white schematic images (Dawidoviz et al, 2010). Therefore, students only considered if the schematic images represent pure matter, homogeneous, or heterogeneous mixtures respectively, and not what kind of molecular entities were represented.

Before working on the next two tasks (Figure 2) the students performed experiments testing solubility of a nickel salt in water and ethanol and solubility (miscibility) of anhydrous ethanol in water. The Group A of students tested the solubility of crystalline nickel(II) chloride haxahydrate, $NiCl_2•6H_2O$ which is soluble both in water and ethanol. The Group B tested the solubility of crystalline nickel(II) sulfate heptahydrate, $NiSO_4•7H_2O$, which is soluble in water and slightly (2.2 g/100 g, Radosevic, 1968) in anhydrous ethanol. This low solubility of nickel(II) sulfate heptahydrate in ethanol gives appearance of no visible dissolution in ethanol even after an extended period of time. The information both groups of students were given was just "a nickel salt" and not its name or formula. That simplified the problems. Both groups followed the exact same experimental procedures. Upon the completion of experiments, the third task examined the conclusions students had made about the solubilities of materials, and the fourth task (analysis/interpretation of data and prediction of outcomes, Smith et al., 2010) asked how many homogeneous mixtures could be created with the nickel salt, water and ethanol.

1. What are mixtures?
2. Observe the images I-IV and answer the questions that follow:



a) Circle the Roman numerals for images representing mixtures.
b) What are the geometric shapes ■, ▲ & ● in the images given representing?
c) Homogeneous mixture is represented in the image(s):
d) Heterogeneous mixture is represented in the image(s):
e) Explain the reason(s) for giving answers to questions c and d.

Figure 1 The definition (task 1) and conceptual questions (task 2) as presented to the students.

Answers in the tasks three and four were crucial for our study. The experimental result gave the Group A students three homogeneous mixtures (nickel salt/ethanol, nickel salt/water and ethanol/water). By analysis and combining the results of the experiments students discover the fourth homogeneous mixture (nickel salt/ethanol/water, Table 1). The Group B students, on the other hand, had two homogeneous mixtures (nickel salt/water and ethanol/water; the third mixture, nickel salt/ethanol was heterogeneous) as their experimental result. The conclusion about the third homogeneous mixture was drawn similarly as for Group A students. The absence of the combined (homogeneous) mixture containing all three substances in both groups of students points to lack of combinatorial abilities and lack of analysis of the results obtained and making the right conclusions. The difference between mathematical combinatorial problems and combinatorial problems with chemistry content is shown in Table 1. If the majority of students in both groups solved correctly tasks three and four the conclusion would have been that they had combinatorial abilities and hence, if only a negligible number of students gave correct answers, they would have lacked combinatorial abilities, providing they had understanding of what homogeneous mixtures were. The effect of different solubilities of nickel salts (obtained from experiments) on combinatorial abilities could have been observed if both groups correctly finished the task 3 and one group completed the task 4 statistically much better than the other group (what could be confirmed with chi-square goodness-of-fit test).

Table 1 The effect of experimental results on the combinatorial ability

Mathematical Combinations						Number of combinations
Three elements (A, B i C)		A-B	A-C	B-C	A-B-C	4
Combinations from experimental data						
Three substances (nickel salt, water, ethanol)		Solubility found in experiments			Experimental data analysis - conclusion	Number of homogeneous combinations
		Salt + water	Salt + ethanol	Water + ethanol	Salt + water + ethanol	
Nickel salts	chloride	+	+	+	+	4
	sulfate	+	-	+	+	3

Perform the experiment following these instructions and then answer the questions 3 and 4.

Ethanol, nickel salt, d.i. (deionized water) and necessary supplies are available for every work space. The test tubes are labeled 1, 2 and 3. Test the solubility of the nickel salt in d.i. water and ethanol as follows. Put one half spoon of nickel salt in test tubes 1 and 2. Add water to the test tube 1 and ethanol to the test tube 2 up to the mark level. Shake both test tubes vigorously and put them back in the rack.

Test the solubility of ethanol in d.i. water as follows. Fill the test tube 3 with water up to the lower mark, and then add ethanol up to the upper mark. Shake and put the test tube in the rack.

NOTE: Do not mix the solutions from different test tubes.

3. Circle the correct part of the following statements:
   a) Nickel salt is soluble/not soluble in ethanol.
   b) Nickel salt is soluble/not soluble in water.
   c) Ethanol is soluble/not soluble in water.

4. Circle the correct answer to the following question: How many homogeneous mixtures can be made from ethanol, water and nickel salt you tested?

a) One homogeneous mixture.
b) Two homogeneous mixtures.
c) Three homogeneous mixtures.
d) Four homogeneous mixtures.
e) Five homogeneous mixtures.

Explain your answer.

Figure 2 The experiment instructions and questions to test students' conclusions about the experiment (task 3) and their combinatorial abilities (task 4)

The comprehension of questions was tested on 24 college students (nine seniors/seventh semester students and 15 freshmen/first semester students of Chemistry – majoring in Chemistry Education at the Faculty of Chemistry, University of Belgrade). Some of the remarks given were adopted and applied to the updated version given to the high school students. 47 (15 year old) high school freshmen from two classes (labeled as I_1 and I_2 in this paper) were tested in November of 2010. All of them had chemistry for two years, two hours per week in the last two years of the middle school. The terms *pure matter, mixture and solubility* were taught in the middle school and again at the beginning of the high school freshmen year (before the investigation presented here). The students from both classes were divided in groups A and B. The bench work space was randomly assigned along with the corresponding code (e.g. 1A for work space 1 and group A) for every student.
The time allotted for the completion of all problems was 25 minutes.

RESULTS AND DISCUSSION

For the task 1 the expected answer was that „a mixture is a combination of two or more pure matters/substances". Instead of „pure matter" the acceptable answers were examples of pure matter, e.g. elements or compounds. The answers such as:

„Mixtures are a set of elements“ (student I_1-11A), or *„Mixtures are sets/mixtures of compounds“* (I_1-1B) were not accepted as correct because they did not give the accurate and/or complete definition of mixtures. The results for the task 1 (Table 2) show that 48.9% of students did not know how to define the term *mixture*. This result may be caused by teachers not insisting that students learn definitions of chemical terms, insufficient ability of students to express their thoughts, not enough motivation to give good answers (the test was not used for grading purposes) and not completely developed metacognition.

Incomplete definition was given by 17.0% of students. In addition incorrect were answers showing the confusion with various terms. For example:

“Mixtures are compounds of pure substances. They can be homogeneous and heterogeneous.” (I_2-2A).

“Mixtures are sets of same substances with different properties.” (I_2-6A).

Table 2. Results obtained for the task 1 (definition of mixtures) and the task 2

(analysis of images of mixtures and pure matter). 47 students took the test.

Number of studens with the correct (+) or incorrect (-) answers, or no answer (x)

	1*	2a**	2b	2c	2d	2e
+	22	19	6	9	13	9

*1 – Definition of mixture(s);
**2a – Differentiation of schematic images of mixtures and pure matter, 2b – interpretation of geometric shapes, 2c – selection of images of homogeneous mixtures, 2d - selection of images of heterogeneous mixtures, 2e – explanation for choosing particular images of homogeneous and heterogeneous mixtures.

The results of analysis of pictorial representations show that students were not successful in differentiation of schematic images of mixtures from those of pure matter (question 2a). Only 19 students (40.4%) chose correct images (four images total) representing mixtures. Assuming that the analysis of schematic images requires a certain level of understanding (Bloom, 1956, Marzano and Kendall, 2007) one can conclude that students did not understand the definition of the term mixture. If we analyze 23 answers categorized as incorrect we find 7 incomplete answers where students did not circle all four correct mixture images. The result obtained can indicate students were not used to with that kind of problems.

The correct interpretation of geometric shapes (question 2b) was given only by six students. Among the 36 incorrect answers, 12 students called geometrical shapes *“substances”*. Those answers were considered incorrect because the term substance includes both pure matter (substance) and mixtures and that is how the term substance is taught in our schools. The majority of the remaining answers listed only elements or only compounds.

Questions 2c and 2d dealt with distinguishing homogeneous from heterogeneous mixtures and produced lower number of correct answers (when compared to the question 2a). Such result indicated that even when students can identify images representing mixtures they have difficulty choosing representative images for homogeneous and heterogeneous mixtures. Somewhat higher number of correct answers for heterogeneous mixtures (2d) than for homogeneous mixtures was due to the fact the some students erroneously categorized pure substances/matter (images IV and VI) as homogeneous mixtures The reasoning for such answers can be seen in answers to the question 2e:

“The images IV and VI represent homogeneous mixtures because the geometric shapes are the same, making them pure mixtures, i.e. they contain the same element and the chemical composition is uniform in all their parts. The images III and V represent heterogeneous mixtures because they contain different geometric shapes, i.e. they are not made up from the same element and the chemical composition varies in different parts of the mixture.” (I_2-8A)

“Homogeneous mixture has the same properties in all its parts (the geometric shapes are the same in all parts of the images IV and VI). Heterogeneous mixture has different properties in all its parts (different geometric shapes in different parts of images III and V).” (I_2-5A)

“The images IV and VI represent homogeneous mixtures because the homogeneous mixture the same in all its parts. The images II, III and V represent heterogeneous mixtures because heterogeneous mixture is different in all its parts”. (I_1-3A)

The majority of incorrect answers to questions 2c and 2d shows that the criterion for distinguishin .

Number of students with the correct (+) or incorrect (-) answers, or no answer (x)

	3a1	3b	3c	4mch2	4exp3
+	40	44	37	5	4
-	6	2	8	42	36
x	1	1	2	0	7

1 Solubility of: a salt in ethanol (a), a salt in water (b), ethanol in water (c)
2 Multiple choice (mch) – number of possible homogeneous mixtures
3 Explanation (exp) – of the chosen number (of homogeneous mixtures)

Unexpectedly, eight students (four in each group) concluded that ethanol was not soluble in water (question 3c). Those students repeated the experiment and seven of them changed their answers indicating ethanol was soluble in water (miscible). The one student didn’t change his opinion and he wrote: *„If the subtance is not visible, then it did not dissolve.“*

Table 4 Results of students' observations about the solubilities of $NiCl_2 \cdot 6H_2O$ (group A) and

$NiSO_4 \cdot 7H_2O$ (group B) in ethanol (3a) and water (3b) and solubility of ethanol in water (3c)

Number of students with the correct (+) or incorrect (-) answers, or no answer (x)						
	A[1]			B[2]		
	3a	3b	3c	3a	3b	3c
+	16	20	17	24	24	20
-	6	2	4	0	0	4
x	1	1	2	0	0	0

1 Number of students in the group A was 23.
2 Number of students in the group B was 24.

Before we analyze the results used for estimating the combinatorial abilities, it is important to point out the differences between Piaget-Inhelder’s approach and our approach on investigating the combinatorial abilities. Piaget-Inhelder’s problems did not require understanding of chemical concepts, whereas in our investigation it was prerequisite. The problem used for estimating the combinatorial abilities can be solved only if a student understands the term homogeneous mixture and is able to combine.

The combinatorial abilities of students were tested with the multiple choice question (4mch). The correct answers were “d” (four homogeneous mixtures) for the group A, and “c” (three homogeneous mixtures) for the group B. The correct answer about the number of homogeneous mixtures was given only by five students (10.6%, Table 3) from both groups combined and four of them gave good explanations of their choices. The low percentage of correct answers should be viewed with the results for the tasks 2 and 3 in mind. The results for the task 2 showed that the majority of students (76.6%) did not understand the term homogeneous mixture when represented with the pictorial image. However, when the term homogeneous mixture was presented in a macroscopic level (outcomes of the experiments) much higher percentage of students (39.1% from the group A chose three, and 58.3% from the group B chose two) knew what the homogeneous mixtures were (Figure 3). The results obtained were in the agreement with the conclusion about difficulties students have in transition through three levels of presenting the term matter (from submicroscopic, through symbolic to macroscopic level) (Johnston 1982; Gabel 1999). The number of mixtures (three and two, respectively) correspond to the maximum number of homogeneous mixtures that can be made under the set experimental conditions. The lower percentage of correct answers for the group A (compared to the group B) was due to the erroneous conclusions about the solubilities of nickel(II) chloride hydrate. The correct understanding of chemical terms was a prerequisite for estimating the combinatorial abilities in this paper and that condition was sufficiently fulfilled. The results presented in the Figure 3 show an absence of the mathematical combination and analysis of the experimental results. The combinatorial abilities are the prerequisite for the results analysis and absence of combinig resulted in only 10.6% of students giving the correct answers about the total number of homogeneous mixtures.

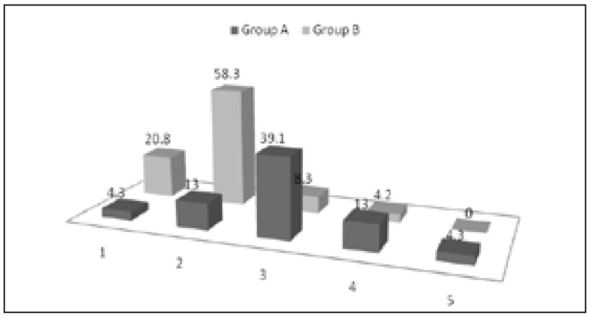


Figure 3 Results for the estimate of the combinatorial abilities (task 4). The chosen number of homogeneous mixtures (1-5) was plotted vs. the percentage of answers for each one of them.

To determine how much the data about (different) solubilities of salts, observed in an experiment, affect the conclusions about the number of homogeneous mixtures salts with different solubilities in ethanol were used. The task 4 results for the groups A and B are presented in the Table 5. Only a small number of students (4) gave the correct explanations not allowing a reliable conclusion about the effect of different information (different solubilities of salts) available on the combinatorial abilities.

Table 5 Results obtained for effects of different solubility information gathered

by the students in groups A and B on their combinatorial abilities.

Number of students with the correct (+) or incorrect (-) answers, or no answer (x)				
	A[1]		B[2]	
	4mch[3]	4exp[4]	4mch	4exp
+	3	3	2	1
-	20	15	22	21
x	0	5	0	2

[1] Number of students in the group A was 23.
[2] Number of students in the group B was 24.
[3] Multiple choice (mch) – explanation for choosing a certain answer
[4] Explanation (exp) of the chosen number (of homogeneous mixtures)

CONCLUSIONS

Combinatorial abilities of students have not been investigated (adequately) in the teaching of chemistry. The study presented is a contribution in the research of ways to estimate (and develop too) combinatorial abilities of students through teaching of chemistry.

With the study goal in mind we concluded that 15 year old students did not show combinatorial abilities during the solving of chemical tasks. The effect of different outcomes from the same experiment (with different solutes) on students' combinatorial abilities could not be established. This study also confirmed some earlier findings about misconceptions for the concept mixture.

One of the conclusions in this work is that if problems requiring combinatorial abilities are used for testing of understanding of chemical concepts gave negative results, we still cannot conclude that students did not understand those terms – the lack of combinatorial abilities could be the cause. The results of such tests provide valuable information enabling a teacher to further plan, execute and follow through the teaching process.

Future investigations are necessary to develop problems not only for estimating combinatorial abilities but also to monitor their development. The present study offered one task of that kind.

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Air pollution: educational activity and research in the secondary schools

La contaminación del aire: actividad docente y de investigación en las escuelas secundarias

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Abstract

This paper describes activities conducted by researchers of Institute for the Study of the Dynamics of Environmental Processes of the National Research Council (IDPA-CNR) in relation to the Department for Education and Skills project of Ministry of Education, University, "Initiatives for the Diffusion of Scientific Culture" (MIUR). The aim was to create an educational activity which included the involvement of the students in experimental research after suitable training, with particular attention to the sampling of aerosols followed by instrumental determination of pollutants. The educational objective was to create a teaching activity, building upon the scientific curiosity of students to transfer basic environmental air pollution concepts in their *daily life and to also develop their attitudes toward pollutants. The indoor and outdoor air quality in three secondary schools in Veneto (Italy) was analyzed and discussed. The final self-reflection and cultural experience assessment can prove to be much more constructive from the educational point of view, as both experiences allow for possibility to exert an active influence on forming student's personality. Self-reflection should allow students and teachers to evaluate the impact of the learning experience in their own level of environmental sensibility.*

***Key words**: educational activity; indoor and outdoor air quality; involvement of the students, experimental research; scientific curiosity.*

Resumen

En este documento se describen las actividades llevadas a cabo por investigadores del Instituto para el Estudio de la Dinámica de Procesos Ambientales del Consejo Superior de Investigaciones Científicas (IDPA-CNR) en relación con el Departamento de Educación y Habilidades de proyectos del Ministerio de Educación de la Universidad, "Iniciativas para la Difusión de la Cultura Científica ". El objetivo era crear una actividad educativa que incluyó la participación de los estudiantes en la investigación experimental después de una formación adecuada, con especial atención a la toma de muestras de aerosoles seguida de la determinación instrumental de los contaminantes. El principal objetivo de la educación era encontrar una actividad docente tendiente a fomentar el aprendizaje de los jóvenes, aprovechando su curiosidad científica y la transferencia de conceptos científicos básicos acerca de la contaminación del aire en el medio ambiente en su vida diaria, también en el desarrollo de sus actitudes. La calidad del aire en interiores y exteriores en tres escuelas secundarias en Veneto (región italiana) fue analizado y discutido. Como parte final de este proceso, la reflexion individual y la evaluaciòn individual de la experiencia cultural puede llegar a ser mucho más constructivo, desde el punto de vista educativo, debido al hecho de que la reflexión individual y la adquisición de la experiencia cultural primaria permite la autenticidad de los conocimientos adquiridos y la posibilidad de ejercer una influencia activa en el proceso de la formación de la personalidad del estudiante. La reflexión individual debería ayudar a unir a los estudiantes y profesores para que puedan evaluar en qué medida la experiencia de aprendizaje influye en el propio nivel de sensibilidad ambiental.

***Palabras clave:** actividad educativa, calidad del aire interior y exterior, participación de los estudiantes, la investigación experimental, curiosidad científica.*

INTRODUCTION

Many educators agree that the presence of green information systems forces educational institutions to investigate alternative methods to make young students aware of environmental quality, pollution and human health. In addition, this scientific awareness of environmental quality is important for the fundamental future of every country. For these reasons the Institute for the Study of the Dynamics of Environmental Processes of the National Research Council (IDPA-CNR) and the Cà Foscari University Venice, took part in a Department for Education and Skills project by Ministry of Education, University which grew from the law 10/01/2000 n° 6 "Initiatives for the Scientific Culture Diffusion". This project was born from the need to support and strengthen existing institutions involved in the diffusion of various scientific aspects including the protection and enhancement of historical sites preserved in Italy. The described activities are part of the ministerial program and/or the formative plan of the schools. The research teams noticed that students appreciate activities in which experts teach them something new in an alternative method. The proposed IDPA-CNR project considers the benefits that can result when universities, research institutes and secondary schools cooperate together in training young students through research activities such as: Raising student awareness of the scientific approach towards analyzing the important questions proposed by modern society; Increasing student awareness of air quality and pollution in their living area; Introducing students to scientific matters, in particular the research inside the universities and research centers; Enhancing student interests in the connections between the environmental, health and social issues; and Involving students in collaborative projects.

People in developed countries are spending more and more of their time in various indoor environments (Farrow et al. 1997) school represents the location where young individuals pass a substantial part of the day (Silvers et al. 1994) and in the past few years there is a growing evidence of comparatively high concentrations of airborne particulate matter (PM) in classrooms (Janssen et al. 2005, Son et al. 2005, Fromme et al. 2005, Stranger et al. 2007). In 1983 Prospero et al. (date1983) defined airborne particulate matter as aerosols where "an aerosol is defined as a suspension of fine liquid and/or solid particles in a gas". Aerosols are increasingly considered to be an important indicator of outdoor air quality, since a number of health problems have been associated with their high concentrations (WHO, 2004). The effects of aerosol on human health vary for different size-dimensional classes of particles and by their chemical composition. An important class of aerosols persistent organic pollutants include the polycyclic aromatic hydrocarbon (PAHs) which are easily found in different locations, and derive partly from traffic.

Considering the importance of aerosol monitoring, the IDPA-CNR project addressed the didactic educational activity by approaching the students with environmental scientific studies. In particular, these studies provide the students with training in the role of aerosols on human health, on the transport of organic pollutants in air, water and soil system and on the effects of climate change on global scale. This training sensitizes the students to the principal characteristics of the terrestrial ecosystem with a particular attention to the role of human interference. This introduces two important sides of an environmental educational approach: the first, relating to *didactics* or transversal approach to organizing teaching and learning; the second, relating to a critical approach to the discipline, considering not only knowledge but also epistemological and socio-historical foundations of knowledge taught.

Based on this understanding of environmental education, the analysis subdivides the educational goals and connected competences into six broad categories (which are derived from the work of Byram, 1997):

Attitudes: - Respect for otherness: a willingness to suspend one's own values, beliefs and behaviours, not to assume that they are the only possible and naturally correct ones, and a willingness to accept that people from other cultures have different sets of values, beliefs and behaviours.

- Empathy: understanding other people's perspectives, and being able to project one-self imaginatively into the beliefs, values, thoughts and feelings of people from other cultures.
- Acknowledgement of identities: ability to acknowledge the identities which cultural others ascribe to themselves, and to acknowledge the meanings which they themselves associate with those identities. This is not always easy because there is a tendency to assimilate other people's identities to the ones which we know from our own cultural perspective.
- Tolerance of ambiguity: recognising that there can be multiple perspectives on, and interpretations of, any given situation multi-perspectivity, that is, the ability and willingness to take others' perspectives on events, practices, products and documents into account, in addition to our own.

Knowledge:- Specific knowledge: Specific knowledge about one's own subject and about its practices and products is acquired primarily through socialisation within the family and the school. However, in order to be able to understand the perspective and to have some ***specific knowledge*** about the culture of that other person and about its practices and products.

- General knowledge: One needs general knowledge about interaction and communication processes and of how these processes are shaped by cultural factors.

Skills of discovery and interaction. Novelty is often encountered in environmental dialogue, and nobody can anticipate all of their knowledge needs in advance. For this reason, it is important to be able to find out new knowledge and integrate it with what is already known. In particular, we need to know how to ask people from other cultures about their beliefs, values and behaviours, and how to seek out further information about their cultures. So environmental dialogue requires *skills of discovery and interaction*, and these sometimes have to be deployed under the constraints of real-time communication with the cultural other.

- Because new cultural knowledge may be acquired during the course of interaction, educational approach also requires ***behavioural flexibility***, that is, the ability to adjust and augment one's existing capacities and to adapt one's behaviour to new situations.
- Problems in environmental communication and education can often occur because the communication partners follow different linguistic conventions. This is because people from different cultures: a) associate different meanings with specific words; b) express their intentions in different linguistic forms; c) follow different cultural conventions of how a conversation should take place with regard to its content or its structure; and d) attribute different meanings to gestures, mime, volume, pauses, etc.

Skills of interpreting and relating. A further important aspect of educational goals was to define the ability to interpret the perspectives, practices and products of subject education.

- These ***skills of interpreting*** require specific knowledge of the subject, as well as empathy, multi-perspectivity and more general knowledge of related cultural practices, products and identities.
- Interpretation also requires ***skills of relating***, that is, the ability to compare the perspectives, practices and products of the other approaches to the

problem with corresponding things in one's own culture, and ***seeing the similarities and differences*** between them.

Critical cultural awareness. This is the ability to evaluate, critically and on the basis of explicit criteria, perspectives, practices and products both in one's own knowledge and in other approaches. It involves:

- becoming aware of one's own assumptions, preconceptions, stereotypes and prejudices;
- identifying the values which are expressed through the perspectives, practices and products both of one's own subject awareness; and
- making an evaluative analysis of those perspectives, practices and products, using an explicit set of criteria in order to do so working on own everyday patterns of perception, thought, feeling and behaviour in order to develop greater self-knowledge and self-understanding.

Action orientation. The final dimension of educational goals identified in our analysis is *action orientation*. The actions can take can be of many forms, for example:

- grasping and taking seriously the opinions and arguments of others, according personal recognition to people of other opinions, putting oneself in the situation of others;
- accepting variety, divergence and difference, recognising conflicts, finding harmony where possible;
- regulating issues in a socially acceptable fashion, finding compromises, seeking consensus, accepting majority decisions; and
- weighing rights and responsibilities, emphasising group responsibilities, developing fair norms and common interests and needs;

According to this model of environmental education, this project's motivation, a positive attitude, purposefulness and commitment are said to be key factors. The development of environmental awareness through educational methods - needs therefore to concern itself with knowledge, feelings, attitudes and behaviors. Par consequence, the teaching should promote activities and learning environments that produce varied, memorable and significant insights about own cultural identity and backgrounds in contrast with others' own, engaging then students on an affective and experiential level. Activities that should be designed to enable students to reflect upon themselves as individuals and as members of the social groups to which they belong, by exploring their behavior within their micro-cultures about pollution in their home country, and enable them to find strategies to cope independently with life in contact with other perspectives and new approaches, or in a foreign environment.

METHODOLOGY

Pedagogical approach

At the end of the project, the students of the three different schools were able to discuss and compare the achieved results, and to take into consideration all of the surrounding factors and aspects. This project served as a resource to schools, and in particular to the students, and was thus designed in order to meet their needs. For this reason the project activities were intended firstly to draw the attention of the students to the theme of air pollution and secondly to physically analyze the problem through an experimental activity. In the light of the above points, the project was organized to allow different steps in the monitoring of the study progress. Classroom activities were designed with the project goals in mind and revolve around two key content areas: understanding the importance of outdoor and indoor air pollution and learning how to sample air to determine the concentration of micropollutants.

For each school involved in the project the first step involved linking the adolescents with the study subject and teaching them the sampling techniques. In particular the theme of lessons were: the principal terrestrial ecosystems; atmosphere and principal pollutants; the most important research on fine atmospheric particles; analytical methodology for chemical characterization of atmospheric aerosol; the role of aerosols in the environment and on human health; and the study of aerosols in the natural and anthropogenic environment. The second step was the sampling activity in the schools that was carried out by the student groups with the supervision of teachers and IDPA researchers.

To reach the pedagogical goals and the most elevated levels of dynamic, metacognitive processes within environmental education and competences, it seems necessary to introduce a new idea of teaching. It is not only a fact of treat some specific issues in class, or changing curriculum in a more "planetary" view, it's also a fact of changing radically didactics. In this sense, as many authors have stated, the ongoing processes of change within educational system, namely, a more flexible and participatory settings in classroom that allow the expression of the several intelligences and cultures present in class, have been claimed not only for environmental education, but also, for the acquisition of a more effective, inclusive education.

According to Italian background, which is confirmed by international trends in research, in order to achieve an environmental approach to teaching, the teacher needs to focus on the following aspect of didactics (Margiotta, 2007, Minello, 2008): Planification (The Learning Unit or educational project with characteristics that promote multiple intelligences); Methodology (the method teaches more than the content: environmental education introduces methods of social mediation); and Evaluation (the environmental education works on the concept of formative evaluation as eco-social co-evaluation).

Nowadays **teacher-conveyed didactics** models are still too utilized. Even though they played an important role in all those experimentations that produced new approaches of knowledge transmission, they are not anymore suitable for the new requirements of identity formation within the growing context of diversity. That is because they favour centrality of teaching, instead of that of learning; and they favour fragile and easily standardizable identity-making representation, too rigid to support the fluid relations undertaken in the postmodern context. It is in this very environment that sharing, negotiation and building of new meanings can all produce learning, considering culture, a forum (Bruner, 1996), continuously changing in order to give place to personal narratives of the world.

According to small worlds theory (Granovetter, 1973), that was initially applied to social contexts - after extended to different conceptual fields, weak links are more efficient in producing connections and in reaching with celerity some previously unknown junctions. Instead, strong links such as hierarchy bonds miss this aims. A new conception of education and training is needed in the fluid context of post-modernity with the use of methods that are not anymore focused on competitive growth of the individual, but on complex, integrated functions. Those functions would be able to stimulate and ease the improvement of all those cognitive and metacognitive abilities that are useful to optimise a wide range of processes of thought and of knowledge building/management and of identity and its social representations. The necessary reflection here is that, if environmental education was a theme or a concern from 90's to recent years, nowadays it is becoming a part of educational shifting, because diversity is no more an unusual situation, but rather the rule of social postmodern condition.

The above depicted scenery, aims to generate dialogue spaces through teaching and learning; an enlarged cultural environment to learn, which superates the environmental vision of education in the sense of separated diverse entities interacting, favouring a vision of diversities creating new cultures of learning. Taking into account this concept, there are specific areas of impact that are to be achieved, through a complex engine of developing, training and experimentation: (a) Use of knowledge as a base for a process of deconstruction of symbols, representations and prejudices enclosed within the idea the teacher select and introduce to the class; (b) The dialogue, as process of participation and social construction of new learning cultures, as activity of meaning making; c) the awareness of diverse positions within these symbolic constructions, against social and cultural exclusion; and d) the impact on identities. Therefore, symbols and metaphors introduced by new knowledge within symbolic universe of learners stimulate and support processes of expansion of cultural context of reference, creating the bases of sensibility to future diversity and tolerance. According to cognitive approach metaphors stimulate "parallel mapping" among emotional and cognitive structures. But the use of a metaphor is in great degree linked to the cultural context where learners live. Therefore, a guided educational process should focus this spontaneous cognitive process, leading to new cultural *contextualization*; we would say that learning resources and activities that allow participatory deconstruction of cultural icons and beliefs, introducing new images, representations and practices will support metaphors of new "possible worlds". Moreover, the process of negotiating a new context through teachers and learners' personal positioning (through expert knowledge, specific productions, narratives), is what makes visible the enlargement of cultural context. This new context can be considered inclusive, since it allows participation not only from the point of view of activity (as is supposed to be in socio-constructivist approach) but mainly from the point of view acceptation of "diverse" scientific and cultural representations of the pollution (as symbols, images, practices) into a new synthesis. The several inputs introduced by the teacher in class (from the particular disciplinary perspective) can generate, several ways of access to dominant and "other" cultural imaginaries; in fact, as specific scientific "narrative", they introduce many cultural symbols through the metaphors that key concepts enact. When deconstructed through discussions and activities in class, they stimulate that essential human activity that Bruner (1996) called the "research of meaning", a psychological activity that help the human being to find reasons to live, to go through conflict and to solve the cognitive and emotional tensions of problems of every kind. Knowledge should, in this perspective, take the learner from a self/ethno-centered vision of the world, to a social/ethnorelative one, which implies tolerance, ability of understanding diversity, and curiosity about it. Moreover, it should make possible to cultivate the necessary skills that put the individual in the positive condition of negotiating his/her own interests towards common, participatory approach of research activity being in any case aware of the own unique identity.

Analytical procedure

The IDPA project was conducted between the years 2007 to2009. The teaching activities examined the exposure of teenagers (14-18 years) to particulate matter with an aerodynamic diameter below 10 µm (PM_{10}). The researchers and students discussed of possible indoor and outdoor sources, and the potential effect of ventilation.

IDPA researchers used participatory strategies in working with teachers and staff in the schools to provide information and to facilitate essential elements to the project. Early in the implementation process, each school selected a group pattern of about 25 students identified by the teachers as the most motivated students who were the strongest supporters of the intervention effort. The student groups, in coordination with the IDPA researchers, actively worked to involve school administrators, teachers and students in other classes and institutes.

The schools involved in the project were: Liceo Scientifico “Da Vinci” in Treviso, Liceo Scientifico “Fracastoro” in Verona and I.T.I.S. “Levi” in Mirano (near Venice). These are three secondary schools in the north-eastern Italian region of Veneto and they represent three locations with three different urban environmental characteristics.

Measurements were performed for periods of about 15 days in the first months of the years 2008 and 2009 with the aim of studying different environments. Study areas included schoolrooms, on the floor of the institutes, and outside in the gardens of schools or in traffic zone near the institute.

The mass concentration of PM_{10} was continuously quantified by DustTrack® (TSI Instruments) and the concentration of 15 PAHs (Acenaphthene, Acenaphtylene, Fluoranthene, Phenantrene, Anthracene, Fluorene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)Fluorathene, Benzo(a)pyrene, Dibenz(a,h)anthracene, Benzo(g,h,i) perylene and Indeno(1,2,3 c-d)pyrene) in operationally defined particulate and gas atmospheric phases was collected on quartz fiber filters (QFF; size 102 mm, SKC, Eighty Four, PA) and polyurethane foam plugs (PUF; height 75 mm, diameter 65 mm, SKC) using high volume samplers (Tish Environmental Inc., Village of Cleves, OH) by students utilizing the procedures reported by Gambaro et al. (2009).

RESULTS

The initial project phases were achieved in all of the schools involved in the project. In fact, the sampling, experiments, and conferences involved not only the previously mentioned student groups but many other students of the institutes even though they were not directly involved in the project.

The acquired PM_{10} data in each school were analyzed and discussed with the students in term of temporal trends and comparison with normalized values for different environments. We can observe similar temporal trends in the three institutes for the PM_{10} concentrations registered during 24 hours inside the classroom. Figure 1 depicts the temporal evolution of PM_{10} normalized concentration in a classroom of Liceo Scientifico G. Galilei from Treviso during a week of observations.

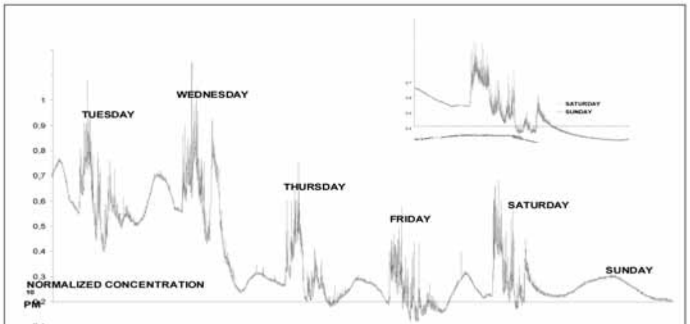

Fig. 1. PM_{10} normalized concentration trend in a Treviso school classroom during 1-6/04/2008 period.

In general we can observe a background trend with higher values during the night and lower concentrations in the morning during the week from Tuesday to Saturday and a lower Sunday concentration. These differences are probably due to humidity variations that are especially evident during Tuesday and Wednesday with a superimposed high-frequency series of short peaks linked to student activities. The most evident peaks are registered during first hours of the morning after the students have arrived at school and between 13:00 and 14:00 when the lessons finished. Conversely, on Sunday the concentration was lower and quite constant in absence of school activities.

Particularly interesting has been the link between the presence of PM_{10} peak with specific school activities identified by students such as blackboard cleaning, the perturbation before an exam, the lesson breaks, and schoolroom cleaning.

Figure 2 show the daily averages of PM_{10} normalized concentrations measured by students for two weeks inside a Verona Institute classroom and an outside neighboring location measured by the Veneto Environmental Protection Agency (A.R.P.A.V.). The two trends show similarities but sometimes the PM_{10} indoor relative concentrations are higher, which is probably due to the input of external and internal sources.

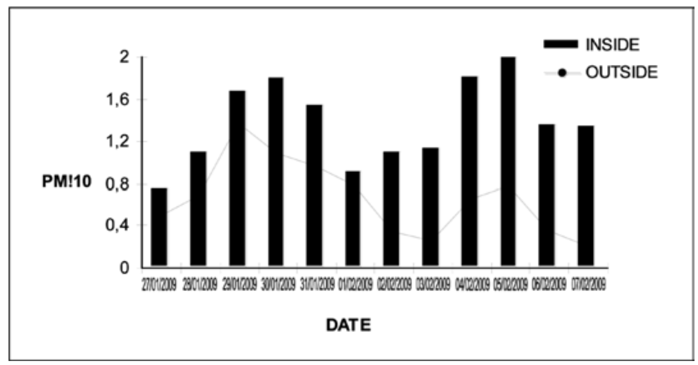

Fig. 2. Daily averages of PM_{10} normalized concentrations registered in Verona inside and outside the classroom between 27/01 to 07/02/2009

In Mirano, the aerosol concentrations were measured on the school roof and in a house garden in a well-travelled zone near the school. In this case the difference between the two environments was evident and clearly showed the daily PM_{10} concentration was lower in the first site (Figure 3).

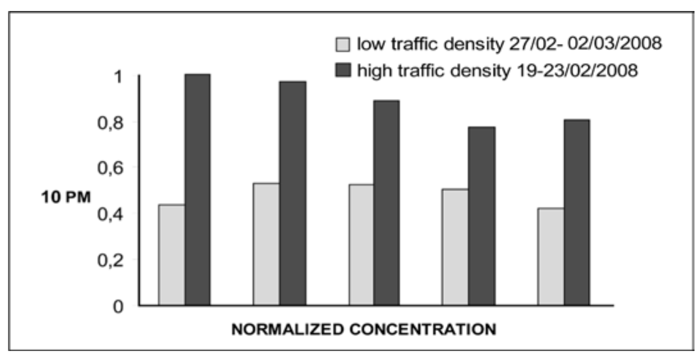

Fig. 3. Daily average trends of PM_{10} normalized concentration in two different locations.

PAHs samplers were placed on the outside of the schools with the aim of detecting the air concentrations and eventually detecting their origin by investigating the ratios of different congener compounds. Our results provide evidence that the sources were principally pyrolytic and that the Benzo(a) pyrene concentration, generally used like an indicator of air quality, did not exceed the 1 ng/m^3 limit required by Italian law (D.Lgs. 152/07).

Workshop

Students presented the analysis and results obtained in the study in a precise, scientific and convincing way at the workshop organized at the end of the project (Fig 4), which involved the participation of the Italian atmospheric aerosol experts and students from diverse institutes. In particular after the salutes of academic and didactic authority (Rector and director of MIUR) the students of Liceo Da Vinci have introduced the aerosol concept and the aims of the project.

Dr. F Belosi (ISAC-CNR) and Prof. A Gambaro (IDPA-CNR) discussed new atmospheric research on aerosol, while Ing. S. Boato (A.R.P.A.V.)

and Dr. C. Carraro (R&C Scientifica) exposed their views on atmospheric pollutants controlled by authority and private laboratories. Finally the I.T.I.S. "Levi" and Liceo Scientifico "Da Vinci" students reported the results and project conclusion.

Fig. 4. Announcement of the final project workshop

This event was attended by approximately 200 students and captured the attention of other school classes and teachers who have expressed the intention to repeat the project and to deepen the discussed main theme.

DISCUSSION

Pedagogical aspect

We can reflect about results of experimentation in term of impacts on curriculum development.

Level 1: Attitude, disposition to environmental education trough cultural diversity.

- Cognitive attitude/abilities (subject awareness, environmental readiness/ comprehension of pollution situations).
- Intra-cognitive level: Acquiring new knowledge of one's own culture. Acquiring new knowledge and awareness of the subject culture and, consequently, encouraging the reflection about one's own approach.
- Environmental understanding of the reality: knowledge of otherness, heuristic approaches to languages and analisis, awareness of the environmental context.

Level 2: Discovery of diversity and modulation of inputs.

Emotional attitudes/awareness and behaviour. Cross-cultural/emotional (affective) level: environmental knowledge, reflection on one's perspective, communication between different approaches (source and target) ability to challenge and question one's own conceptual models, tolerance for ambiguity.

Level 3: Transfer of environmental awareness to life.

Dynamic intermodal communication and acting. Dynamic level: Response to on one's own anthropological/cultural experiences, dynamics (action) in cross-cultural referencing, ability to modify one's own beliefs, positive attitudes and standpoints related to target pollution approaches.

The proposed methodology is supposed to enable the portfolio user to gain a deeper insight into his/her scientific and environmental experience. By writing down and analysing his/her findings, the user will start to develop his/ her environmental sensibility and awareness, which is, needless to say, a life-long process. Metacognitions and meta-learning, in the sense of awareness of the own cognitive and emotional processes here seems to play an important part as individual strategies that promote a kind of approach to environmental dialogue and interaction contact where understanding and empathy have place.

CONCLUSIONS

The educational approach detailed in this paper focused on providing activities for students that encouraged active participation in understanding the importance of atmospheric pollution studies with particular attention to fine particles and their impact to human health. Classroom activities, and implementing training-through-research activities extended the research purpose.

More research is needed towards understanding how to use diverse processes to learn environmental competence. The role of learning is important both because uses processes within an environmental orientation and because it provides valuable information about students' actual learning. The process of learning depends on who the learners are and their understanding of what it is that is important to learn. The challenge is to expand the repertoire of learning to accommodate a more complex view of processes that includes the development of environmental competence. Grounded research with teachers and lecturers, as in the reported studies in progress, begins to provide a detail picture of the nature of this environmental competence. It generates ways of of understanding and evidencing learning, while referring back to intimate relationship between process, culture and meaning, which are the core work of teaching process.

The development of mutual respect, trust and clear expectations by teachers and researchers created a partnership which resulted in a cohesive, integrative approach to promoting environmental and scientific education in the schools. We paid particular attention was paid to include the students in the sampling activity and in the analysis carried out at IDPA laboratories. This attention increases secondary school students' interest in university and research environments. The active participation of students in the research project, the continued relationship between students, researchers and teachers in the interpretation of data, and the exposition of results represent important results of this study. This participation included the workshop organized at the end of the project where the students presented the analysis and results obtained in the study in a precise, scientific and convincing way. The success of the workshop and the study is represented by the evident interest of the other students in the scientific concepts illustrated by their contemporaries manifested by the request for deepening the project activity.

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Painting a brighter picture: using art to enhance the learning of chemistry

Pintando un cuadro más atractivo: el uso del arte para facilitar el aprendizaje de la química

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Abstract

This study explored the findings of a pilot study of a Chemistry and Art club run for 11-13 year olds. Analysis of field notes and a student-generated video indicated a high level of enthusiasm for this interdisciplinary approach to the learning of Chemistry. It was noted that students were more able, and more confident, after the four sessions; these benefits corroborate the findings of a limited number of earlier studies in this area. The impact on teachers in the participating school was positive, but their colleagues expressed concern regarding a wider implementation of the scheme.

Key Words: *art, chemistry, cross-curricular, applied learning*

Resumen

Esta investigación exploró los descubrimientos de un estudio piloto de un Club de Química y Arte diseñado para jóvenes de 11 a 13 años. A través del análisis de las notas de campo y un video producido por los estudiantes, se ha determinado un alto nivel de entusiasmo por esta manera interdisciplinaria de aprender Química. Se identificó que los estudiantes se sentían más seguros de su capacidad, después de las cuatro sesiones; estos beneficios confirman los descubrimientos de un número limitado de estudios anteriores en esta área. El impacto de este enfoque para los profesores de la escuela participante fue positivo, pero algunos de sus colegas expresaron preocupación acerca de la implementación general de este esquema.

Palabras clave: *arte, química, materias que se comparten, aprendizaje aplicado*

INTRODUCTION

Chemistry versus Art or Chemistry harnesses Art?

Many teachers of Chemistry are familiar with the problem of low levels of interest and engagement with the subject. The same students commonly rate creative subjects highly. Other recent authors have identified the common culture of Science pedagogy, with its very positivist treatment of Science, as a contributory factor (Cachapuz and Ferreira, 2010). The focus on well-established material often denies students insight into the tentative and fluid nature of scientific enquiry. Learners are left feeling that they have nothing of originality to offer but must, instead, follow well-trodden paths and recall someone else's journey accurately. (Lee and Erdogan, 2007; Murray and Reiss, 2005). This intellectual disengagement then leaves the student with little motivation to tackle to difficulties inherent in the subject, such as those imposed by the three levels of representation (macroscopic, sub-microscopic and symbolic) first described by Johnstone (1991). School Art lessons, on the other hand, offer many alternative means of representation and every student has opportunities to create a unique interpretation, which has meaning to them and is valued within the discipline. This is often motivating and may also be associated with positive social and academic development by students (Deasy, 2002).

The situation described suggests that an interdisciplinary approach could benefit students. There certainly are historical precedents for chemists and artists working together, such as was exhibited by the eminent chemist Sir Humhry Davy's, publication on the ancient pigments of Rome and Pompeii. And as recently as 2001 the American Chemical Society took 'Chemistry and Art' as its theme for National Chemistry Week. Nevertheless, the dichotomy described in Snow's (1959) book, 'The two cultures and Scientific Revolutions', continues to operate in U.K. secondary schools, where the two subjects are generally viewed in school as being entirely distinct.

A partial answer may reside in Snow's second edition (1963) which included an essay on a third, mediating, culture in which non-scientists bridge the gap between the scientists and humanists. Interdisciplinary working between Science and Art teachers has previously been highlighted as a fruitful area for teachers to explore and there is an abundance of practical suggestions on possible approaches(Cachapuz, 2010; Cachapuzz and Ferreira, 2010; Hohn and Harsch, 2009; Furlan, Kitson and Andes, 2007; Greenberg, 1998) The research described here assessed the scope for Chemistry and Art teachers to work together in an interdisciplinary way that would benefit students in both their art and chemistry studies.

METHODOLOGY

The researcher was undertaking a one year teacher training course and was working in her second placement school. The work was undertaken as a piece of process evaluation action research (Livesay, 2002; Rappoport, 1970), stemming as it did from the trainee's concern about de-motivated students. Her proposed solution, formulated in collaboration with a trainee art teacher, was to offer four voluntary one hour sessions, summarised in Table 1, which were billed as 'an Art club with a difference'. These two trainees jointly undertook the role of problem solvers, and undertook joint teaching and evaluation of the activity.

Questionnaires were administered before the start of the club and again after the sessions were completed; data from questionnaires was augmented by interviewing four of the students. In addition, the two trainees made field notes during the sessions, transcribing student comments and actions. At the end of the series of sessions, the students were asked to make a video to explain what had happened about the club, and this captures free responses about the impact of the intervention. The administration and collation of all findings were compliant with ethical guidelines and all those whose comments are used were willing volunteers (British Educational Research Association, 2004).

The sample size was small, with a total of 10 students attending and completing questionnaires. Whilst the sample size limits the usefulness of the quantitative data generated, it also furnished the opportunity to gather rich qualitative data, predominantly comments made during the sessions. These comments were subjected to thematic coding (Alexiadou, 2001) in order to identify the major themes embodied in student comments.

RESULTS, DISCUSSION

Art improved students' perceptions of Chemistry

There was a change in attitude towards chemistry as a subject. At the start of the sessions students were asked to rank their school subjects in order of preference. Chemistry appeared as one of the bottom three positions at the start of the intervention but, by the end, was in 9 out of 10 students' top three subjects. Their experiences seem to have convinced them of the value of the subject, with two commenting that,

"To be a really good artist you do need to know about chemistry!"

"I think chemistry is good. It makes you think about things, like in art"

Their realisation that Chemistry could support other curriculum areas was not confined to Art. Students reported feeling that Chemistry was more useful now they had seen some of the ways it is linked to other aspects of their life. After taking part in the club, students independently identified a central role for Chemistry in in cooking, specifically in understanding the role of the ingredients and the reactions that take place during cooking, and also identified how chemical concepts being helpful in understanding the properties of materials as would be needed in Design Technology and Physical Education. Their increased awareness of the scope of Chemistry also enabled participants to identify suitable areas for future exploration in the club, including the different properties and chemistry of modelling materials, making pictures with iron filings using magnets, a comparison of different dyes and textiles, the connection between properties and uses of textiles, including how properties were incorporated into clothes design and the Chemistry of pottery glazes. However, these findings suggest that at present the way in which this age of students learns Chemistry does not persuade all of them of its value. This is a shame when our interview data corroborates previous findings (Bennett and Lubben, 2006) indicating that Chemistry taught in a meaningful context is less off-putting for the learners.

Table 1, a summary of the four taught sessions

Topic	Art activities	Science activities	Scientific concepts
Graphite and charcoal	Looking at the effects of pencils containing different proportions of graphite, compared to the effect of charcoal on drawing pictures	Making graphite circuits Making charcoal	Graphite's many uses including fuel, electrical conductor and adsorbent; reduction of wood through chemical change; the layered nature of graphite.
Inks	Mixing inks on pictures	Chromatography of ink	The different solubility of dyes in water and oil
Wax resist	Making lava lamps and wax resist paintings	Solubility and miscibility	
Breaking down materials	Noting the appearance of materials as they are broken into smaller pieces		Structure of different materials linked to their properties and uses.

Participation appears to have boosted self-confidence, which might reasonably be expected to improve their participation in both Art and Chemistry classes.

"I never thought I could make my own art equipment!"

"I didn't even know what chemistry was, but I'm doing work that year 10s (i.e. students two years senior) do now".

Whilst this might be a consequence of high levels of teacher attention, or teacher expectancy (Jacobson and Rosenthal, 1992) rather than any specific aspect of the activities, it is doubtless a positive outcome of the intervention. Expressions of this enhanced self-esteem suggest that the existing classroom activities may not succeed in giving students sufficient experiences of success. The growth in confidence expressed in post-intervention interviews was associated with a higher self-reported level of involvement in Science lessons and a greater willingness to try activities in class. This attitude was exemplified by comments such as,

"I want to carry on with this I'm actually enjoying science a bit more now"

"I like the fact that we don't have to have an end to it, just trying it out to see what happens".

"Why can't we do more things like this in science?"

Art gave students a tangible experience of abstract concepts

The difficulties inherent in Chemistry which are due to the abstract nature of the models are well-recognised (Johnstone, 1991).The combination of a limited number of abstract ideas concurrent with a relevant concrete experience seems to have been effective at securing students' understanding of the chemical concepts. Although it is common to attempt to give illustrative experiences whilst teaching, the club seems to have been especially successful. Allowing for the fact that students were self-selected the data is nevertheless very positive. It is possible that the limited number of concepts, coupled with a significant time spent on practical experience helped increase students' assimilation of concepts. This gain in understanding was observed in all four activities (figures 1-3).

For example, when students used their fingers to smudge the graphite, they related this to the fact that graphite is made up of strongly bonded layers,

"I can actually see the bonded layers being applied to the paper"

"The graphite is making up layers on the paper and you can keep adding to the layers to get a darker shade"

After this discussion, students were able to make a scientific sketch of the layers of graphite and explain what was happening when these were applied to the paper.

Similarly, during the wax resist activity, students were able to make detailed observations of water based paint running over and off the wax and describe how water 'stuck to water' and 'wax to wax', which culminated in the use of the terms hydrophobic and hydrophilic. They also commented on how easy it was to melt wax and how quickly it solidified on the paper, which led to ideas about using melted wax to paint with and the limitations and benefits. The students demonstrated that they were starting to relate the properties of materials to uses in art in a more global way, illustrated by a student saying,

"*I understand what it means now if you talk about the 'properties' of a material"*

The work with the digital microscope provided an opportunity to consider what materials are made of, which might be considered one of the ultimate questions of Chemistry. Students were gaining an appreciation of chemistry through developing an understanding of how a seemingly solid single object can be broken down into component parts. Students were fascinated with the way textiles are made up and particularly the components of gem stones and rocks, which were discussed during the science part of the activity. It is easy to see how the shift in their understanding illustrated by the comments below would pave the way for a consideration of the atomic theory of material,

"*It just looks one colour, but it's full of different grains"*

*"The coloured parts of the rock show us different chemicals***"**

At the conclusion of the four sessions, 7 of the 10 participants said they felt that they understood Science better than they had at the outset.

Art activities stimulated scientific discussion

The activities appeared to stimulate meaningful discussion of the basis of the properties of the art materials. One difference between the club and the use of materials as a stimulus in a Science lesson may have been the less closed format offered by the club. Whilst the trainee Science teacher was able to moderate discussions to ensure that valid models and concepts were deployed, she was not perceived as working towards a clear learning outcome; this encouraged students to engage in more exploratory talk (Barnes, 1976). Moreover, the activities were open to modification in response to student demand. For example, when the students looked at the chromatography results they attempted to explain how the inks were wicked up the paper. They then discussed the implications for this in terms of their artwork, the different types of paper that are suitable for ink drawings and how the colours blend together. They compared the paper used for chromatography and the paper used for their artwork and, as a result of their discussion, decided to experiment with different types of paper. The trial with different papers had not been planned by the teacher, but came about due to the students' interest. Similarly, whilst making charcoal conversations took place regarding the desirable properties of charcoal in relation to its use in art and the effect that differing amounts of clay hardener have on the properties of a pencil. The conversation was relaxed and relatively unstructured, switching between the properties of charcoal and what happened when creating different artistic effects using the graphite.

However, the conversation was far from aimless. After an unsuccessful attempt to make charcoal by simply burning wood, they were able to describe the differences in the properties of burnt wood and artist's charcoal. This then prompted them to research the conditions necessary to produce charcoal and why this made a difference to its properties. Field notes show that the session on wax resist pictures resulted in students deciding to conduct a series of investigations into the effect of different thicknesses of wax and different quantities of paint on the final picture. The gain in scientific thinking was summed up by one student as,

"I would just draw, I never really thought about the materials I was using, but now I do and I ask more questions to find out what will work the best."

An associated shift, and one which received positive comment from other science teachers, during the course of the activities was an increasing confidence in using technical terms to talk about the materials, such as,

"I can see the paint rolling off the wax, because it is hydrophobic"

The Chemistry and Art club benefitted the participating teachers

The initiative was felt to have been of mutual benefit to both the participating teachers. Both were able to identify a number of shared approaches to some aspects of their subject and its pedagogy, in the light of which both subsequently revised aspects of their classroom practice.

Fig. 1. Using graphite to produce art work. The use of graphite in art was discussed and linked with its chemical properties

Fig. 2. This shows the first attempt to make charcoal. Students then conducted internet research to identify that the wood needed to burn more slowly with reduced oxygen present to improve the quality of the charcoal. They then conducted a similar experiment, but with the wood covered in a layer of sand.

Fig. 3. Graphite used in the original artwork above was used to complete a simple circuit. Students discussed how the chemical structure of graphite enabled it to conduct electricity and looked at various uses for graphite other than as a medium for creating art.

The Science teacher said that she had found confidence to extend her presentation of Science and to actively challenge stereotypes about scientists that she encountered. She also began to look for opportunities in lessons to portray the creativity of Science. The Art teacher started to use some of the approaches to material that had been trialled at the club, and borrowed Science equipment to do this. Thus a higher level of collaboration took place between an extended group of colleagues. Both staff identified similarities and common ground based on art and chemistry both being practical subjects. However, both participants expressed concern for the sustainability of this type of initiative because of the time demands that the planning stage had created.

Other Science teachers were positive about the enthusiasm for Science, and scientific knowledge, that the club had engendered. Nevertheless, reservations were expressed about devoting time to activities which were not **seen** as directly underpinning exam performance were expressed as well as concerns about working in an area in which they lacked expertise. It is interesting to note that teachers did not generally perceive the work as having direct connections with the curriculum, despite the important concepts that were developed, as described above.

CONCLUSIONS

Focusing on cross-curricular aspects of Chemistry improved students' recognition of the subject's scope and the value of the knowledge provided by the study of Chemistry. Students showed an improvement in their ability to apply their learning, and a greater engagement with the science, outcomes which are in keeping with current educational initiatives in the U.K. Although the approach was demanding of staff time at the planning stage, the positive shift in both students' attitudes and knowledge indicated that the investment of time was justified. The longer term outcome of interdisciplinary working could not be ascertained by this small scale pilot study. The participating teachers felt that the activities gave them worthwhile professional development. Despite this, the response of other teachers to the initiative suggests that, in a content-driven assessment framework, the affective and cognitive gains observed are not viewed as sufficient justification for expending time and effort ON SUCH ENRICHMENT ACTIVITIES.

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Factors influencing student success and failure in introductory chemistry laboratory courses

Factores que influencian el éxito y el fracaso del estudiante en cursos introductorios de laboratorio de química

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Abstract

The goal of this study was to identify the specific factors considered to have important influences on student success and failure in the introductory chemistry laboratory (ICL) courses. The study was conducted in two stages involving open-ended and Likert-type scales. Research data revealed that there were substantial similarities as well as differences between both groups in terms of their perceptions about factors influencing student success and failure. For instance, "lack of interest" was found to be the most likely factor that attribute to failure by both groups. The factor "a well-designed laboratory environment" by the teaching assistants (TAs) and "reading manual before entering the laboratory" by students were found to be the most influential factors that contributed to success. This paper also discusses results of the scales and possible implications for student success in ICL courses.

Key words: *laboratory instruction, introductory chemistry, student success, student and teaching assistant perceptions*

Resumen

La meta de este estudio era identificar los factores específicos considerados materias influyentes importantes en el éxito y el fracaso del estudiante, en los cursos introductorios de laboratorio de química (ICL). El estudio fue conducido en dos partes de etapas ampliables y Likert-tipo escalas. Los datos de la investigación revelaron que había semejanzas sustanciales, así como diferencias entre los grupos en términos de sus opiniones sobre los factores que influenciaban éxito y el fracaso del estudiante. Por ejemplo, se vio que la "carencia de interés" es la causa más probable del fracaso en ambos grupos. El factor de "un ambiente de laboratorio bien diseñado" por los ayudantes de enseñanza (TAs) y "la lectura del manual por los estudiantes antes de entrar en el laboratorio", fueron descubiertos como factores más influyentes que contribuyeron al éxito. Este papel también discute los resultados de las escalas y las implicaciones posibles para el éxito del estudiante en cursos del ICL.

Palabras clave: *Instrucción de laboratorio, opiniones introductorias del curso de laboratorio de química, el éxito del estudiante, el estudiante y el ayudante de enseñanza.*

INTRODUCTION

Laboratory instruction has been given a central role in science programs and curriculum of most schools (Wilkenson & Ward, 1997; Hofstein & Lunetta, 2004; Henderson, Fisher & Fraser, 2000). Science educators have recommended that many profits gather from attributing students in science laboratory exercises (Garnett & Hacking, 1995; Hodson, 1990; Lazarowitz & Tamir, 1994; Tobin, 1990; Barrier, 2005). Many studies have examined different aspects of student learning in the laboratory (Arons, 1993; Herrington & Nakhleh, 2003; Kapuecinski, 1981; Novak, 1988; Domin, 2007). There are many other reports and reviews that investigate the role of laboratory in the way of allowing the acquirement of cognitive, affective, and practical goals (Blosser, 1983; Bryce & Robertson, 1985; Hodson, 1990; Hofstein & Lunetta, 2004; Lazarowitz & Tamir, 1994).

Numerous studies have reported that students enjoy laboratory work and that laboratory experiences have resulted in positive and improved student attitudes and achievement in science (Freedman, 1997; Freedman, 2002; Hofstein & Lunette, 2004). However, some scholars have criticized laboratory work by claiming that it is unproductive and confusing when it is used without any clearly thought-out purpose (Hodson, 1990; Tobin, 1990; Domin, 1999; Hofstein & Lunette 2004). Hodson (1990), for instance, suggests that more attention should be paid to what students are actually doing in the laboratory. In a similar vein, Tobin (1990) states that effective learning can accrue in the laboratory if students are given possibilities to manipulate the equipment and supplies so that they can develop an understanding of scientific concepts and phenomena.

Laboratory instruction is an essential part of learning chemistry from the high school through the graduate programs (Sheppard & Horowitz, 2006; Elliott, Stewart & Lagowski, 2008). It helps students to comprehend concepts and to develop skills to a degree that cannot be accomplished by lecture alone (Abraham et al., 1997). Introductory Chemistry Laboratory (ICL), surely, has a considerable effect on student success as an effective tool for learning chemistry concepts (Rund, Keller & Brown, 1989; Johnstone, et al., 1994, 1998). Although the ICL has been taken seriously in science education, we still need some quantitative investigations that clearly demonstrate the connection between student experiences in the ICL and their acquisition of knowledge. The ICL courses are mostly conducted in the traditional laboratory style and in places where hundreds of students must share the laboratory facilities every week. In recent years there has been renewed interest in renewing general chemistry courses in colleges and universities (Talanquer & Pollard, 2010). Much of this interest has focused on the laboratory. Curriculum and instructional strategies used in the laboratory will potentially change over the next few years; it would be useful to learn where we stand now and what students are doing in the laboratory. Thus, it is very important that the specific factors that influence student success and failure in these courses are identified and interpreted. In addition, we believed that this research is an important first step in addressing more long-term goals and developing more effective programs for these courses.

The goal of this study was to identify the specific factors that are seen to have an important influence on student success and failure in ICL courses by using the perceptions of both students and Teaching Assistants (TAs). Consistent with the main goal of this study, the following sub-research questions were also addressed:

- Is there any significant difference between student and TA perceptions of student success and failure?
- Is there a gender difference in student perceptions of their success and failure?
- Is there a performance difference in student perceptions of their success and failure?

METHODOLOGY

In research design, both of the qualitative and quantitative methods will be used. In data collection both qualitative and quantitative data collection vehicles will be utilized.

1. Sample

The participants of the main study consisted of 183 science and engineering students (117 males and 66 females) who were enrolled in an ICL course and 12 TAs (all males) responsible for the laboratory courses at different faculties in a state university, in Turkey.

1. Instrument

Data collection instruments were formed in two stages involving exploratory open-ended and Likert-type questionnaires.

Stage one: To identify factors that have an important influence on student success and failure, 45 students from a range of ICL courses and 8 teaching assistants (TAs) experienced in ICL courses were asked to complete a questionnaire composed of two open ended-questions: "Please list five factors that you think are most important in contributing to student success in ICL courses" and "Please list five factors that you think are most important in contributing to student failure in ICL courses".

Stage two: In order to further investigate the feedback collected in the first stage, the factors identified as important for success and failure by students and TAs were used to create two parallel scales (one for the student success and one for the student failure). The scales contained 20 items related to factors influencing student success and 19 items related to factors influencing student failure in ICL courses. The items were selected on the basis of frequencies from the first survey. The items were rated on a 5-point Likert-type scale ranging from "very important" (5) to "not important at all" (1).

Procedure

A pilot study was conducted to calculate the validity and reliability of the scales using a group of 50 students who had enrolled in an ICL course for science and engineering. The evidence of construct validities of scales was calculated with "item-total score" correlation using the Pearson's correlation coefficient (r). Four items out of 20 were described as marginally appropriate ($0.20 < r < 0.29$); six as appropriate ($0.30 < r < 0.39$) and ten as quite appropriate ($0.40 < r$) in factors influencing student success. Six items out of 19 were described as marginally appropriate ($0.20 < r < 0.29$); five as appropriate ($0.30 < r < 0.39$) and eight as quite appropriate ($0.40 < r$) in factors influencing student failure. These results indicated that all items contributed to the validity of the scales. The reliabilities of the scales were calculated by two different techniques: (a) split-half reliability and (b) reliability of "internal consistency". The results, listed in Table 1, showed that the scales have a satisfactory and acceptable reliability.

Table 1

Calculations of reliability from the pilot study data

	Scale for student success	Scale for student failure
Split-half reliability		
Correlation between forms	0.84	0.84
Gutman split-half	0.86	0.82
Reliability of internal consistency		
Cronbach's alpha	0.89	0.86

RESULTS

Statistical analysis of data involved comparison of student/TA responses, ranking analysis, split-half reliability, reliability of internal consistency and construct analysis.

Factors Influencing Success

Data analysis was used to determine whether there were some statistically significant ($p<.05$) differences between student and TA scores for each item. An analysis of scores and respective ranking of success items is presented in Table 2. In general, ranking agreement between students and TAs was high ($p<.05$). As can be seen from Table 3, the responses to only four items were significantly different at the level of 5% ($p<.05$). Students placed more emphasis than TAs on factors "a well-designed laboratory environment", "pre-laboratory exercises that are depend on the experiment and the student background knowledge" and "the student is paying active attention in laboratory exercise". In contrast, TAs gave significantly more support for "experiments related to daily life".

Factors Influencing Failure

Overall, there was general accord between students and TAs' scores displayed in Table 3. Only six items showed a significant difference at the 5% level ($p<.05$). Students placed significantly more importance on all of these items, than did TAs. These items were: "lack of laboratory equipment and supplies", "insufficiently designed laboratory environment", "worrying about being unable to complete experiments ", "the student isn't paying active attention in laboratory exercise", "inadequate background knowledge of chemistry", and "inappropriate use of significant digits".

Table 2

Factors influencing student success

Scale items	Mean Student	Mean TAs	*p*	Rank Student	Rank TAs
A well-designed laboratory environment	4.74	4.00	.001	1	14
Opportunities to manipulate laboratory equipments and supplies	4.68	4.66		2	4
Interest in the laboratory exercise	4.59	4.33		3	9
Individual completion of each experiment by each student	4.47	4.66		4	3
A helpful relationship between student and TA	4.47	4.33		5	11
Pre-laboratory exercises that are depend on the experiment and the student background knowledge	4.44	2.33	.000	6	20
Feedback on laboratory reports that is helpful	4.41	4.66		7	6
Reading the manual before entering the laboratory	4.40	5.00		8	1
A TA who thoroughly understands the laboratory exercise	4.40	4.00		9	11
Appropriate experiments for students' level	4.36	4.66		10	5
The student is paying active attention in laboratory exercise	4.36	3.66	.019	11	16
Self motivation	4.34	4.33		12	8
A TA who motivates students to do their best in the laboratory	4.19	4.40		13	7
Suitable study environment outside of the laboratory	4.14	3.66		14	17
Good dialog between group members	4.12	4.33		15	11
Parallelism between the contents of laboratory exercises and the chemistry lecture	4.12	3.66		16	18
A TA who has a warm and friendly character	4.11	4.00		17	12
Laboratory report for each experiment	3.96	3.66		18	15
Experiments related to daily life	3.95	5.00	.018	19	2
Opportunity of repeating an experiment	3.71	3.33		20	19

Table 3

Factors influencing student failure

Scale items	Mean Student	Mean TAs	*p*	Rank Student	Rank TAs
Lack of interest	4.46	4.66		1	1
Lack of laboratory equipments and supplies	4.41	3.33	.01	2	11
Insufficiently designed laboratory environment	4.33	3.66	.04	3	5
Lack of relationship between student and TA	4.33	4.33		4	3
Insufficient knowledge of chemical properties	4.31	3.66		5	6
Worrying about being unable to complete experiments	4.21	3.33	.03	6	12
The student is not paying actively attention in laboratory exercise	4.14	3.34	.03	7	10
Inadequate background knowledge of chemistry	4.13	3.33	.03	8	13
Lack of a clear purpose for the experiment	4.10	3.66		9	8
Not reading the manual before entering the laboratory	4.07	4.66		10	2
Lack of self motivation	4.01	3.33		11	14
A TA who does not thoroughly understand the laboratory exercise	4.00	4.00		12	4
Lack of intelligence	3.75	3.00		13	16
Lack of parallelism between contents of laboratory exercises and chemistry lecture	3.74	3.66		14	8
Being anxious about making mistake in performing experiment	3.35	3.03		15	15
Not enough time for the laboratory exercise	3.34	2.66		16	17
Group study	3.26	3.66		17	9
Insufficiently checked laboratory reports	3.17	2.66		18	18
Inappropriate use of significant digits	2.57	1.33	.04	19	19

"Lack of interest" was the item rated most likely to influence failure by both students and TAs. Both students and TAs ranked the items "insufficiently checked laboratory reports" and "inappropriate use of significant digits" as the least influential of the factors that contributed to failure.

Performance Comparisons

When comparing a student's perception of performance based on success (defined as receiving a passing grade) and failure (defined as receiving a failing grade) inconsistencies were observed. With respect to the "success scale", successful students placed more importance ($p<.05$) than TAs on "pre-laboratory exercises that are depend on the experiment and the student background knowledge", "a TA who thoroughly understands the laboratory exercise", and "the student is paying active attention in laboratory exercise", but less importance to "individual completion of each experiment by each students", and "experiments related to daily life".

In response to the "failure scale" successful students placed more importance ($p<.05$) than TAs on "the student is not paying active attention in laboratory exercise", and "lack of self motivation". However, the same students ranked "study in group" as a less important contributor to failure than did TAs.

Gender Comparisons

No statistically significant ($p<.05$) difference was noted in the students response, by gender, to the "failure" scale and only one difference was found in the response to the "success" scale. Female students placed more importance on the influence of "self motivation" as a reason for success.

DISCUSSION

There are items related to the student responsibility on learning in our scales, such as the student is paying active attention in laboratory exercise, TAs (responsible for running the laboratory in this study) placed significantly ($p<.05$) less importance on these items than did students, especially successful students. This means that TAs see their role as information providers, rather than providing opportunities for students to be actively engaged in laboratory exercise.

The impact of the laboratory in learning chemistry, especially during the first year, has traditionally been an important area of research (Tobin, 1990; DeCarlo & Rubba, 1994; Abraham, et al., 1999; Reid & Shah, 2007). Results from this study showed that meaningful learning is possible in the laboratory if the students are given opportunities to manipulate equipment and supplies in an environment suitable for them to construct their knowledge of phenomena and related scientific concepts. It is telling that students placed great importance than TAs on factors related to the laboratory environment, such as opportunities to manipulate laboratory equipment and supplies.

The results of our study showed that the items related to TA behaviour were ranked among the most important items (score 4 or upper) in both scales by both students and TAs. Both students and TAs responses indicate value in a TA who wants to help students, has a warm and friendly character, and has knowledge about the laboratory exercise and that these characteristics are important for student success in the ICL course. This indicates that maintaining good interpersonal relationships in the laboratory is being recognized as a factor that has an important influence on student success.

In the science education literature it has been reported that laboratory activity is a distinguished environment for improving attitudes, stimulating interest, and motivating students to learn science concepts and skills (Fraser, 1980; Okebukola, 1986; Freedman, 1997). In the scales used in this study there are items related to students' interest and motivation. The findings related to relevant items showed that although there is agreement in both group perceptions, the TAs assigned a lower score to these attributes than did students. The results revealed that both groups accept motivation and interest as very important factors for student success. These results are similar to what has been reported in the literature. Both groups rated "lack of interest" as the most important factor influential student failure: this confirms the contention that motivational factors are key to student success.

CONCLUSIONS

The present study provides two scales with a satisfactory degree of validity and reliability for assessing factors influencing student success and failure in ICL courses. The scales developed in this study can provide feedback for laboratory instructors to improve the effectiveness of their own teaching. That feedback, of course, could also be used to help students understand how they are progressing as learners in the laboratory courses. This study also brings together the voices of students and TAs. The comparison between student and TA perceptions provides a basis for further research into how perceptions are formed and which of the perceived influences have an effect on the learning and teaching approaches and the subsequent learning outcomes. In addition, the results of this study can provide a starting point for identifying effective ICL instruction.

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Using cartoon pictograms to engage undergraduates in health and safety

Uso de pictogramas animados para involucrar estudiantes en actividades de laboratorio saludables y seguras

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Abstract

The use of eSerialisation to encourage the engagement of undergraduates in acquiring a greater appreciation of health and safety issues has been investigated. In contrast to the single event induction lectures and e-learning systems, the work here describes an innovative method of dissemination which employed the repetitive delivery of an email cartoon-caption competition to refresh and reinforce the safe working practice message. The strategy marries the emerging literary format of flash fiction with modern communication to foster a synergy that captures the imagination of the students and markedly contrasts conventional essay / assignments / induction material. The efficacy of the approach has been critically assessed and found to possess the advantage of being in a format that is both accessible to the student body and which staff can readily deliver, by email, with minimal effort. The strategy is generic and could therefore be applied across the life, physical and engineering disciplines.

Key words*: cartoon pictograms, laboratory, activities, natural science, health, safety*

Resumen

Se ha investigado la serialización electrónica para fomentar la responsabilidad de los estudiantes de grado en temas de salud y seguridad. En contraste con clases introductorias impartidas en una sola sesión y sistemas de educación electrónica, el trabajo aquí descrito es un método de diseminación innovador para refrescar y reforzar el mensaje de la práctica segura de trabajo. Consiste en la entrega repetitiva por correo electrónico de un concurso donde los participantes han de pensar en una leyenda para la viñeta que se les envía. La estrategia incorpora el emergente formato literario de ficción flash con la comunicación moderna para crear una sinergia que despierta la imaginación de los estudiantes y contrasta claramente con los ensayos / trabajos de clase / materiales de introducción. La eficacia de este método ha sido evaluada críticamente y se ha llegado a la conclusión de que posee la ventaja de ser a la vez un formato accesible a los estudiantes y que el profesorado puede entregar fácilmente por correo electrónico con un mínimo esfuerzo. La estrategia es genérica y como consecuencia podría ser utilizado por las disciplinas de la física, biología e ingeniería.

Palabras clave: *pictogramas de dibujos animados, laboratorio, actividades, ciencias naturales, salud, seguridad*

INTRODUCTION

Health and Safety is a mandatory component of all science and engineering programmes and serve as an important introduction to the hazards that can be faced in the laboratory sessions (BSC,2010; HSE,2008; HSENI, 2002). There are, however, always some concerns over the extent to which the students engage with the material (Lehto, 1998; Janicak, 1996). It is likely that in most cases, that the preparatory induction lectures will be supplemented by informal explanations and cautionary statements strategically placed within the lab scripts such that particular hazards are identified and highlighted (Philips et al, 1999). There is always a worry however that the long term retention of the key messages that underpin safe practice is seldom achieved (HSE, 2008) and that the students, rather than being aware of the need for vigilance in the identification of hazards and subsequent management of risk, become reliant upon the demonstrators to simply highlight the issues (McDonald et al., 2009). The aim of this preliminary investigation has been to investigate a novel approach aimed at enhancing the engagement of the students with hazard appreciation.

Interactive methods designed to highlight the importance of the H&S message such as those based on web/Flash animation components or through WebCT based collections have become more available but the general approach has some critical limitations. Prime among those is the fact that they represent isolated events that, while initially interactive, are seldom retained or reinforced beyond the lecturer's instruction to view them. Our rationale has been to provide a mechanism through which the periodic release (eSerialisation) of the messages through email distribution throughout the year will continue to reinforce the core tenets of the safe practice ethos and allow some reflective learning that embeds the significance of being proactive in the adoption of safety procedures within the memory of the student. A key ingredient has been to induce a component of interactivity that stimulates a desire to actually read the messages upon receipt of the email and not treat it like a spam message (Yengin et al., 2010; Chen et al, 2010).

METHODOLOGY

Our approach was to rediscover and reintegrate the art of story telling as a means of conveying the significance of the health and safety message but in a way that would be easily digestible to the student and adapt its delivery such that it could be exploited as the basis of an interactive hook through which to capture the imagination of the student. Rather than have the lecturer provide the stories, our approach was to have the students construct them (Moon, 2010; Gillard, 1996). The strategy was to provide a cartoon illustration of a prehistoric scene that had some resonance with a particular health and safety hazard (trip, fire, manual handling, COSHH etc) which would then be delivered to the students through email and a competition instituted for them to provide a brief caption – the story – that underpins the safety message but in a humorous light. The mailshot would be distributed post induction lecture and it was envisaged that the former would provide the interactivity needed to encourage reflective learning of the lecture material with the competitive element enhancing the quality of the submission but also, importantly, the drive to examine future releases of the best/winning entries delivered through the email (Yengin et al., 2010; Chen et al, 2010). It was anticipated that eSerialisation through email would be more appropriate than a blog, as the latter requires the student to actually visit the site hosting it, whereas email is delivered direct and requires little more than opening the message. The sample audience were first year engineering students (Total N = 270).

RESULTS AND DISCUSSION

An example of the mailshot delivered to the students post induction lecture is detailed in **Figure 1**. A key feature of the setting is that while there can be a key theme – as set by the caption question – it still allows the more subtle embedding of health and safety messages within it and thus encourages subliminal uptake (Watanabe et al, 2001; Mayer et al., 1996; Mayer and Gallini, 1990). The email was tagged with delivery and read receipts in order to facilitate evaluation of the transfer and allow an estimate of the viewing figures. The number of read return replies and entries to the caption competition were then assessed. In general, the read return was 71% (based on a successful delivery notice of N = 270). Engagement of the students with the email message is clearly promising and can be attributed to: the competitive element, the humour and the fact that the work required to participate in the challenge is not too onerous. The caption embodies the spirit of nanofiction (limited to 69 words) and thus, in terms of student perception, is more easily accommodated within their time management plans than a traditional essay.

Evaluation of the approach was done qualitatively through follow up questionnaire designed to extract feedback on their attitude towards the mailshot, their desire/ability to participate and the benefits that they thought accrued from it. Assessing the long term assimilation of the health and safety message is beyond the scope of the present communication and would be the subject of follow-up investigations but it is clear that the eSerialisation represents a facile method for reinforcement of the core message which actively engages the student imagination (Chen et al. 2010) with over 90% accessing the email. Of the respondents to the questionnaire – over 96% found the cartoon to be informative supplement to the material presented in the lecture. The cartoons themselves can also be used in a lecture format and some example of the Powerpoint slides used to convey Health and Safety themes (i.e. eye protection etc) are highlighted in **Figure 2**.

Figure 1. Typical example of an email cartoon-caption competition highlighting the placement of embedded reminders.

Figure 2. A selection of the cartoons used to highlight different aspects and themes of Health and Safety within the laboratory.

The central theme in the strategy adopted at Ulster has been to exploit humour as a means of making the material more accessible to the students. Health and Safety procedures are, in contrast to the academic disciplines, the storyteller's ideal realm in that they contain all of the key ingredients (principally the presence of danger but with an added dusting of humour) necessary for the construction of stories that can capture the interest of the reader (Diekhof et al., 2011). In this case the context (prehistoric) has been selected but the variety of storyline is dependent only on the imagination of the teller and it is capable of being moulded in an inexhaustible number of ways that can serve to emphasize specifics or generalities and can be tailored to any context. Rather than presenting isolated data or facts – the combination of cartoon and nanofiction offers a means of delivering the theme in an entertaining, accessible and reflective style that is more amenable to being embedded within deep memory (Mayer et al., 1996; Mayer and Gallini, 1990; Shaffer, 1989). There is an additional advantage in that it can tap into the imagination (Shaffer, 1989, Roebers and Schneider, 2005) in a way that conventional lecture material often fails to achieve and facilitates learning of the bigger picture (or in our case the ethos/ process) and is much more effective than attempting to impart isolated facts about Health and Safety doctrine (Chen et al, 2010).

The exploitation of eSerialisation provides a drip feed throughout the year, thereby enabling a continual refresh of the memory (Shaffer, 1989; Watanabe et al., 2001). While email is increasingly used as the principal form of communication between faculty and student, it presents an ideal route through which to disseminate the cartoon-captions, it is important to consider the fact that delivery of the email however does not necessarily mean that it will be read (Chen et al., 2010). We are all adept at deleting mail perceived to be spam and of no interest to us but there is a safeguard. In the present case, the mail exploits the all too human traits of curiosity and competitiveness whereby the natural tendency of the student is to see what the latest cartoon is. Each email would contain the new competition and the winner(s) of the previous one which again serves to reinforce the core messages and exploits the student need to see who won and to compare the winning entry with their own. Importantly, the adoption of the nanofiction format also provides a concise text which is easily read but which has the capacity to provide the core tenets of the messages.

Fiction is often exploited in the construction of problem based learning materials and used by every lecturer at some point and is most clearly evidenced by the construction of context to support the presentation of what-if scenarios and tutorial/exam questions (Moon, 2010) – each a story in their own right. The great strength of this approach is that it reverses the roles and encourages the students to write the story. Once the central problem/hazard (i.e. trip, electrical, manual handling etc) is set, the students create a humorous fictional account (essentially the caption) of a potential scenario to match the cartoon. This provides a number of advantages:

1. In setting the scene the students are required to consider the likely cases where such hazards can arise and the risks involved. This involves the anticipation of the problem and thus they are more able to recognise the situation in the real environment.
2. In supporting character development they are seeking a degree of emotional engagement – albeit through humour. It also serves to stimulate debate within their cohort and wider friends.
3. The process promotes reflective learning associated with considering the implications of the hazard failing to be identified and resolved.

Through empowering the students to create the story, the time demands on the lecturer are lessened and it enhances the experience of the student through being proactive in the story process rather than relying on the passivity of reading (Moon, 2010; Shank, 2006; Gillard, 1996). The process also fulfils many of the learning outcomes associated with the pursuit of transferable skills. The strategy integrates the various forms of communication – oral, written and technological – which are key components of the "Professional Skills" required by engineers and thus embodies a more coherent/integrated approach than conventional essay assignments.

CONCLUSIONS

The approach taken here provides students with a more accessible and fun challenge that stimulates a greater degree of engagement than the conventional single event induction lecture. While more long term assessment of the degree to which the message is retained is required, the results from this initial study highlight the potential effectiveness of the approach. It offers an imaginative alternative to the conventional writing assignments and passive lectures typify the health and safety inductions taken within most science engineering faculty. It offers a means of introducing and reinforcing health and safety issues in way that can be easily adopted irrespective of curricula and possesses a format that is complementary to existing modules. The availability of free, cartoon samples means that it can also be accommodated / delivered without any additional information technology outlay.

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Creating comics in physics lessons: an educational practice

Construcción de cómics en las clases de física: una práctica docente

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Abstract

This article presents the results from an intervention program with 119 students during physics and astronomy lessons. This program has taken place in the public school "Colônia dos Pescadores" in the City of Caraguatatuba, State of São Paulo. The goal is to show the importance and possibility of learning with support materials, either in the classroom or at home,created by the learners themselves. The results show that students can demonstrate their creativity while building up their own knowledge related to Astronomy as they are able to produce comic strips about the theme afterwards.

Key words: *astronomy teaching, meaningful learning, physics.*

Resumen

Este artículo presenta los resultados de la disertación, que se realizó en un programa de intervención con 119 estudiantes en las clases acerca del tema de la física y astronomía, en la escuela secundaria "Colônia dos Pescadores" en la ciudad de Caraguatatuba en el Estado de São Paulo. El objetivo es probar la importancia y la posibilidad del uso de los materiales didácticos de apoyo en clase o en casa realizados por los alumnos mismos. Los resultados muestran que, mediante la elaboración de los cómics, los estudiantes pueden demostrar sus creatividades en la construcción de sus propios conocimientos relacionados con la astronomía.

Palabras clave: *enseñanza de la astronomía, aprendizaje significativo, física.*

INTRODUCTION

This article presents results of a research (Albrecht, 2008; Albrecht and Voelzke, 2008) that points out the importance of the work with the Teaching of Astronomy in basic education. This study may support teachers, especially those who instruct Physics at the high school level.

The initial idea was to find out the students' prior knowledge on the subject of Astronomy and subsequently to develop an intervention with the involved students with a view to build up a Meaningful Learning (Moreira and Masini, 1982), based on pre-existing concepts, i. e. brought by the student himself.

Those pre-existing concepts are very important as they provide a basis and as they facilitate the learning of related concepts and themes. However, in most cases the teaching of physics only occurs as a reproduction of formulas without considering the prior knowledge of the learner. Usually this kind of teaching happens while using a traditional approach, emphasising the use of formulas and mathematisation, which causes a rapid student disinterest in learning Physics.

According to Moreira (2000) and Araújo (2007), the comprehension about physics education began to change and to improve in Brazil from the 70's when the applications of curriculum projects in middle school were started. But this attempt to change did not last long because the project made clear how physics should be taught (by experimentation, demonstration, workshops, historical aspects, among others), but it did not define how to learn this new physics.

In an attempt to define how to handle the Teaching of Physics in order to facilitate students´ learning, new proposals have emerged as those suggested in the National Curricular Parameters (PCN), (BRASIL, 1999), in the Supplemental Educational Guidelines for National Curriculum Parameters (PCN+), (BRASIL, 2002) and the Curriculum Proposal of the State of São Paulo (SÃO PAULO, 2008). But even so, the inclusion of current issues in the curriculum does not take place.

One of the themes suggested in the proposals is astronomy, one of the oldest sciences of human history (Máximo and Alvarenga, 2008). However, astronomy is little understood by the general public, including children and teachers of all educational levels. This possibly explains the fact that the expected inclusion of astronomic concepts is not implemented in almost all school curricula (Elias et al, 2005).

Studying Astronomy means to go one step further. According to Oliveira (2007), student maturity in high school enables a deepening of the concepts learned in elementary school because the students are more able to abstract, and thus they can better understand the phenomena which happen in their surroundings.

It is important and challenging to expand on our knowledge and to recognise the environment. In this sense, exploring the previous educational conceptions about other planets and smaller bodies (asteroids, meteoroids, comets) that wander around the solar system can be a way that amplifies significant learning during the teaching of astronomy.

In this sense, the study of astronomy may serve to help the student to know more about the world where we live and, of course, the rest of the universe.This is an issue that can arouse the students' wishes to learn, sharpening his curiosity. So whenever possible, the content of physics should be worked out in practiceand tied to physical phenomena in the students' daily life (Moreira and Masini, 1982).

Associated with change and constant innovation, we find that working with the content of astronomy is an important issue to be worked out at high school with a view to meaningful learning. However, some issues are compelling to teachers who work with this content at this level of education to work differently from traditional lessons. The teachers want to know how to provide effectively a significant learning of this content.? What strategies and procedures are adequate for teaching the subject at hand?

Based on these questions, this paper aims to demonstrate the possibility of working with comic books while teaching Astronomy. To support this work and to bring it closer to students of different levels, the results of some other studies were used, such as the paper on the site http://www.scienceinschool.org/2010/issue14/web that brings science-related stories in comic format and recommends how to work with them in lessons. In addition to the comics, which provide an incentive to interest pupils in science, there are also sites which attempt to popularise science for children and young people from five to thirteen years, like The Young Scientist Magazine, available on http://www.theyoungscientists.in/products.html. - All of these sites are free of charge.

The work also tries to understand the differences, highlighting the "I" of each student in this classroom, trying to raise and to structure forms that allow the student to be owner of his own learning, constructing a shape to demonstrate concepts learned during the lessons.

The creation of comics in the classroom shows the possibility to enjoy science as it brings the student to scientific concepts and values what students can do in the classroom. Transforming Science is often seen by students as something heavy, is a difficult challenge, but with the use of new and differentiated educational resources it is possible to enhance the knowledge of the student and encourage him to create.

METHODOLOGY

The research was conducted at the public school "Colônia dos Pescadores", in three classes of the third year of high school, with a total of 119 students. For administrative reasons, the three classes involved in the study were divided into class A, class B and class C. For the constitution of data lectures were made, involving the use of audio-visual resources during two months. At the end of this period it was suggested to the students to draw up a comic book, which served to see if the previous concepts had changed and if new ones had been added.

The analysis of the stories was divided into three parts:

- Creativity,
- Discussed topics,
- Correct application of the studied concepts.

At the end fourteen stories were fabricated, two of them are revealed in this work.

THEORETICAL FRAMEWORK

Cognition, according to Moreira and Masini (1982), is the process in which one establishes relations, attributing meanings to the reality that surrounds him. Taking these meanings, one builds up a cognitive structure which forms the initial concepts, called anchor points, where new meanings are grounded and developed.

These anchor points are now called "subsumers", the point of origin to build up new knowledge by building the so-called "cognitive bridge" between all knowledge the student already has, capable of serving as an anchor for new information to which meanings can be attributed (Aususbel et al. 1980; Ausubel, 2003; Moreira, 1983, 1999).

In this way it is possible to form concrete concepts, the students form and understand their meanings broadly and, mediated by language, the students process new information which should be organised progressively so they can anchor their new knowledge. This process allows the occurrence of meaningful learning, which, according to Moreira (1999), can be understood as a process where new information is anchored in the existing information of the learner's cognitive structure, changing the existing information and thus forming a new concept, a new idea.

In this concept, one realises that every student, every teacher, as well as each individual has previous concepts which influence the acquisition and development of new concepts. By building knowledge itself it is possible that a student can make changes in his behaviour. This refers to learning and is also linked to a paradigm shift, forming a new truth. An accepted truth is set up in the way that a student can understand that scientific concepts are constructed by humans, or he can realise that science is a human construct.

Physics is a subject that explains that nothing happens accidentally. But physics clearly needs thinkers, thinkers who made and make history. Thus, it is worth highlighting the importance of conceptualising physics in a more humanistic way and to make it more attractive because for a long time learning physics had been reduced to pure calculations, to an act of decorating formulas. This must be rethought for the new proposals as the PCN 's.

RESULTS

The analysis of the stories developed by students at the end of the study reveals that the creation of comics facilitated significant learning. The creative aspects in these stories must be pointed out because the comic strips are hand-made since the students didn't make any use of technological resources. The topics were all related to astronomy and, in most cases, the studied concepts were applied correctly. This became evident in the efforts the students made and also in the quality of the learning matter, as exemplified in the two stories that follow.

First story:

Translation of comics: **1** - Astronomy; **2** - Wow! Look what I just found:

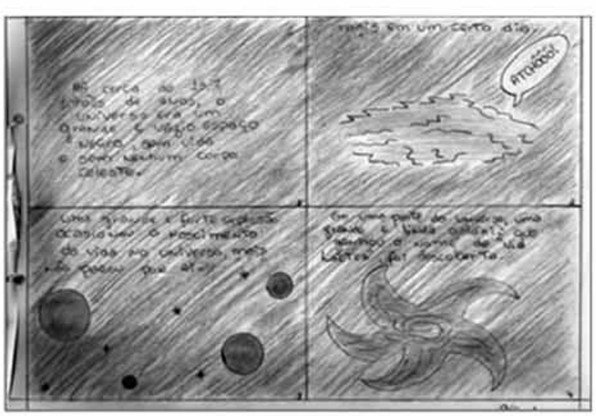
an Astronomy magazine.; **3** - That's interesting, it talks about planets and galaxies.; **4** - Pluto is now a dwarf planet, wow!; **5** - Hahaha ... The Sun is a medium sized star, which radiates heat that warms the Earth!; **6** - Somewhere in space ...; **7** - Ahhh ... A comet! - No, you're wrong, it's a meteor. I'll explain ...; **8** - The meteor is a meteoroid that enters in the Earth atmosphere when it suffers a friction, and turns into a fireball. And the meteorite is nothing but a piece that falls on Earth's surface. **9** - Got it? Now you can run! - Yes, very crazy....

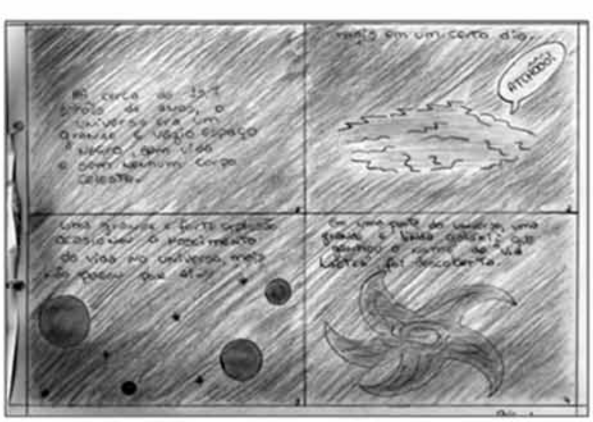
The story is about two boys arguing about the cosmic objects that wander through space. In this comic, they find a definition of a meteor – a ball of fire because of the friction with the atmosphere - and also an explanation about the terms 'meteoroid' and 'meteorite'. Despite presenting an incomplete concept, this story shows that the students have drawn a better concept than the original one they had presented in class before when they had to describe the phenomenon of a meteor shooting star.

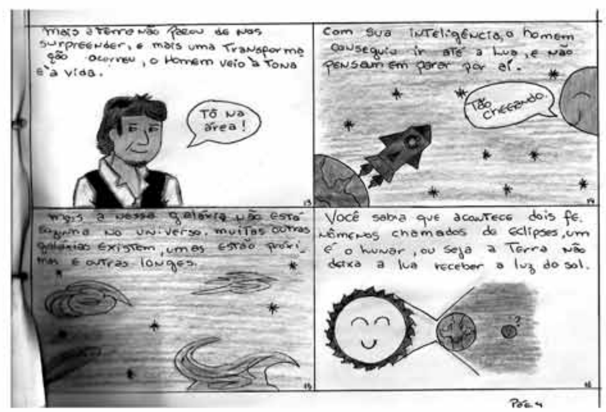
Another utilised concept in this history is the theory that a possible event responsible for the formation of the Moon may have been the collision of a meteorite with the Earth. This idea is presented in this story, possibly because it has been discussed in class during physics lessons before.

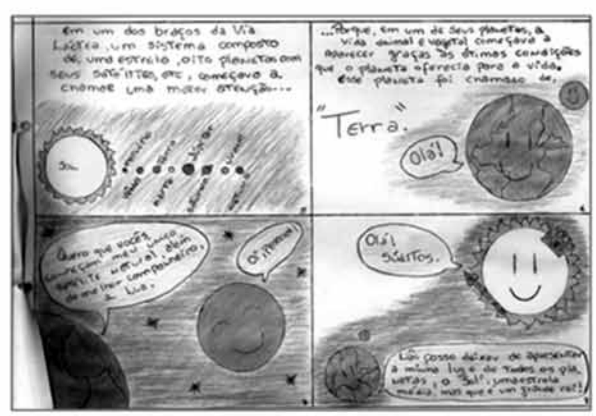
Not all concepts covered in the story are correct, but they clearly show a significant and effective learning, meeting the initial proposal to develop new concepts and to incorporate them into the cognitive structure.

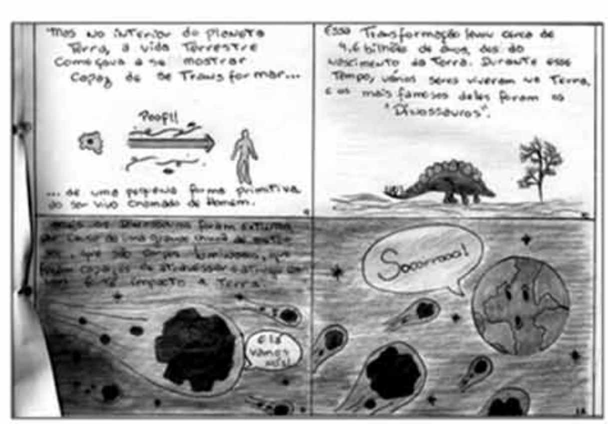
The second story is a little wider, as follows:











Translation of the comic: **1**– Astronomy; **2**– A *Atchôôô* which brought us to heaven.

3– 13.7 billion years ago, the universe was a very large and empty black space, lifeless and without any celestial body. -But in one day. - A large and powerful explosion caused the birth of life in the universe, but did not stop there ... - In a section of space, a large and beautiful galaxy that received the name "Milky Way", was discovered.; **4**– In one arm of the Milky Way, a system composed of a star, eight planets with their satellites, etc., began to attract attention ... - Because in one of its planets, plant and animal life began to appear thanks to the excellent conditions in the planet for life. This planet was called "Earth. " - Hello! - I want you to know, my single natural satellite, and best friend, the moon - Hi, everybody! - Hello! vassals. - I must present my light and all the planets' light. The Sun is an average star, but a great king!

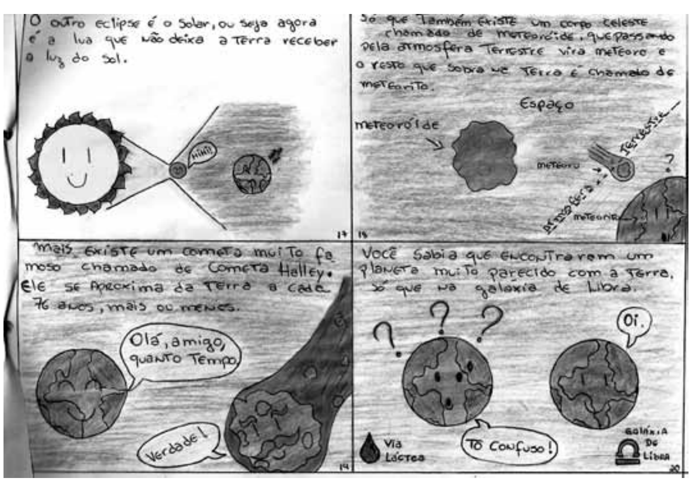
"5– But inside the Earth, life on it began to show itself capable of transforming... into a small primitive form of life, called man. - This transformation took about 4.6 billion years since the birth of the Earth. During that time, many animals lived on earth, the most famous of these were dinosaurs. - But dinosaurs became extinct because of a large meteor shower, which are luminous bodies, capable of hitting the Earth with a big and strong impact.; - Here we go!; - Help!; **6**– But the earth did not stop surprising us, and yet another transformation occurred, man came to light and life. - With his intelligence, man managed to get to the moon and does not plan on stopping there. - Our galaxy is not alone in the universe, there are many other galaxies, some are close and others distant. - Did you know that two phenomena called eclipse occur on Earth? One is the Moon Eclipse, i.e., the Earth does not let the moon receive the sunlight."

This story contains a lot of information, is rich in detail and indicates an effective learning. In the comic, the learner attempts to define when and how the universe had its beginning. It includes an idea about the Big Bang, though not entirely correct, but it shows a trend, taking into account that initially the same pupil had responded to questions about this subject area much less coherently.

The authors discuss throughout the history the solar system, planets, the theory of evolution, the receipt of light by the Earth, among others. They highlight the existence of life only as known on Earth.

In this history, the students bring in a lot of illustrations of facts that they had gained - either read during the lessons or seen in some moments of their life, such as eclipses. These representations are out of scale.

The present interdisciplinary approaches as the theory of evolution of the species are another fact that proves the occurrence of meaningful learning in this comic. On this topic the student portrayed the arrival of humans and the hypothesis of extinction of dinosaurs.



7 – "The other one is the solar eclipse, now it is the moon that doesn't allow the Earth to receive the sunlight; - There is also a celestial body called meteoroid, passing through Earth's atmosphere it becomes a meteor and the rest left on Earth is called meteorite.; - But there is a very famous comet named Halley's Comet, it approaches the Earth every 76 years or so. - Hello friend, it's been so long! - I mean it! - Did you know they found a planet very similar to Earth, in the galaxy of Libra? - I'm confused!; **8** - With all that being said, I say one thing: The intelligence of man is going to take the astronomy to the sky."

The comic contains a lot of information and also shows how much the students like their school, which is explicit in the last picture with all its details and the accentuation on the facade of the school, a factor that is important for the development of classes and activities. This work underlines the need to update and to change contents and also emphasises the importance of a more contemporary and a more attractive physics throughout high school time, because all groups accomplished their work and submitted results within the requested timeframe.

All of these works were carried out after the intervention. According to the learners themselves the theme had been developed in a very different way, moving away from the kind of topics that are usually discussed in physics classrooms.

Actually, in most cases learning physics is done by rote. Under this learning condition a pupil is able to reproduce knowledge, but only for a short period of time. Moreira (1999) describes some typical situations of this kind of mechanical learning:

> "In physics, as well as in other disciplines, the mere memorisation of formulas, laws, concepts, can be taken as an example of rote learning. Maybe that last minute learning, on the eve of trial, which only serves to nothing else than the exam - since it is soon forgotten after - also characterises the mechanical learning. Or regard that kind of typical argumentation of a student who claims to have studied everything and he even knows everything, but at test time, he is unable to solve problems or issues which require the utilisation and transfer of knowledge (Moreira, 1999, p.14)."

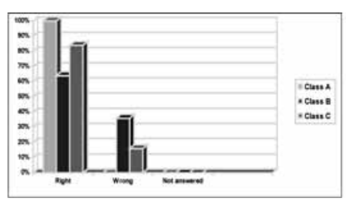
Under this focus, it becomes explicit in the material made by the students that learning points to another approach, a more humanistic approach, which regards the form of expression of concepts by the students involved in this learning process.

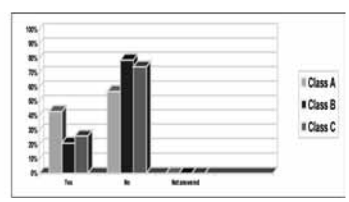
CONCLUSIONS

The results indicate the need for an effective work on the theme, since it is practically not developed in schools. For learners, the content in question is potentially significant, and following from Jafelice (2002), the factor that awakens interest is "the human search for origins and the connections between Astronomy and the origin of human consciousness."

Based on initial results of the questionnaires (Albrecht, 2008; Albrecht and Voelzke, 2010), it is observed that the learning of astronomy does not only happen in the classroom, but also in different spheres, which was observed when the students began to associate studied phenomena with scenes of movies they had watched and newspapers or other texts they had read. This is an evident fact of the obtained results.

When the students defined Astronomy, the responses were as in the following figures 1 and 2 :





The two graphs represent the answers to this question. The first represents the responses in the initial stage of the work and the second one those after the intervention. Significant improvement after the work is evident, demonstrating the importance of working the issue differently.

In this approach, it is important to realise that learning does not only depend on the educator or learner, but rather on the whole process. As the learners themselves responded when asked whether or not they would like to learn more about the theme astronomy, the responses were: "*the presented contents in physics were different, important, challenging, interesting*".

Thus, the theme astronomy can be considered as an unusual topic that arouses interest and which is within the theoretical framework of the proposal a "potentially significant issue"; but the emphasis placed on it is still very far below the necessary (Oliveira, 2007).

Student curiosity and the fact that the subject may be considered as potentially significant can be pointed out as factors that led to the production of comics. This suggests that physics can be approached in various ways, generating significant results, which can even be facilitated with the use of resources such as computers, overhead projector and films in class.

The possibility of working with comics in astronomy lessons was identified in this work as a different way of learning the content of astronomy.

In this way learning becomes more interesting, holds the attention of students and encourages them to study. All these aspects result in meaningful learning; a fact that can be demonstrated by means of the many details in the produced comics and the additional information contained in it. Another aspect could be observed when the students were asked about whether or not the sun is a star.

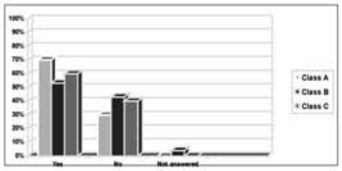


Figure 3. Before the intervention

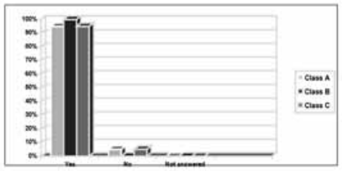


Figure 4. After the intervention

The graphs show that a done work of a significant astronomy lesson begins to make sense to the student. It is incorporated by the student's cognitive structure and results in a conceptual change. This certainty can be seen in comic books, designed as an assessment for completion of the work with that theme.

stopped here

While analysing the comics it was noticed that a few students had been confused by some questions; partially they answered them from the standpoint of religion, which shows that some concepts are built under other sources. This is a fact that complicates a bit the acquisition of scientific knowledge since religious belief is a factor usually present in a student's life.

Working in a different way can be rewarding as seen in the comic strips and the listed concepts. Physics today may be present in the classroom and can be extended to other areas involved in the process of teaching and learning, leading to occurrence of interdisciplinary teaching, to the envisioned dialogue between disciplines which is part of the present guidelines of the PCN's. They really generate a learning that will be brought to life, and this can be understood as meaningful learning.

Another point that stands out is that when students were asked in the first phase of the work whether they had an interest in the study of astronomy, only four answered no, but they didn't justify it.

Overwhelmingly, the respondents showed in the first question, which addressed whether students had studied about astronomy, that they never had, although this is proposed in the National Curriculum Parameters (BRASIL, 1999): "The possibility of an effective learning of Cosmology depends on the development of the theory of gravitation, as well as basic notions about the constitution of matter and stellar energy. These and other necessary updates of the contents point out an emphasis on a contemporary physics throughout the whole course, should be understood as a necessary link between each topic and ongoing knowledge, not just as a single theme of modern physics only at the end of the course. It would be interesting if the study of physics at high school was completed with a discussion of issues that would allow comprehensive summaries of the elaborated contents. There would thus also be space for systematic general ideas about the universe, looking for a cosmological vision (to date) (of the present universe?). "Thinking about this, we thought fit to propose a discussion and a possibility of learning and confrontation with it." (what is *it*? confrontation with what?)

After the completed intervention the questionnaire was given again, but the first question (*"Would you like to learn about Astronomy in lessons of Physics?"*) had been eliminated and number twenty (*"Would you like to learn (more) about the theme Astronomy?"*) had been changed into the following one: "Now answer, have you enjoyed learning about the astronomy theme? Comment on it."

It was observed in response to the question that all students who learned about astronomy liked and considered it as an important content, different, which made the lessons more interesting, providing a more effective learning, with real meaning.

The fact that they have never studied astronomy is justified in the following chart, which is represented by answers to the question: "Have you ever studied astronomy in basic education or high school?"

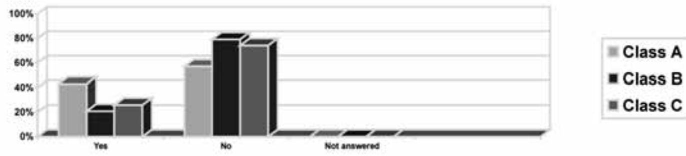


Figure 5. Have you studied astronomy in other years of basic school.

These responses are very alarming, because astronomy is recommended starting with basic education, as following to guidelines of official documents relating to Brazilian Education (PCN's). This recommendation allowed a different work using comics built by the students since it resulted in an extremely rich work of great significance, making clear the importance of working different themes and different forms of assessment. The student needs to be challenged and encouraged to create, produce materials that can serve as support to work with other series, in other years. The importance of having a model to develop the work must urgently be recalled.

It is noteworthy that the mediating role of the educator is of paramount importance, since in this case the teacher does not teach, but supports and intervenes so that the students learn. Thus, he values and respects the "I" of each student in this classroom and encourages him or her to build up his or her own concept and to demonstrate various forms of the knowledge he or she has acquired.

This fact becomes clear upon inspecting the comics that show an evolution in relation to conceptual graphs, spelling out some initial setup and adjustments after the intervention work done by the teacher. These themes point to a facilitation of the teaching-learning process, since the theme for the students is interesting and potentially significant, and may be extended to other curriculum subjects.

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Causal explanation thinking skill: an active student-centered methodology for understanding the practical section of organic spectroscopy course

Habilidad de pensamiento basado en explicación causal: una metodología activa para comprender la parte experimental de un curso de espectroscopia

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Abstract

Engaging students in meaningful learning is essential for receiving an intellectual and proficient level of education. This paper investigates the impact of introducing a student-centered learning environment into the practical section of organic spectroscopy course by infusing the critical thinking skill, causal explanation. The protocol used is a multi-step strategy and students' perceptions were recorded and evaluated. The study illustrated that causal explanation skill is a potential tool for understanding and utilizing, efficiently, [1]H NMR spectroscopy. It also discusses the benefits of the transition of teaching methodology from teacher centered to student centered methodology for future use.

Key words: *meaningful learning, active learning, critical thinking, causal explanation, NMR spectroscopy*

Resumen

La participación de los estudiantes en el aprendizaje significativo es esencial para recibir una educación intelectual y competente. Este estudio investiga el impacto de un ambiente de aprendizaje centrado en la parte experimental en estudiantes de un curso de espectroscopia orgánica a través del pensamiento crítico y con la explicación causal. La metodología está basada en una estrategia de múltiples etapas y las percepciones de los estudiantes fueron grabadas y evaluadas. El estudio demostró que la explicación causal ayuda a comprender mejor la espectroscopia [1]HRMN. Se discuten los beneficios de cambios de la metodología de enseñanza, centrada en el docente hacia una basada en el estudiante.

Palabras clave: *aprendizaje significativo, aprendizaje activo, pensamiento crítico, espectroscopia de RMN*

INTRODUCTION

Learning is a process by which knowledge is increased or modified. "Learning is an increase in expertise due to an alteration in long-term memory. If nothing has been altered in long-term memory, nothing has been learned." (Schnotz & Kürschner, 2007) Research underline the importance of teaching for understanding, and the difficulty of the enterprise. (Perkins & Blythe, 1994) Knowledge acquired in school is usually limited to situations in the classroom, rather than being applied to students' lives. (Wegerif, 2002) A meaningful way of learning is to enable the learner to use this knowledge constructively to make a better understanding of the world. Research on students' learning suggests two main learning patterns: surface learning which focuses on reproduction and memorization, and deep approach which focuses on meaning-making and relating. (Weurlander *et al.*, 2009)

The surface approach is the traditional method in which learning is teacher-centered where the teacher has all the knowledge of the subject being studied and the student will only gain knowledge that the teacher allows or finds appropriate. (Carmody & Berge, 2005) In this method, the lecture is a useful vehicle for transmission of information and doesn't usually engage students in processing and integration of ideas and concepts. (Kember, 1997) Therefore, students become passive listeners rather than active participants. This methodology is a superficial learning process that doesn't develop the students' abilities and skills for lifelong learning as it often focuses on rote learning (memorization) rather than meaningful learning.

Many studies show why providing only lectures frequently do not work. (Bransford *et al.*, 2000) To improve student's learning and achievements, students should be involved more in the learning process and the environment is shifted to an active students-centered methodology, *i.e.* the deep approach. (Gerjets & Hesse, 2004) In this method, the students' opinions, backgrounds, and goals are acknowledged and incorporated within the learning process. (Thamraksa, 2011) The instructor play the role of the facilitator that provides students with opportunities to learn independently and from one another, and also coaches them in the skills they need to do so effectively. (King, 1993)

Student-centered methodology incorporates various techniques during the learning process in which proper implementation of these techniques can lead to increased motivation of learning, greater retention of knowledge, deeper understanding, and more positive attitudes towards the subject being taught. (Brown, 1988; Collins & O'Brien, 2003; Felder, R. M.; Brent, 2003; Gillies, 2003) Students discuss the spectra in groups, following a structured procedure under conditions that meet the five criteria of the cooperative learning method (Johnson *et al.*, 1991; Felder, 1996; Cooper *et al.*, 2008; Geiger *et al.*, 2009).

One of these techniques that creates a students-centered learning environment is to infuse critical thinking skill(s) into the course contents. Critical thinking is a way of thinking that does not accept any assumption without questioning its validity and correctness. It is a process of evaluating various situations, ideas and experiences. (Cokluk, 2009; Al-Ahmadi & Reid, 2011) Another definition of critical thinking "*is reasonable reflective thinking that is focused on deciding what to believe or do*". (Ennis, 1987; Cokluk, 2009) Applying critical thinking can help us acquire knowledge, improve our theories, and strengthen arguments where we can use it to enhance work processes. (TUTORIAL C01, 2011)

Critical thinking is an important learning outcome for most areas of study today and getting students to think about things in a new way, or provide alternative explanations for events, is an important learning goal that has been incorporated into courses in history, economics, nursing and psychology disciplines. (Angeli & Valanides, 2009) Teaching critical thinking is most effective when it is embedded into subjects already taught, not as a separate concept and incorporating its skills into course content will enable students to solve future problems. (Broadbear & Keyser, 2000; Ritchhart & Perkins, 2005)

Spectroscopy has always been a challenging course to teach and learn (Silverstein & Silberman, 1973), and because of educational value, efforts are constantly being made to improve the conception of this tough subject. (Welch, 1997; Veeraraghavan, 2008; Mills & Shanklin, 2011; Villalba *et al.*, 2011). Organic spectroscopic studies require considerable amount of critical thinking to accurately describe and analyze the information provided in order to solve the chemical/stereochemical structure of an organic compound. Too often, students either cannot correlate the spectral data with the given structure, or more challenging, find difficulties to interpret the data and elucidate the structure of an unknown compound. This paper describes how infusing the critical thinking skill, causal explanation, into the practical sections of organic spectroscopy course helped students to use [1]H NMR data correctly and effectively. It also shows how collaborative work led to an interactive learning of the lab sessions. Feedback of the students is also presented and the results of the study are discussed.

METHOD

Causal Explanation is a method used to identify an immediate precipitating cause(s) of a particular occurrence. (Fortus, 2009; Causal explanation, 2011) Knowing the causes of events or conditions is an important step in solving many real-world problems and can enable us to foster desirable results such as producing higher grades. We can also try to alter causal condition in order to block or minimize undesirable results. (Swartz *et al.*, 1998) In science, it is important to learn the causes of various phenomena in order to better understand these phenomena. Student can be guided to determine these causes using skillful causal thinking. Clarifying what causes people to make choices can bring students insight about human motivation as well as an understanding of how to make reasonable judgments about why people do what they do. (Swartz *et al.*, 1998)

Infusion of causal explanation skill into the practical section of organic spectroscopy course.

The participants in this study were third and fourth years chemistry students of the chemistry curriculum at KAU. The infusion lesson consists of four steps: lesson introduction, thinking actively, thinking about thinking and applying thinking. In the lesson introduction step, the students were introduced to the thinking skill by asking them about the causes of some examples that happen in their daily life. Relating the skillful causal explanation with students' own experiences increases the student acceptance of the lesson and makes it more meaningful. Students were directed to do causal explanation skillfully by a series of guided questions. These questions represent the thinking map of skillful causal explanation (figure 1). The thinking map helped students to manage and change the way they think about their own causal explanation and to avoid hasty judgments.

Skillful Causal Explanation

1. **What are possible causes of the events in question?**
2. **What is possible evidence that would show that these causes are likely?**
3. **What actual evidence is there that is relevant to what caused the event in question?**
4. **Based on the evidence, what is the likely cause of the event?**

Figure 1. Thinking Map of Causal Explanation

After the introductory part, the students moved to the main activity of the lesson. A copy of ^{1}H NMR spectra (figure 2) with two alternative structures and tables of ^{1}H chemical shifts were provided to each student to assign the correct compound for this spectrum using a strategy of causal explanation. In this part of the lesson, "thinking actively", the students were grouped to work collaboratively according to the criteria of the cooperative learning method. By using the questions in the thinking map of causal explanation (figure 1), each group recorded possible causes (solutions) of the spectrum and analyzed each solution to decide which is the correct answer.

In this process the students take charge of their own thinking. This metacognitive reflection is "useful in helping students to make their own thinking visible by engaging them in reflecting on and analyzing what they believe they did mentally to carry out a thinking skill or mental habit." (Brown *et al.*, 1981)

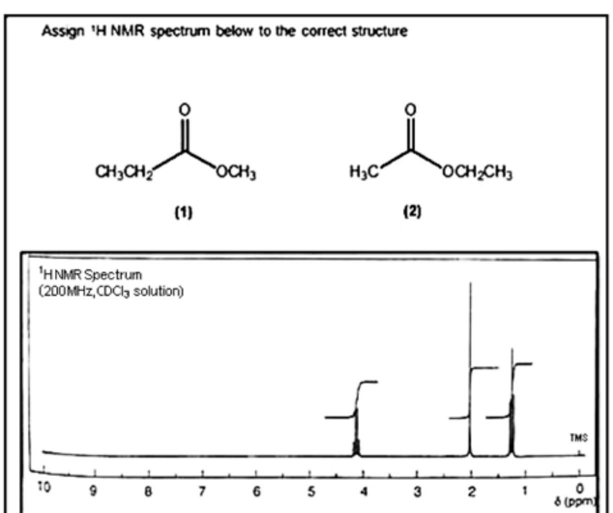

Figure 2. An Example of ^{1}H NMR Spectrum with Two Alternative Structures

Graphic organizer, or schemas (Goodwin & Orlik, 200), was used in order to help students to organize and visualize their thoughts through the thinking process (Collins *et al.*, 1991; Ritchhart & Perkins, 2008) and to download information that is difficult to hold in memory (Miller, 1956; Baddeley, 2001; Johnstone, 2010). Students used the graphic organizer (figure 3) for each structure (cause) and listed all possible evidences (*e.g.* number of signals expected to show, chemical shifts and multiplicity for each set of protons). Then, they listed the actual evidences that appear in the given spectrum. Subsequently, the groups evaluated each actual evidence and decided whether it counts in favor of (+) or against (-) the possible cause to determine if the possible cause (solution) is likely or unlikely based on the evidence. Finally, they made judgments about the correct structure for the spectrum.

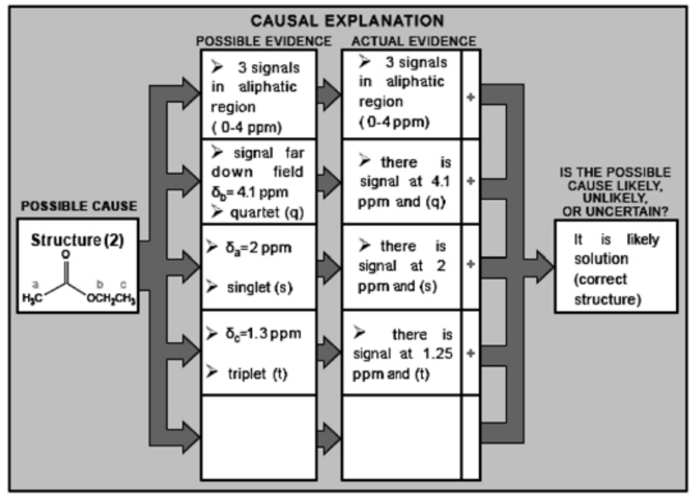

Figure 3. Sample of Graphic Organizer for One Structure

In the following part of the lesson, thinking about thinking, students were helped to think about thinking process by asking them direct questions about what kind of thinking they did, how they did it, and how effective it was. This step helps students to do the same kind of thinking in the future. In the final part of this infusion lesson, applying thinking, other example was introduced to the students to help them to transfer the use of this skill in other situations.

RESULTS

Applying a strategy of causal explanation to solve a ^{1}H NMR spectrum of an unknown organic compound(s) was evaluated by collecting and analyzing the students' answers (figure 4) in the thinking about thinking part of the infusion lesson. All students reported that the skill of causal explanation is a useful learning tool and helpful in understanding ^{1}H NMR spectroscopy. Most students mentioned that this thinking skill helped them to use all spectral data in spectrum interpretation and to choose the correct structure. Answering the questions in the thinking map helped them to avoid hasty and unfounded judgments about causes (solutions) of a problem. Students used graphic organizers to organize and visualize their ideas (information).This helped them to avoid any mistake. Students preferred collaborative work which helped them to present and correct their misunderstanding.

Compared to the traditional method of teaching this lab for the past few years which was based on teacher centered methodology, the results of applying the technique of causal explanation demonstrate an improvement in students' performance and, furthermore, achievement of an active learning environment.

CONCLUSIONS

This paper analyzes the extent of students' learning by a new teaching method that is based on the implementation of a critical thinking skill into course content. It proposes the use of the skill as a potential methodology to understand the concept of employing ^{1}H NMR spectral data for solving the structure of an organic compound. With the incorporation of the causal explanation skill into the practical section of the organic spectroscopy course, prior knowledge of the subject was actively engaged and the quality of the students' learning was improved relative to the conventional method that was used. The results of this study showed that the causal explanation skill is an effective strategy at leading the students towards a better understanding of the topic.The results also suggest thatmore research be done about further application of other thinking skills.

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A causal model of some school factors as determinants of Nigerian senior secondary students' achievement in physics.

Un modelo causal de algunos factores determinantes del rendimiento en física de los alumnos de escuela secundaria en Nigeria

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Abstract

The study was undertaken to examine the causal effect of some senior secondary school factors as it affects students' performance in physics. Hence, the investigators specifically developed and validated a school model involving causal linkages between characteristics such as school type, gender, teacher's qualification, school principal's area of specialization and physics learning resources, and achievement in physics (the dependent variable). The sample comprised of: three hundred and thirty (330) students comprising of 167 males and 163 females Nigerian senior secondary physics students. Twenty schools with twenty-two school principals (21 males & 1 female) and twenty-two physics teachers (all males) participated in the study. A multistage sampling technique comprising of two stages was employed to select the subjects. A stratified random sampling technique was used to select the schools while purposive technique was used to select the students, the principals and physics class teachers. Three validated instruments were used to collect the data while path – analysis and multiple regressions (using backward solution) were employed for data analysis. The findings of this study documented the more parsimonious model, which is effective in predicting the senior secondary students' academic performance in physics. The results further indicated that two (School Type & Gender) out of the five predictor *variables have both direct and indirect causal linkages. The implications of these findings for education policy makers, administrators and teachers are discussed.*

***Key words**: causal modelling, school factors, achievement in physics, teacher's qualification.*

Resumen

El estudio se realizó para examinar el efecto causal de algunos factores de la escuela secundaria superior, ya que afecta al rendimiento de los estudiantes en la física. Por lo tanto, los investigadores desarrollaron y validaron un modelo de escuela la creación de vínculos causales entre características como el tipo de escuela, el género, calificación de los docentes, el área principal de la escuela de especialización y los recursos de aprendizaje de la física, y los logros en la física (la variable dependiente). La muestra está compuesta de trescientos treinta (167 hombres y 163 mujeres) estudiantes nigerianos de cursos superiores de física de secundaria. Veinte escuelas con veintidós directores (21 varones y 1 mujer) y veintidos profesores de Física (todos hombres) participaron en el estudio. Una técnica de muestreo aleatorio estratificado se utilizó para seleccionar las escuelas, mientras que la técnica con arreglo a fines se utilizó para seleccionar a los estudiantes, directores y los profesores de física de la clase. Tres instrumentos validados se utilizan para recoger los datos, el análisis y regresiones múltiples se emplearon para el análisis de datos. Los resultados de este estudio permitieron construir un modelo, que es eficaz en la predicción de rendimiento de los estudiantes de la secundaria académico en física. Los resultados indicaron además que dos de las cinco variables predictoras (tipo de escuela y género) tienen los vínculos causales directos e indirectos. Las implicaciones de estos hallazgos para los responsables de política educativa, administradores y maestros se discuten.

Palabras clave: *modelo causal, escuela, logros, física, calificación de profesores.*

INTRODUCTION

Any meaningful and conceited effort to enhance more participation and high achievement in science and technology should be sensitive to school factors. The benefits of physics (as one of the physical sciences) to the nation cannot be over emphasized. It is one of the bedrock of all development brought about by the modern science and technology. The improved means of transportation via airplane, ships and motor vehicles, electrical/electronic benefits for domestics and industrial activities, heat energy transfer, information technology such as the use of internet, personal computers, handsets, and warfare weapons among others are all significantly product of physics technology among other variables. Earlier researchers have noted that physics is significantly influenced by the sensitive measures of the type and location of schools, pupils' attitudes towards school's work and learning in general (Miller, 1971; Keeves, 1973; Lawrentz, 1975 and Majoribank, 1976). At least students spend two-third (2/3) of the day (i.e 8 hours daily) at school. It can then be deduced from the above assertion that school contribution to the transformation process of any nation's scientific and technological development cannot be neglected. There is need to produce sufficient numbers of technicians and engineers with the skill to meet the needs of modernizing the economy.

As important as physics is, secondary education in Nigeria is associated with unfavourable performance of students in physics (Iroegbu, 1998, Orji, 1998, Ariyo, 2005). This situation however is not peculiar to Nigeria alone; rather it is a general world-wide trend (Hurd, 1983). For instance, table 1 below reveals the trend of students' performance in physics in the West African Examinations Council's (WAEC) - Senior School Certificate Examinations during 1994 – 2003.

From table 1 above it could be observed that less than fifty (50%) of the students who enrolled for physics do not usually attain credit pass in the subject. This suggest that most students who graduate from secondary school with physics background may not be able to continue in physics related courses at tertiary school level. Previous researchers, (bajah and okebukola, 1984: obemeata, 1995) ascertained that the performance of science students, physics students inclusive has been observed to be rather below expected standard. It could also be observed from table 1 that there is a positive trend in physics achievement between 1998 to 2003 compare to previous yearly performance. In 1998, waec body changed her pattern of setting physics theory questions from one single section to two sections and also the number of questions was increased from five to fifteen. The investigators suspected that the sudden change in waec physics questioning pattern must have enhanced the performance of physics student achievement. The waec increased the number of physics questions perhaps in order to cover the new examination syllabus. In the essay part, section a is usually made up of simple items while section b consists of more difficult items from which candidates were expected to make their choices. The students could now express themselves about some aspects of physics they understand. This is unlike previous years where candidates were limited and restrained to some aspects of physics in which they may not have been properly prepared for. The issue of students' poor performance in physics is a cause for worry. There is still need to look for more possible factors that must have contributed to this.

Learning opportunities in nigerian schools differ from school to school as in uk and usa schools also. Different types of secondary school type exist within the countries based on owners and location. Nevertheless the students from each school type have the same common goal i.E. The senior secondary certificate examination. Command schools are owned by the military sector. Private school type is either owned by the voluntary agency such as a mission body or a corporate body or by an individual. The state government owns the state school type while the federal government owns the federal school type. On the other hand the schools could also be gender biased. Both coeducational and single – sex schools also exist within the nation. For instance, jonathan – ibeagha (1986), in a study using a sample of 502 students and 12 teachers in ibadan examined instructional strategies of university trained physics teacher as correlates of learning outcomes in secondary school physics. The selected schools cut across 'boys only', 'girls only' and 'co-educational school type. It can be seen that school type is a relative term. The present study was more interested in looking at the

Table 1: distribution of students' performance in ssce
Physics examination from 1994- 2003

YEAR	TOTAL NUMBER OF ENTRY FOR SSCE PHYSICS EXAMINATION	TOTAL NUMBER & PERCENTAGE OF STUDENTS WHO SAT FOR SSCE PHYSICS EXAMINATION		NUMBER AND PERCENTAGE OF STUDENTS OBTAINING GRADE… GRADE 1 – 6 (CREDIT)		GRADE 7 – 8 (PASS)		GRADE 9 (FAILURE)		NUMBER OF STUDENTS WHO WERE ABSENT & AS PERCENTAGE OF ENTRY	
		NUMBER OF STUDENTS	%	NUMBER OF STUDENTS	%	NUMBER OF STUDENTS	%	NUMBER OF STUDENTS	%	NUMBER OF STUDENTS	%
1994	150,316	146,000	97.1	21,490	14.7	40,472	27.7	84,038	57.6	4,316	2.90
1995	120,768	120,768	100.00	22,825	18.9	41,544	34.4	56,399	46.7	0.00	0.00
1996	147,738	132,768	89.87	16,929	12.80	40,392	30.4	75,446	56.8	2,518	1.80
1997	127,486	127,486	100.00	12,796	10.00	43,456	34.0	71,234	56.0	0.00	0.00
1998	172,223	169,657	98.51	19,231	11.33	54,337	32.02	93,639	55.19	2,566	1.48
1999	213,864	210,271	98.31	64,283	30.57	61,772	29.37	77,709	36.95	3,593	1.68
2000	158,640	154,808	97.58	46,671	30.14	60,190	38.88	47,947	30.97	3,832	2.41
2001	295963	287,993	97.30	99,264	34.46	110,242	38.27	78,487	27.25	7,970	2.69
2002	261687	254,188	97.13	120768	47.51	81,814	32.18	51,606	20.30	7,499	2.86
2003	280818	275369	98.05	130982	47.56	84,413	30.65	53,079	19.27	5,449	1.94

Source: waec research and statistics unit.

effect of students being in federal, state and privately owned school type on their physics achievement. Coeducation schooling is considered by some educators and parents to be more equitable and to represent the real world that girls and boys will have to spend their future lives (willis & kenway, 1986). Although this view has been challenged by other researchers such as sarah, scott and spender (1980), rossister (1982), howe (1984), mahony (1985), rowe (1988) and jones (1990). The findings of steedman's (1983) of higher science achievement of girls in single – sex schools than co-educational schools and higher science achievement of boys in coeducational schools than single – sex schools in England conflicts with research by Lee and Bryk (1986) in the United States. Carpenter and Hayden (1987) in Australia found that girls and boys attending private single schools had significantly higher academic achievement than students attending government co-educational schools. However, the school environment often confounds research findings. Educational researchers often fail to adequately address the fact that single schools are often private and have higher socioeconomic groups of students attending them. The higher achievement of students in the single schools could be simply because a majority of them comes from upper class background.

A considerable amount of literature has concerned itself with the unique position of teachers on students on student's scholastic achievement and the relationships between characteristics of the instructional staff and academic performance. Thus, the National policy on Education (NPE), in recognition of the positive relationships between the quality of teachers and quality of education given to children, states that 'no education system can rise above the quality of its teachers (Federal Republic of Nigeria, 2004). The role of teacher in academic achievement especially physics cannot be overemphasized. Physics as some students perceive it, is an abstract subject that requires imagination, observation, calculation and explanations. The teacher has always been someone who instructs others or provides activities, materials and guidance that facilitate learning in either formal or informal situations (Olaoye, 2005). In fact, studies have shown that teacher's quality is the most important educational input predicting student achievement. Goldhaber (2003), defined teacher's quality as a teacher's quantifiable ability to produce growth in student achievement rather than by the individual qualifications or attributes a teacher brings to the classroom. For the fact that teachers serve as role models in the classroom, teacher quality has historically been synonymous with personal traits such as high moral character and intellectual curiosity. Teachers and School Principals are the most expensive and possibly the most critical components in establishing quality in educational system. New and more effective approaches to the preparation, development, utilization, compensation and conditions of service for teachers accompanied by more effective school leadership are therefore necessary in achieving higher standard of quality in secondary education in Africa. Interest in student performance and teacher qualifications has been intensified among education policy makers and researchers. Some past research studies (Ferguson, 1991; Ferguson, 1998; Goldhaber and Brewer, 2000; Mayer, Mullen, and More, 2000) links student's achievement to the qualifications of teachers. Students' learning in the classroom has been associated with teachers' knowledge and ability (Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld and York 1966; Ferguson, 1991). Murname (1975), tested whether some teachers on average produced better test – score gains among their students than others, even after taking account of variations in the standard measures of teacher qualifications and other factors. He found strong evidence that teachers did vary systematically in the rates at which their students' achievement improved over time. Numerous studies since that time have replicated Murnane's findings that teachers do vary in quality in ways that cannot be explained by credentials, education, and the like (Goldhaber, 2002; Walsh, 2002). There is no disputing the need for a teacher to know his or her subject matter.

In the school the Principal is basically responsible for the quality of the curricular and instrumental programme. Most scholars believe that school principal's influence on students' learning and achievement is indirect. This is because the Principal's influence on students' learning and achievement is through the teachers. If the Principal provides conducive atmosphere that is necessary for the teachers to carry out their duties, students' achievement in school subjects may also be positively influenced. The direction of the relationship is likely to affect students attitude to learning and hence their achievement.

Student's poor performance is traced to the absence of instructional materials for effective teaching – learning in most schools. This has limited teachers to constant use of the talk and chalk method in the classrooms (Adeyegbe, 1988). Some researchers and educationist making contribution to the state of educational facilities in Nigerian schools noted that schools have become an eyesore because of poor quality of the buildings and the non-existence of essential teaching learning facilities like libraries, and laboratory equipment (Obanya, 1982, Awomole & Adeyegbe, 1995). The present study is expected to provide empirical basis and add more to literature on this difficult situation in our classrooms and instructional materials. As the demand for science for all increases, so do costs – consequently successful laboratory teaching of physics will depend more on individual teachers' ingenuity and resourcefulness. Effective science teaching depends largely on the teacher and availability of equipment (Adeyegbe, 1993, Bajah, 1995; Osokoya, 2002). If learning in schools is to be facilitated, it is necessary that teachers should be adequately provided with instructional materials (Obemeata, 1995). Onocha (1985) rightly observed that when parents provide academic material needs for their children, they are likely to improve their scholastic performance in science subjects. Parental engagement is probably as or more important than the school.

Maccoby and Jacklin (1974), in a review of sex differences, discussed six cognitive areas in which such differences have been documented among early adolescents. They were not certain of the extent to which such differences between the sexes can be linked to any of the measured traits. There is a large overlap between the distributions of scores for the two sexes. The first area for which differences have been documented is general intelligence. Females perform better on general IQ tests during the pre-school years, but males perform better in high school. After age 10, gender differences in verbal ability are not large, but females perform better in grammar, spelling and word fluency. Gender differences have been noticed in number ability. According to Haertel et al (1981), no gender differences are apparent in the early years, but by high school age (approximately 14), males do better at arithmetical reasoning. Also males consistently outperform females on tests of spatial ability; this difference persists from the early grades through high school. It was discovered that males' average scores on the mathematical scale on Scholastic Aptitude Test (SAT) scores were above females' average scores. Walberg (1969) examined possible discontinuity between the attainment of eminence in science and the traditional feminine role model. He administered intelligence and achievement tests in addition to activity and personality inventories to about 1,800 Harvard Project Physics in grades 11 and 12 and found that girls scored higher on three or four cognitive variables (all of which emphasize verbal factors): IQ, Scientific Processes Inventory, and the Test of Understanding Science. Boys scored higher on the physics achievement test, which stresses quantitative and spatial abilities. On a semantic differential, girls score significantly higher than boys on social aesthetic and religious-value scales. Boys scored higher on economic, political and theoretical measures. On personality measures, girls scored higher in needs for affiliation and change, and lower on Dogmatism. Girls perceived the psychosocial climate of physics class as more satisfying, egalitarian and intimate than did boys.

The investigators contends that any meaningful and concerted effort to enhance more participation and higher achievement in physics should be sensitive to school factors such as school type, gender, teacher's qualification, school principal's area of specialization and physics learning resources. This is because these variables have been identified to effectively influence performance in physics. However, the literature indicates that the earlier studies did not take many of the variables together at the same time in a particular study. Also the data analyses employed have not been able to determine and establish the sequence, direction and strength of interactions among the school factors and achievement in physics.

PROBLEM

The study sought to construct and test a six-school-variable model: School type, Gender, Teacher's Qualification, School Principal's area of specialization, Learning resources and Achievement in physics of Senior secondary three physics students' academic achievement in physics. More specifically, it provided answers to the following questions:

- What is the most meaningful causal model (involving the listed variables?
- What is the direction as well as estimate of the strengths of the causal paths of the variables in the model?
- What are the direct effects of the variables on achievement in physics?
- What proportion of the total effect is (i) direct (ii) indirect?

METHODOLOGY

Sample

The subject consisted of twenty-two (22) physics teachers (all males), twenty-two (22) school principals (21males, 1 female) and 330 students (167 males and 163 females) that were selected on the basis of stratified and purposive sampling procedures.

Instrumentation

The instruments used in this study are :

- Physics Learning Resources Questionnaire (PLRQ). Cronbach coefficient value = 0.74
- Physics achievement Test (PAT). Test-retest value = 0.78.
- Principal Area of specialization Questionnaire (PAOSQ).
- Physics Teacher Questionnaire (PTQ).

Data Collection and Analysis

The investigator and two research assistants directly participated in data collection exercise, which lasted for seven weeks. Data analysis employed the two closely related multivariate analytical techniques: Multiple regression (backward solution) and path analysis.

RESULTS

The hypothesized model (figure 1) which shows the path coefficients and the zero order correlation coefficients (in parenthesis) provides twelve (12) paths. Using the criteria of significance and meaningfulness, only five out of the twelve- (12) paths survived. The hypothesized model was therefore trimmed to produce a more parsimonious model (Figure 2).

To verify the efficacy of the more parsimonious model, the reproduced correlation coefficients were compared to the original coefficients. The correlation matrix is presented in Table 2.

Table 2: Correlation Matrix for the Model

Variable	1	2	3	4	5	6
1. School Type	1.000	-0.092	0.188	0.092	0.128	-0.065
2. Gender	-0.092	1.000	-0.082	0.041	0.033	-0.256
3. Teacher's Qualification	0.188	-0.017	1.000	0.341	0.152	0.105
4. Principal's Area of Specialization	0.064	0.066	0.340	1.000	0.056	0.005
5. Physics Learning Resources	0.025	-0.002	0.132	0.045	1.000	0.128
6. Achievement in Physics	-0.083	-0.243	0.008	0.002	0.133	1.000

Note:
Significant at $p< 0.05$.

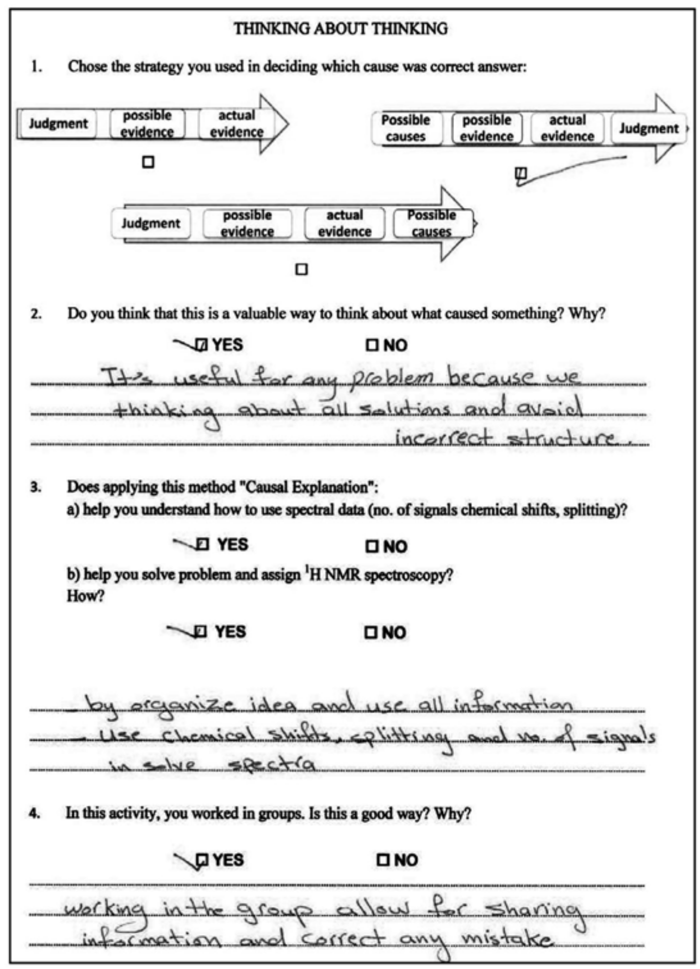
Entries above the diagonal are original correlation coefficients while entries below are reproduced correlation coefficients.

From Table 1, the discrepancies between the original and the reproduced correlation are considered very small (since the discrepancies are less than 0.05). This is an indication that the pattern of correlation in the observed data is consistent with the new model. The parsimonious model is therefore considered tenable in explaining the causal interaction between the predictor variables and the criterion variable. Figure 2 is considered to be the most meaningful causal model.

The pathways are significant and meaningful as well as have a link with the criterion variable (var. 6). The beta weights are associated with these pathways (path coefficient) provide the estimates of the causal paths of the variables. Out of the five significant and meaningful pathways through which the predictors cause variation in the criterion, only 2 are direct while 3 are indirect. The two direct paths are associated with school type (var. 1) and students' gender (var. 2). The total effects (direct plus indirect) of all the five predictor variables are shown in table 3. The table also shows the proportion of the total effect that is direct and indirect respectively.

DISCUSSION

It would also seem that school type is a potent predictor of senior secondary school student's achievement in physics, as it exerted a direct and significant influence on students' achievement in physics. This finding is in support of previous findings of Lee and Bryk (1986); Carpenter & Hayde (1987); and Ariyo, (1995). This may be due to the fact that availability of human and


THINKING ABOUT THINKING

1. Chose the strategy you used in deciding which cause was correct answer:

Judgment → possible evidence → actual evidence ☐

Possible causes → possible evidence → actual evidence → Judgment ☑

Judgment → possible evidence → actual evidence → Possible causes ☐

2. Do you think that this is a valuable way to think about what caused something? Why?

☑ YES ☐ NO

It's useful for any problem because we thinking about all solutions and avoid incorrect structure.

3. Does applying this method "Causal Explanation":

a) help you understand how to use spectral data (no. of signals chemical shifts, splitting)?

☑ YES ☐ NO

b) help you solve problem and assign ^{1}H NMR spectroscopy? How?

☑ YES ☐ NO

- by organize idea and use all information
- use chemical shifts, splitting and no. of signals in solve spectra

4. In this activity, you worked in groups. Is this a good way? Why?

☑ YES ☐ NO

working in the group allow for sharing information and correct any mistake

Table 3: Proportions of Total Effects of the Predictors that are Direct and Indirect.

Variable	Total Effect (T.E.)	% Relative to T.E	Direct Effect (D.E.)	% Relative to Total T.E.	Indirect Effect (I.E.)	% Relative to Total I.E.
5	0.128	22.898	-	-	0.128	44.755
4	0.005	0.895	-	-	0.005	1.748
3	0.105	18.784	-	-	0.105	36.713
2	-0.256	45.796	-0.251	69.916	-0.005	1.748
1	-0.065	11.628	-0.108	30.084	0.043	15.035
	0.559	100%	0.359	100%	0.286	100%

material resources differs across school types. The findings suggest that the management of schools where students have poor performance in physics should borrow leaves from factors that make students succeed in other excelling school type.

Student gender was found to predict students' achievement in physics as it also has a direct effect on achievement in physics. The empirical finding is not unexpected considering the fact that other researchers (Erinosho, 1992; Mbano, 1997; O' Counor, 2001; Lenga, 2001) have shown that gender had a significant effect on students' achievement in physics. It thus follows that teachers, Guidance Counsellors, parents and guardians should endeavour to encourage girls to study science. Presently, male students out number their female counterparts in physics enrolment as the investigators had observed from the field of study. The government could motivate females by providing scholarship grants for those of them who desire to offer physics or related course at the tertiary level.

CONCLUSIONS

A major finding of this study is that two out of the predictor variables (School Type & Gender) had both direct and indirect effects on senior secondary school students' achievement in physics while the remaining three variables (Teacher's qualification, Principal area of specialization and Learning Resources) only had indirect effect. The rank in which the predictor variables contribute in totality is shown below; $X2 > X1 > X5 > X3 > X4$

The implication is that curriculum planner / policy makers should fill the gaps existing across the available school types in the country. This knowledge in effect would encourage positive academic competition among Nigerian secondary schools. Conclusively, physics teachers should note the various linkages in the new parsimonious model (figure 2) since these could provide a strong basis for promoting gender equity and high achievement in physics. Teachers should then understand that boys and girls perceive physics learning in different ways.

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ANNEX

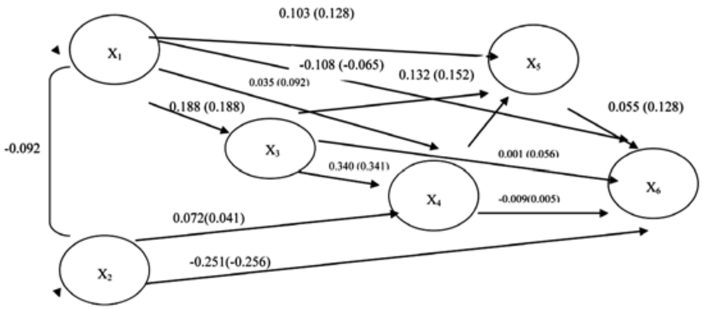

Figure 1. Hypothesized recursive path model (12 paths) of a six – variable system showing: (i) Path Coefficients and (ii) zero order correlation.

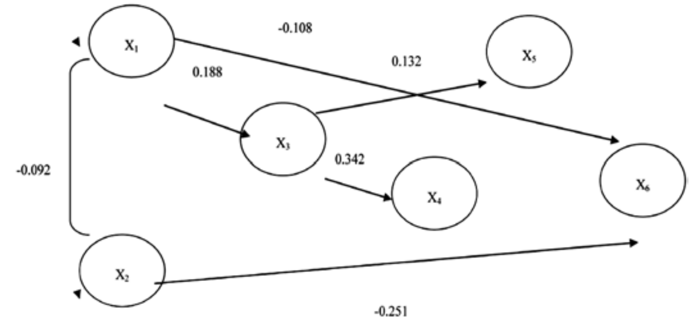

Figure 2. The New Path Model (5 paths) of a Six variable System.

Key

X_1 = School Type
X_2 = Gender of Student
X_3 = Teacher's Qualification
X_4= School Principal Area of Specialization
X_5 = Learning Resources
X_6 = Achievement in Physics

X_2 = Gender
X_3 = Teacher's Qualification
X_4 = School Principal Area of specialization.
X_5 = Learning Resources
X_6 = Achievement in Physics.

Quimiludi: virtual didactic application on the alkanes classification

Quimiludi: aplicación didáctica virtual en la clasificación de alcanos

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Abstract

The article presents the results of the research on design and application of educational software QUIMILUDI as a resource of the teaching-learning process of the alkanes classification and the alkanes formulation on the secondary education. This educational tool is designed in order to improve the student's interest towards this subject and also their classification knowledge. The software was designed based on Courselab and it shows a sequence of slides with all the interactivity on the subject of chemical classification. The results show that the virtual methodological strategy for teaching and learning of classification and formulation of the alkanes, based on QUIMILUDI, has contribute to improve the cognitive, procedimental and attitudinal aspects of the chemistry course students.

Key words: *teaching, organic classification, educational software, ICT.*

Resumen

El artículo presenta los resultados de la investigación en el diseño y la aplicación de QUIMILUDI software educativo como un recurso del proceso de enseñanza-aprendizaje de la clasificación de alcanos y la formulación de alcanos en la educación secundaria. Esta herramienta educativa se ha diseñado con el fin de mejorar el interés del estudiante hacia este tema y también sus conocimientos de clasificación. El software fue diseñado sobre la base de CourseLab y muestra una secuencia de diapositivas con toda la interactividad en el tema de la clasificación de productos químicos. Los resultados muestran que la estrategia virtual metodológica para la enseñanza y el aprendizaje de la clasificación y formulación de los alcanos, con base en QUIMILUDI, ha de contribuir a mejorar los aspectos cognitivos, procedimentales y actitudinales de los estudiantes de química del curso.

Palabras clave: *enseñanza, clasificación orgánica, software educativo, las TIC.*

INTRODUCTION

The subject of classification and formulation of the chemical compounds have several difficulties for the students (Montagut Bosque, P. 2010), some of them are:

a. Difficult terminology and sometimes confuse.
b. Some students' books do not show a good explanation of the subject.
c. Many times, the methodology used by the teacher is theorized without a good quantity of examples.

In the traditional chemistry teaching, the teachers use the common tools as expositions, workshops, activities on the notebooks, the board, and others, but many times it is difficult to achieve good understanding and learning of this material of organic chemistry. Also, it use different active teaching tools, for example, the educational games, (Palacios.2006; Franco, Cano 2007).

As itis known, the educational software of good quality can help to the teacher and the chemistry student in the teaching process (Orlik 2002). One of the reasons which promote the use of the computer in the education is the interaction about the machine. The computer produce the control sensation, the pleasure to think and to do that something happens, a pleasure that itis not easy in other kind of learning. (Galvis, 1992).

It exists a wide range of software educational programs that have been designed for the improvement of teaching and learning process on chemical issues, specifically on classification and formulation of organic compounds, between them, the alkanes. This software can be classified by groups according to the aim that is needed, as:

- This one that was thought for modular models in 2D and 3D. It permits the development of the spatial thought applied to the molecules structure. It used to be use in advance courses where the students have the skills for subjects like basic organic classification. Some chemistry courses of organic chemistry and biochemistry exists a wide reference of this kind of educational software in several studies, one of them emphasized on the goods of RasMol as a display of complex molecules. (Garcia Ruiz, Valdez-Velazquez & Gomez-Sandoval, 2008).
- This one that is integrated with other resources that give the TIC as audios, videos, interactive boards etc., an experience of this kind of inclusion of the Windows Movie Maker software in the chemistry curriculum in

order to generate meaningful learning in the studies of chemistry history (Sá Menezes, Frazão, & Kalhil, 2010).

- This one that works as a simulator in the laboratory and can do a lot of virtual experiences as VlabQ, Chem Lam and systems of recollection and analyses of data as LabVIEW o Molvilab.
- This one that is been designed exclusively for specific chemistry subjects such as this research, in this sense we can find software designed for subjects as the balance of chemical reactions, study of gases, chemical, chemical balance, electrochemistry, atomic theory, periodic table between others. It has been found several and interesting resources about the organic compounds classification, one of them is the Organic Nomenclature (Shaw, 2001)

The main objective of this work is to design and to implement an educational software that helps the assimilation of classification rules and formulations of alkanes, and permits the students to go forward in their learning in order to be responsible of their own process and to develop it in an autonomous way according to their own timing.

What is intended with this educational software is to complement other teaching-learning media and materials and to develop in the students the self-management skill.

THE SOFTWARE DESIGN

Itis known two possible approaches for the educational activities supported with the computer, the first one is algorithmic approach and the second one heuristic approach.

The algorithmic approach permit to resolve problems well-defined (Orlik 2002), thatis why itis necessarily to know which are the initial and final situations such as the different intermediate levels of the process. When this kind of problem solving is brought to the field of design educational software, it is possible to transform it in a way of behavior of teacher and students.

As the name suggests this is to define and perform predetermined sequences of activities that, when it succeeds in assumptions about the input level and expectations of receivers and when carrying out the activities as expected, lead to achieving Goals also predetermined. The algorithmic approach has the merit of giving structure and precision to what wouldotherwise be a tangled and confusing process, and capturing such precision so that it is reproducible.

The heuristic approach, in turn, allows learning process by sudden insight from experiential and conjectural situations, by the discovery of what someone is interested to learn, not through the transmission of knowledge.

To promote this learning by discovery is not enough to have heuristic devices that enable the experience underlying physical or mental experiences made by the student. It is necessary that the teacher encourages the development of self-management skills (Cardona. 2006).

Teachers who incorporate an educational software activity must feel comfortable with it and master it, so it should not have any fear about its use. The students must learn to use it skillfully in order to focus all their attention on the performance of the proposed tasks.

The interaction between the user and educational software is through the input and output devices to make available the program and intercom systems that have been provided for the user to express their decisions to the computer. As it is essential to clearly define the following communication variables (Franzolin, 2006):

- Input Devices
- Input Interface
- Exit Devices
- Output Interface

The program chosen for the design of the educational software is CourseLab, this is a free download, free software, which has great strength and whose management is relatively easy after a proper instruction. In the following Web site you can learn everything about this software and you can be downloaded and used freely http://www.courselab.com/.

This software has the general structure of power point but with additional features of advanced programming. The program allows you to design a sequence of slides with all the interactivity that the programmer wants and is able to sequence.

Using formats designed for planning software will give structure to itself by scenes that properly articulated carrying students to develop expected competences in an interactive way, many navigation systems allow the students go forward or backward in the content in an easily way. The following are some scenes that characterize the QUIMILUDI software.

The figure 1 shows how one of these slides has been designed in order to work as one of three ways to surf by the software:

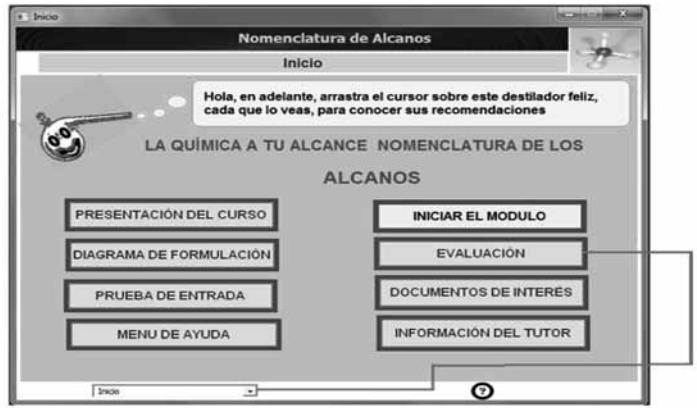


Figure 1. Surf buttons for the course.

Figure 2 allows you to view one of several activities that you can work with QUIMILUDI, what is sought here is that students know the main alkyl radical relating them with application examples and seeing their usefulness in the nomenclature.

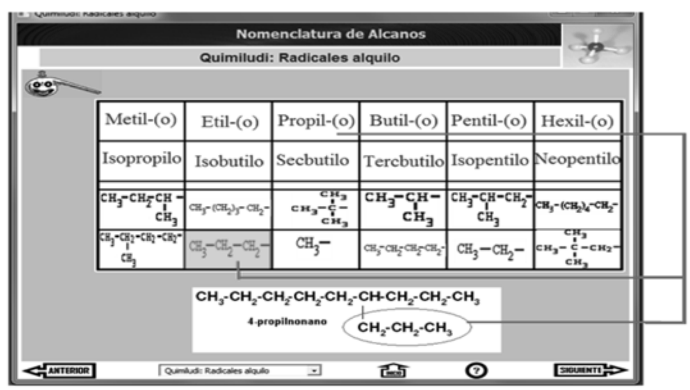


Figure. 2. Model of activities with Virtual QUMILUDI

METHODOLOGY

The teaching experiment was conducted with high school students who start the curriculum program for the eleventh grade in formal education in Colombia.

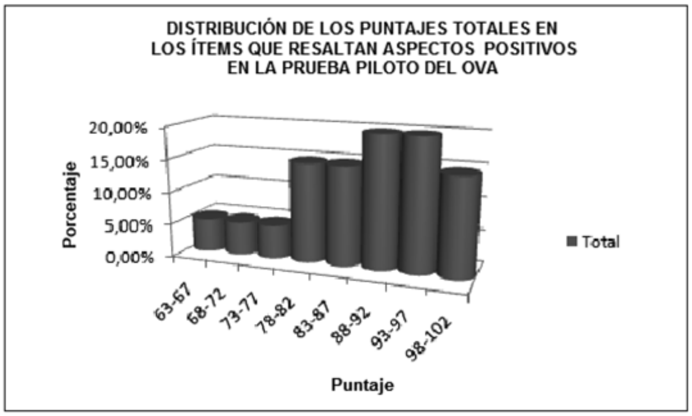
The sample consisted of 38 students of 1101 grade at "Institucion Educativa Compartir" School JT , which we will work with the designed software, with all the assessment tools developed for this this purpose, since in accordance with the hypothesis, and the premise that action -research does search primarily, the production of new knowledge, but the improvement of educational practice. It is expected to prove that academic performance in this group be improved with the implementation. Only at the end, with the aim of having a benchmark in order to compare with the rest of the population of the municipality of Soacha, Cundinamarca, Colombia, it will be applied a multiple choice test as applied on the state level, both experimental and two control groups, the control group are: 31 students of 1101 of "Institucion Educativa Compartir" School JM and 40 of the 1103 level of "Institucion Educativa Integrado de Soacha" School JM. What is sought here is to compare the level of competence shown by students, which formed under different methodologies faced with this type of test, and if the experimental group obtain a higher level in the results of them.

The following hypothesis can be formulated: implementing a virtual innovative methodology of teaching and learning of the alkanes classification generates learning processes that promotes academic achievement shown by students in their cognitive , procedural and attitudinal components.

RESULTS

Software evaluation by experts. It has requested the collaboration of three professionals with reconignized experience and high fitness, so that through this virtual instrument value the virtual recourse from their specialty. The contributions and suggestions made by these experts has led to the publication of a second version which includes the changes.

Pilot testing (Annex 1): Applied to 20 students from pre-university course(Centro de Asesorias Integrales) where the teacher-researcher works part-time ,want to recognize strengths and weaknesses of virtual resource which, together withthe contributions made by experts , let make adjustments and ensure a quality educational software. This test was applied to 20 students with the following results:



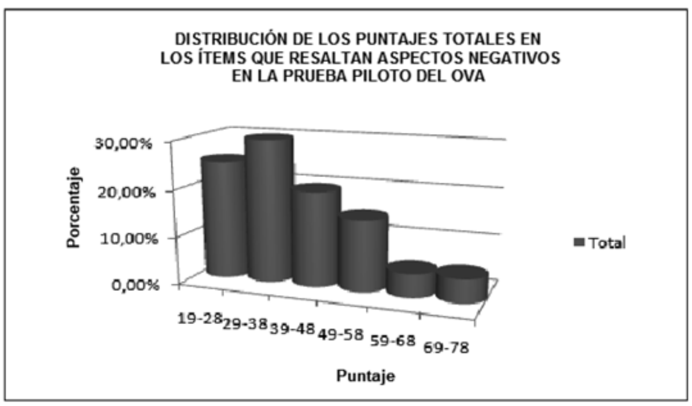


Figure 3. Results of the pilot implementation

These data were applied the index of internal consistency Cronbach alpha, providing an index of 0.91, indicating a "Very High" consistency in the 37 items that inquire.

From the above data may be perceived that:

- For questions that stand out positive aspects, a large proportion is occupied by the limits between 80 and 100 points, showing the acceptance of the designed computer resources.
- The questions that stand out negative aspects, a large proportion is occupied by the boundary between 20 and 50 points, showing dissatisfaction with the designed computational resource.
- The graphics on the left panel show high percentages on the students who accumulate high scores on the sum of the items of the answers to questions that explore positive aspects of educational software, while right panel, high percentages of students accumulate low scores in the sum of the items of the answers to questions that inquire unfavorable aspects of educational software, which is interpreted as greater acceptance of those respondents about this virtual resource.
- The high rate in TA, A, I in question No. 4, 8, 12 and 19 has led to rethinking the response system in order to encourage more the feedback from the evaluated contents in the educational software.

As a result we have obtained an educational software that satisfy the purposes for which it was created, it has two ways of surfing, diagnostic test, audio explanations when it is required, interactivity, web resources when it is possible to use the network , innovative activities, feedback systems, evaluative test with different types of questions using summative system. This educational software can be distributed in an executable format on CD or you can upload to an LMS (Ortiz. 2007) in SCORM format. We have overcome many obstacles and others have not been overcome, probably they even have not been identified and only with the start-up with the students we could notice them, we will take careful note and we will correct, supplement and improve them in order to give an improved version.

The information provided by the instruments were triangulated with information obtained from all assessment tools, with a film record, the interview and survey, in order to give them the appropriate statistical treatment.

DISCUSSION

The results have validated the hypothesis, this virtual methodological strategy for teaching and learning of the classification and formulation of alkanes, based on QUIMILUDI, has helped to improve the cognitive, procedural and attitudinal aspects on level 1101 in the " Institucion Educativa Compartir" School.

The software has been successfully implemented, there were some problems, expressed by some students regarding the use of virtual resources extra-class because they had not had the equipment or resources all of the time. Therefore, they received a timely solution. There is a part of victory because both qualitative and quantitative resulted . For a final corroboration, we compared the performance of this group with two eleventh level groups, one from the morning schudule and another from another school of the neighborhood, in the solution of a test with multiple-choice questions, the results are also favorable.

The complete software has been reviewed by fellow teachers of chemistry, by a skilled professional and has worked in the pilot test in a group of senior high school and was tested in middle school in eleventh grade, target group for which it was thought. Most of the suggestions received were addressed and given timely solution (fonts, color scheme, some adjustments in the chemical formulas, etc.). Clearly, for a teacher, to make quality educational software, it becomes a difficult but an exciting challenge.

There are many obstacles that have to be overcome, at times tempers tend to go down and that is where it should dominate the proactive attitude and the spirit of research of the teacher who never let him fall into routine.

CONCLUSIONS

The application of soflware QUIMILUDI on the issue of classification and formulation of the alkanes in eleventh level, let to consolidate a learning environment that gives solution to the problems initially identified and gave rise to this work. This study provides new knowledge to specific teaching of Science Chemistry, putting on stage QUIMILUDI as a virtual resource innovator that both real mode and virtual classroom promoting the teaching and learning of some content otherwise, the classes are tedious and meaningless to students. It is proposed to implement this teaching unit in the curriculum of the institution, disclose it at the municipal level through the website of your Secretary of Education and through local workshops with teachers in the area. It also proposes the design and implementation of new versions of software covering other topics of chemistry and thus be in accordance with the principles of action- research that has guided this work, in the sense of using the results of the investigation, spearhead to take another larger, thus the spiral that keeps the existing teacher-researcher, critic and active, away from the temptation of stagnation.

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Tool for improving students' knowledge of the combinatorial properties

Herramienta para mejorar los conocimientos de los estudiantes de las propiedades combinatorias

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Abstract

Based on a previous research (Garcia, O., 2006) where it was proved that students can find combinatorial theory properties, we designed questionnaires with a structured set of problems to guide students towards this objective. These questionnaires were applied to students who were selected to participate in the Colombian Mathematics Olympiads. They have to solve first and second level mathematics problems. They were also being trained for an international competition. This paper's objective is to identify and analyze the unusual solutions to combinatory problems made by a student who had an outstanding performance in international competitions; then, an analysis of his subsequent performance as a student will be presented. The study, thus, covers four years.

Key words: *unusual solutions, Mathematics Olympiads, trained student, combinatorial problems.*

Resumen

Sobre la base de la investigación (García H., O., 2006) en la que se mostró cómo los estudiantes pueden descubrir propiedades de la teoría combinatoria, se diseñaron cuestionarios con un conjunto estructurado de problemas que guiaban a los estudiantes al objetivo propuesto. Estos cuestionarios se aplicaron a estudiantes seleccionados y entrenados en la resolución de problemas matemáticos de primero y segundo nivel de las Olimpiadas Colombianas de Matemáticas quienes estaban en un entrenamiento para una competencia internacional. El objetivo de este trabajo es identificar y analizar las soluciones inusuales a problemas de combinatoria, por parte de un estudiante de secundaria que en el año 2006 fue identificado como un gran triunfador en competencias académicas de matemáticas a nivel internacional para luego realizar un informe sobre su actuación posterior como estudiante. Es por ello que el estudio de este caso se muestra, en este trabajo, cuatro años después.

Palabras clave: *soluciones inusuales, olimpiadas de matemáticas, entrenamiento de estudiantes, problemas de combinatoria*

INTRODUCTION

Mathematics teaching through problem solving has been used systematically and successfully in the Colombian Mathematics Olympiads since the 1980s. In this article we will show that a student who has participated in this competition obtains very good results in his subsequent academic life, as posited by Barratt (1975). The training in combinatory problems in 12-15 years old children produces a higher level of success in older students.

For the present study a set of problems in questionnaires were designed to be solved with open answers to see the development of the answers. The themes included in the questionnaires had uncommon questions for high school and even university students like permutations and combinations with repetition. These questionnaires start with problems where the student must do systematic counting, while designing a way for solving the problem. The following problems have the goal to make the student go from a trial and error to an algorithmic procedure. At the end, the student will find problems in which he is supposed to generalize the combinatory principle.

The student of this study was in 10^{th} grade and was 15 years old when he presented the test with the questionnaires. He was selected for the solutions he gave to the problems. It is interesting to note the solution he gives to the last problem, because when trying to solve it, he discovers a very important combinatory property that was not stated in the problem; the student finds it and uses it to solve the problem.

At the end of 2010 the student is still in the academic team of the Colombian Olympiads and is double majoring in Mathematics and Electronic Engineering with an almost perfect GPA of 4.91/5.0. He is 19 now and will graduate at the end of 2011. The student affirms that a good part of his success is due to the training he received in problem solving. Four years ago, when he was taking the tests the basic theory of the problems he was facing was unknown to him almost in its entirety; despite that, he answered almost all the questionnaire correctly and in some cases with uncommon and impressive solutions for his age and school level.

The application paper developed then (Garcia, O. 2006) consisted on proving if some students who have never seen combinatory theory could generalize some counting principles solely through problem solving techniques.

METHODOLOGY

The first part was the analysis of the quantitative and qualitative answers the student gave to each question. The second part was to follow the student subsequent academic performance through an interview.

The student information by the time of the test was:

A year of training by the Colombian Mathematics Olympiads team.

His knowledge in combinatory theory was very scarce, until he arrived at the Olympiads in Mathematics team at Antonio Nariño University. There, he was trained in problem solving, while learning new themes in mathematics. Up to that moment he had participated in two international competitions: IMO (International Mathematics Olympiads) in 2005 and OIM (Iberoamerican Mathematics Olympiads) in 2006, with an honors mention in the latter. At the time the student was outstanding in the Colombian team.

RESULTS AND DISCUSSION

Here we present the problems with their corresponding solutions; we want to highlight the solution to the last problem:

1. There are 3 red balls and 2 blue balls in a bag. You want a line with all of them. ¿How many possible lines can you arrange?

The goal of this problem is to have the student do systematic counting, and see a general way of solving the problem.

1. A chess player wants to put two white pawns, 4 black pawns, and the two black rooks in a line ¿In how many ways can she do it?

The goal of this problem is that the student starts moving from a trial and error to an algorithmic procedure and, thus, looks for a non systematic procedure in the formation of the permutations with repetitions.

1. We have n objects in k classes so that there are n_1 objects that belong to one class, n_2 objects that belong to a second class, n_k objects that belong to a k-th class, where $n_1+n_2+\ldots+n_k = n$. Find the number of arrangements of these objects in a line.

Does the author mean:

1. Here we try to get the student to generalize using the permutations with repetitions principle.

The solutions for these problems given by the case student were:

Solutions one, two and three

1. If all balls were different the answer would be 5!, but since there are 3 red balls and two blue balls we are counting 3! * 2! Times each combination,

thus, they are: 5!/3!2! = 5*4/2 = 10

2. As in the previous one, they are:

$$\frac{8!}{2!\,4!\,2!} = \frac{8*6*7*5}{2*2} = 6*7*5*2$$

3. The same as before $\frac{n!}{n_1!\,n_2!\,...\,n_k!}$

We verify that the student has a great counting ability, since he didn`t even use systematic counting. That is, he goes straight to find a systematic and algorithmic procedure to solve the problems; consequently he generalizes the result when using the variable and a proper notation for this kind of problems. On the other side, although the student did not know the formula, he could deduce it.

1. ¿How many solutions to the equation x + y = 6 in positive whole numbers (remember that whole numbers are 1, 2, 3, 4,…) are there?
   Here we are looking for two things, first, we want the student to do a systematic enumeration and if he solves problems 4 and 6, apply this same procedure in the solution of this kind of problems.
2. ¿How many solutions to the equation x + y + z = 8 in positive whole numbers are there?
   The goal of this problem, as all second problems of each class, is to go from systematic counting to an algorithmic procedure.
3. ¿ How many solutions to the equation x + y + z + w = 10 given in positive whole numbers x, y, z, w are there?
   The goal is that the student proves his algorithmic procedure since he must have found it in the previous problem.
   Let k and m be whole positive numbers with k ≤ m How many solutions formed by whole positive numbers of the are there?
   $x_1 + x_2 + x_3 + ... + x_k = m$

The objective here is to generalize the principle, fixing one or more variables and giving an appropriate notation.

These are the solutions given by the student:

1. For each x between 1 and 5 there is only solution for y, thus there are 5.
2. With x = k, for fixed k, it is the previous exercise; so one just have to take a look at the results for each k between 2 and 6:
   $$6+5+4+3+2+1 = \frac{6*7}{2} = 21$$
3. With x = k, it is the previous exercise:
   $$\frac{7*8}{2}+\frac{6*7}{2}+\frac{5*6}{2}+\frac{4*5}{2}+\frac{3*4}{2}+\frac{2*3}{2}+\frac{1*2}{2}$$

The same as before, one just varies the x value, between 1 and m – k + 1 and see all the cases.

We can see that in problem 4 the student did not even have to do systematic counting, he simply observes the range of each variable.

For exercises five and six we can see that the student did not do systematic counting, he uses the result of the previous problem and then he goes to an algorithmic procedure to try and look for the generalization of the solution, something very unusual in the normal solution of these kind of problems; besides, we have to note that he does not use the combinations notation, for he does not know it and the result he gets is $\binom{n}{3} - \sum_{i=3}^{n}\binom{i-1}{2}$, which is equivalent to $\binom{n}{k} = \sum_{i=k}^{n}\binom{i-1}{k-1}$. As can be seen, it is a solution different from all the rest and at the same time an outstanding deduction of this little known property.

He knows the generalization and he enunciates it without the formula, since he does not know the combinations notation, which is really impressive.

Four years later, in an interview with the student we could obtain the following information:

He started his training in problem solving in seventh grade. After finishing high school he started his university training; he is double majoring in Mathematics and Electronic Engineering; he plans to finish his studies by the end of 2011. Now he has an almost perfect GPA of 4.91/5.0 and he has not decided on a line of specialization, for he finds interesting all research fields in mathematics and does not find any field difficult. The student believes that the training and participation in the Olympiads were important for his formation as a mathematician, since he acquired very important problem solving abilities; that is the reason why he recommends students with good mathematics abilities to be a part of the Mathematics Olympiads team.

The student's record of achievements is:

Gold diploma in the 2008 XI Iberoamerican Mathematical Olympiad for University Students.
Gold diploma in the 2009 XII Iberoamerican Mathematical Olympiad for University Students.
Gold medal in the 2009 I Interuniversity Mathematics Competition.
Second place in the 2009 XVI International Mathematics Competition for University Students (IMC).
Silver medal in the 2009 XIII Colombian Mathematics Olympiad for University Students.
Silver medal in the 2010 XIV Colombian Mathematics Olympiad for University Students.
First place in the 2010 XVII International Mathematics Competition for University Students (IMC).

CONCLUSIONS

With this case study we can conclude, in general terms, that combinatory analysis, with its methods and concepts presents not only a defined mastery of mathematics but also expresses an operational scheme, an important structural prerequisite for the dynamics and the creative potential of logical reasoning.

For this student, we can conclude that the training in problem solving during high school guaranteed him a great academic success at the university and, obviously, in his professional future.

We can note that with the problem solving training the student acquired a more solid and critical formation to develop in more complex mathematical fields.

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All-Russian congress of teachers of chemistry

All-Russian congress of teachers of chemistry was held on 16-18 February 2012 at the initiative of the rector of the Lomonosov Moscow State University (MSU) - academician of RAS V.A.Sadovnichiy

The congress was attended 693 representative of the pedagogical public of different cities and regions of Russia, academicians of the Russian Academy of Sciences, representatives of the Ministry of education and science of the RUSSIAN federation, the Russian union of chemists, research institutes, editors-in-chief of the journal "Chemistry and life", "Chemistry in the school", "Chemistry: the 1st of September". In the delegations of the most active and indifferent to the problems of education of the Russian people - teacher of chemistry of secondary schools, teachers of chemistry higher educational institutions, colleges, lyceums, researchers, heads of departments, associate professors and professors.

The solemn opening of the congress took place on 16 February 2012 in the new palace of "Shuvalovsky". With interesting and informative report "ON chemistry and its teaching in secondary schools" was made by rector of the Lomonosov MSU, vice-president of the RAS, academician *V.A.Sadovnichiy*.

His speech "Chemistry is our life, our future" is the motto of the international year of chemistry-2011" devoted to the vice-president of the RAS, the dean of the faculty of fundamental physico-chemical engineering of the MSU, academician of the *S.M.Aldoshin*.

With the report "Cooperation of the union of lyceums of the central regions of the Russian Federation "the Russian lyceum" and the MSU on search and support of talented children" was made by the chairman of the Union of lyceums of the Central regions of the Russian Federation *P.V.Tariko*.

With salutatory words were made by: deputy Minister of education and science of the RUSSIAN federation *M.V.Dulinov*, the dean of chemical faculty of the MSU, academician of RAS *V.V.Lunin*.

17 February 2012, the congress continued its work in the form of a plenary session in the palace of "Shuvalovsky". At the plenary session were presented scientific reports and presentations.

1. *Lunin V.V.*- academician of RAS, the dean of chemical faculty of M.V.Lomonosov MSU - "QUALITY EDUCATION IS the BASIS of PROGRESS AND SUSTAINABLE DEVELOPMENT of RUSSIA".
2. *Golubkov S.V.* - vice-president of the Russian union of chemists, the head of the CJSC "Roshimneft`" - "CHEMICAL COMPLEX of RUSSIA".
3. *Strel`nikova L.N.* - editor-in-chief of journal "Chemistry and life. XXI century" - "CHEMICAL EDUCATION: BETWEEN the PAST AND the FUTURE".
4. *Moskvin S.A.* - excellent worker of education of the RSFSR, a teacher of chemistry of gymnasium N° 9 (Ekaterinburg, Sverdlovsk region) - "KIDS CHEMICAL EDUCATION".
5. *Orzhekovskiy P.A.* - head of the department of methods of teaching of chemistry of the Moscow institute of open education, professor - SCHOOL of CHEMICAL EDUCATION: PROBLEMS AND WAYS of THEIR SOLUTION".
6. *Popkov V. A.* - academician of RAE, professor of the First Moscow state medical university named after I.M.Sechenov - "PROBLEMS of PROFESSIONAL-PEDAGOGICAL THINKING AND COGNITIVE PROBLEMS IN CHEMICAL EDUCATION of school children".
7. *Levina L.S.* - editor-in-chief of journal "Chemistry in the school" - "CHEMISTRY IN the SCHOOL" - YESTERDAY, TODAY, TOMORROW".
8. *Usherov A.I.* - associate professor, Magnitogorsk state technological university named G.I.Nosov (Chelyabinsk region) - "The GOAL of the STUDY of CHEMISTRY IN the SCHOOL".
9. *Berkovich A.K.* - the senior scientific employee of faculty of chemistry of MSU - "ON ORGANIZATION of inter-regional ASSOCIATION of TEACHERS AND TEACHER of CHEMISTRY", and others.

In the evening in the lobby of a Large Chemical Audience was a reception in honor of participants of the all-Russian congress of teachers of chemistry.

On February 18, 2012, the congress continued its work in the lecture halls of chemical faculty of the MSU. At 10 a.m. the participants of the congress gathered in the Big Chemical Audience at the *workshop* "Modern achievements of chemical science". The chairman of this section was academician of RAS, the dean of chemical faculty of the moscow state university, professor *V.V.Lunin*. In the section with great interest listened the lecture.

"The BEAUTY AND CHARM of CHEMISTRY" - lecturer *A.L.Buchachenko*, academician of RAS, head of the department of chemical kinetics of the chemical faculty of MSU.

"BATTERIES of the FUTURE" - lecturer *E.V.Antipov*, corresponding member of RAS, head of the department of electrochemistry, chemical faculty of the MSU.

"NEW REAGENTS AND NEW REACTIONS IN ORGANIC CHEMISTRY" is a lecturer *N.V.Zyk,* honored worker of science of RUSSIAN federation, honored professor of moscow state university, head of laboratory of biologically active organic compounds of chemical faculty of the MSU.

After the break the participants of the congress were divided into 2 sections:

Section 1. "Educational-methodological provision of chemistry course in the school and textbooks on chemistry", co-chairmen of which were: *V.V.Eryemin* - professor, doctor of physico-mathematical sciences; *P.A. Orzhekovskiy* - professor, doctor of pedagogical sciences.

In the agenda of the work of the section was composed of the following *problems*: 1) the content of school chemistry course and its compliance with the new standards, 2) experience of teaching chemistry in the different educational systems, 3) the problem of correlation of school textbooks to modern level of development of science, 4) innovative methods of teaching chemistry, 5) use of information resources, 6) the practice of distance learning chemistry, 7) the professional education of chemistry, 8) implementation of the system-activity approach in teaching chemistry, 9) experience of achievement of the interdisciplinary, integrative results of the study of chemistry, 10) experience of research activity of schoolboys, 11) elective courses, 12) questions of quality of preparation of students in chemistry and problems of certification.

In the section were representatives of schools of Moscow, Bryansk, Volgograd, Ulyanovsk, Saransk, Irkutsk, Kaluga, Nizhny Novgorod, Yaroslavl, Kirov, St. Petersburg and other cities.

Section 2. Interaction of the secondary and high schools in the field of chemical education", co-chairmen of which were: N.E.Kuzmenko - professor, doctor of physics-mathematical sciences; G.N.Fadeev - professor, doctor of pedagogical sciences.

The section on the following issues were discussed: 1) the issues of quality of preparation of students in chemistry and problems of certification, 2) improving the training of teachers of chemistry, 3) the training of teachers, 4) quality issues of higher pedagogical education, 5) continuity of educational strategies "secondary school - higher educational institution", 6) additional education in chemistry, 7) various strategies to attract students in the chemical universities, 8) chemical olympiads and competitions among school children and students, 9) chemistry and objects of natural science, 10) the internet-community of teachers of chemistry.

The participants of the section were: the M.S.Pak (Saint-Petersburg), N.A.Belan (Omsk region), V.A.Emelyanov (Novosibirsk region), E.E.Minchenkov (Moscow), A.N.Kosheeva (Perm krai), L.V.Lebed` (Saratov region), A.A.Zhurin (Moscow), I.V.Myalkin (Nizhny Novgorod region), S.V.Pershina (Volgograd region), L.B. Pogorova (Ingush republic), I.A. Podshivalova (Moscow region), O.G.Rogovaya (Saint-Petersburg), E.I.Tupikin (Moscow), V.M.Shabarshin (Lipetsk region), E.G.Zlotnikov (Saint-Petersburg) , etc.

Total closing session of the congress was dedicated to the remarkable event in the social life of Russia. All-Russian congress of teachers of chemistry at M.V.Lomonosov Moscow state university was the founding congress of the inter-regional public organization "Inter-regional association of teachers and lecturers of chemistry" (IATLC – МАУПХ in Russian). The participants of the constituent congress were acquainted with the project of the Charter, the structure, the governing bodies of the IATLC and the order of management of the Association. Were nominated and approved by the candidates to members of the Presidium.

With the closing remarks at the closing of the congress was made by academician V.V.Lunin. He thanked the delegates for their active participation and expressed the hope that the congress will play an important role in the renewal of chemical education in Russia.

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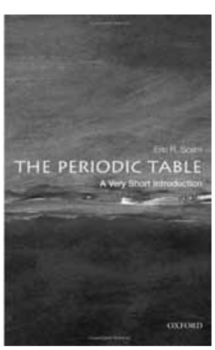
Book reviews



Eric R Scerri. The periodic table: a very short introduction. Oxford University Press, 2012.

The name of Eric Scerri is becoming indelibly attached to studies related to the Periodic Table and this latest book, although designated 'very short' provides a rich overview of the development of the Periodic Table. It provides a lively introduction to the debates and controversies of scientists (chemists, physicists and others) from the past and those that continue today. The author's personal enthusiasm for the subject and his wide ranging historical and philosophical perspectives are clear in the text and add greatly to the appeal of this book. This book should be on the reading list for all chemists, whether they be undergraduates or much more experienced. Science teachers will find the book a useful source of anecdotes and 'science stories' that provide valuable insights into 'the way science works' and the importance of commitment, debate, inventiveness and insight as well as experimentation and factual information.

I am not sure how accessible the book would be for readers who do not already have a substantial background and interest in the subject. The author's – somewhat optimistic – statement (p6) "… the appeal of the elements in the public imagination has now truly arrived" is based on the popularity of Primo Levi's 'The Periodic Table' and Oliver Sacks' 'Uncle Tungsten' as well as popular books by Sam Kean and Hugh A-Williams. I am not familiar with the work of these last two authors, but one could also cite the publications of John Emsley and Theodore W Gray. However, I still wonder whether this book would be attractive to the general reader.

Although restricted to 147 pages, including the index and numerous diagrams and illustrations, this book does not seem 'very short'. Most chemistry texts dispose of the background to the Periodic Table in a much more cursory manner before getting down the serious detail of the structure and reactivity of the elements and their compounds. During my three readings of the book I constantly came across unfamiliar nuggets of information that raised questions in my mind and suggestions about the Periodic Table some of which still make me uncomfortable – In the next section of this review I shall briefly describe the contents of each chapter and explore some of these issues.

1. **The elements;** explores the development of the *idea* of an element and the naming of elements.
2. **A quick overview of the modern Periodic Table;** beautifully sets the scene for the remaining sections of the book and many of the ideas are revisited in more detail in subsequent chapters.
3. **Atomic weights, triads and Prout;** introduces in some detail the ideas of Richter (equivalent weights), Lavoisier, Dalton, Gay-Lussac and Avogadro. I was surprised to read (p35) that Dalton never accepted the idea that diatomic molecules of elements could exist since he was convinced that atoms of the same element repelled one another. This seems to run counter to the fact that that most elements exist naturally in the solid state. The chapter ends by introducing Prout's suggestion that all atoms are made up from atoms of hydrogen and the beginnings of the organization of elements, initially into 'triads.

4. **Steps towards the Periodic Table;** I learned here that the first person to discover periodicity was De Chancourtois, a geologist (p43) who published his paper in 1862, 7 years before Mendeleef, but his paper did not contain a diagram and failed to make any impact on the chemistry community of the day. In 1863 Newlands (Law of octaves) began publishing and in 1866 his ideas were ridiculed at a meeting of the Royal Society. The work of Odling and Hinrichs is then described followed by that of Lothar Meyer. Since there was a priority dispute between Meyer and Mendeleef as to the Periodic Table it was fascinating to learn that Meyer produced a table in 1868 that was lost by his publisher, seemingly forgotten by Meyer, and not published until 1895 after Meyer's death. (Meyer and Mendeleef were jointly awarded the Davy Medal by the Royal Society for their work on periodicity of elements in 1882.)
5. **The Russian genius – Mendeleef;** The date of his discovery seems to have been narrowed down to 17th February 1869. This chapter summarizes material familiar from other texts but also explores his predictions and ideas that turned out to be mistaken. For example (p71) when argon was discovered, and before the group of noble gases was recognized Mendeleef initially argued that argon was probably a triatomic form of nitrogen since it was discovered in experiments with that gas from the air.
6. **Physics invades the Periodic table;** This chapter follows the impact of discoveries relating to radioactivity, X-rays, atomic number and isotopes and the famous names include, Einstein; Thompson; Röntgen; Moseley; Curie; Rutherford; Soddy and others.
7. **Electronic structure;** introduces the development of the quantum theory by Bohr and the requirements for three other quantum numbers by Sommerfeld and Pauli. This followed by the use of the *aufbau* principle to relate electronic structure of atoms of elements to the Periodic Table. We then return to the work of Lewis, Langmuir and Bury.
8. **Quantum Mechanics;** extends the discussion of the previous chapter to cover the contributions of Schrödinger and Heisenberg and the development of atomic orbital ideas.
9. **Modern alchemy: from missing elements to synthetic elements;** four 'missing' elements and 25 trans-uranium elements have been synthesized during the past 80 years.
10. **Forms of the Periodic Table;** In the period since Mendeleef's Table was published well over a thousand variants have been published although, it is argued, most of these involve only changing the shape of the table whilst conveying essentially the same information. There are however some arguments for some arrangements that I personally find quite challenging. The chemical arguments as to whether it is lanthanum or lutetium and actinium or lawrencium are in group 3 of an optimum version of the table are subtle. However, *only* when Lu and Lr are in group 3 do the elements remain in the order of atomic number – for me, this is the obvious option. Previously, I simply placed all the lanthanides and actinides in group 3! I find it difficult to consider seriously versions that place helium with the alkaline earth metals – even though these all contain two 2s electrons in the outer shell – outer shell for helium is full! I still have problems with the placement of hydrogen in group I (as in the standard IUPAC variant) and prefer to 'let it float' across the top of the second period of typical elements. After all hydrogen is unique in using *all* its electrons when its atoms combine. Dr. Scerri (p135) clearly considers this to be a 'cop-out' and an unwillingness to commit. He subsequently suggests that an organization of the table to maximize the number of 'triads' in place might help define the optimum placing of the elements. This would place hydrogen at the top of group VII. There are other arguments for this since hydrogen readily forms H^- ions with reactive metals, however I have yet to be convinced whether this suggested return to triads is chemistry or numerology.

The book is well presented in a convenient pocket-book format and seems to contain few errors. Two minor ones I noticed were firstly, on pages 48 and 68 reference is made to the Royal Society of Chemistry in the 19th century. I believe this should be The Royal Society of London – this certainly awards the Davy Medal annually. (The Royal Society of Chemistry was not formed until 1980 when The Royal Institute of Chemistry merged with three other UK Chemical Societies.) Secondly, we are told (p79) that "Moseley's experiments consisted of bouncing light off the surface of samples of various elements and recording the characteristic X-ray that each one emitted." In fact the samples were bombarded with an energetic stream of electrons (cathode rays.)

Overall this is an excellent text – all the better since it encourages the reader to reexamine her/his understanding and opinions. It is fully to be recommended to anyone with an interest in chemistry. I have just purchased a copy from Amazon UK for £4.71 – about $7US. Incredible value for money!

Alan Goodwin
Manchester Metropolitan University, UK

Eric Scerri is a lecturer in chemistry and in the history and philosophy of science at the University of California, Los Angeles. He has written and published more than 100 research articles, numerous book chapters, is featured in many online video & audio lectures, is the editor of the academic journal, *Foundations of Chemistry*, and has edited or written six books. His 2007 book, *The Story of the Periodic System: Its Development and Its Significance* earned him UCLA's Herbert Newby McCoy award, which honors significant contributions to the science of chemistry. *The Periodic Table: A Very Short Introduction* is Dr Scerri's sixth book. Visit Dr Scerri's website.

Utopia looking for the possibility: interdisciplinary approaches for natural sciences teaching

The eighteen papers of this book (in Portuguese) were orally presented at the Latin American Seminar on Natural Science Interdisciplinary Teaching, held in Foz de Iguaçu, Brasil (8 – 11 december, 2010), with financial support from the Brazilian agency Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES – Coordination for the improvement of the university teaching personal), from the Universidade Federal da Integração Latino-Americana (UNILA – Federal University for the Latin American Integration) and from Itaipu Binacional.

The first two papers, from Olga Pombo are related to a reflective model to prepare science teachers and to using epistemology on science teaching. In their paper, Rodolpho Caniato give us a beautiful review on interdisciplinarity in science teaching.

The papers from Maria Elena Infante-Malachias (EACH-USP) and Maria de Lourdes Lazzari de Freitas (UNB), presented two different approaches to prepare science teachers with interdisciplinary pedagogy. As Infante-Malachias said:

The knowledge from different science areas along the centuries were, separated and fragmented, but on the school practice this separation is not perceived as artificial (…). As an illustration: a college student asked during a laboratory activity if the carbon from chemistry is the same as that one from biology.

To avoid so a distorted view of science, the undergraduate course from UNILA, to prepare science teachers to the secondary education has been formatted with a radical interdisciplinary approach, as described by Carlos Alberto dos Santos. About 75% of the content related to biology, chemistry and physics is developed having energy and matter as key concepts. Thus, for example, the role of carbon in biology, chemistry and physics is simultaneously discussed.

The last three papers are examples of interdisciplinary approach to teach specific topics. Considering the earth as a pepper grain, Maria Helena Steffani discusses the characteristic distances in the solar system and the interplanetary distances as well. Marco Sacilotti and collaborators present a quite innovative approach to teach photosynthesis based on advanced physics concepts. Jair Koiller present an extensive essay on the possibilities of using mathematics on the biology teaching.

Titles and authors of the eighteen papers are listed below:

For a reflexive model concerning the formation of teachers – Olga Pombo.

Epistemology and science teaching – Olga Pombo.

Interdisciplinarity on the science teaching – Rodolpho Caniato.

Revisiting interdisciplinary experiences on the science teaching – Alberto Villani and Juarez Melgaço.

Energy and matter: key concepts for interdisciplinary nature science teaching – Carlos Alberto dos Santos.

Interdisciplinarity and problem-solving: some questions to whom prepare future science teachers – Maria Elena Infante-Malachias.

Undergraduate science teaching course in the UnB Planaltina Faculty – Maria de Lourdes Lazzari de Freitas.

Planning projects for collaboration among teachers – Érika Zimmermann and Ângela Maria Hartmann

Using concept maps for planning interdisciplinary science projects – Jeremias Borges da Silva, André Maurício Brinatti and Sílvio Luiz Rutz da Silva.

Interdisciplinarity and selection process for undergraduate courses: from the inevitable influence to the wanted interaction – Ricardo Gauche.

University political formation: A view on the directives for the undergraduate natural science courses – Berenice Lurdes Borssoi, Renata Greco de Oliveira and Maria Elly Herz Genro.

A curricular adaptation of a physics course for agronomy science students – Ana Lúcia Figueiredo de Souza Nogueira.

The use of scientific reportage as alternative for the scientific knowledge construction – Glória Regina Pessôa Campelo Queiroz.

Argumentative process at school environment about social and scientific questions – Liz Mayoly Muñoz Albarracín, Washington Luiz Pacheco de Carvalho, Francisco Nairon Monteiro Júnior and Amadeu Moura Bego.

Chemical teaching to adult student: teachers understanding and practice – Marcelo Lambach.

The earth as a pepper grain – Maria Helena Steffani.

Photosynthesis - revisiting an enigmatic question: why are the plants green? – Marco Sacilotti, Euclides Almeida, Cláudia C. Brainer de O. Mota, Thiago Vasconcelos, Fredrico Dias Nunes, Marcelo Francisco Pompelli and Anderson S.L. Gomes.

Biological motion: mathematics on the nature science teaching – Jair Koiller.

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La Universidad un espacio para el aprendizaje. Más allá de la Calidad y la Competencia), by Erika Ramírez Moguel, Narcea, S.A. de Ediciones, Madrid, España, 2012.

As the title may suggest this book look for a different view of the university role. Instead of a place for teaching, investigate and offer communitarian services, the authors argument that it is mainly a place for learning. In other words, the sole objective of the university is to provide learning as a new knowledge for people through professional courses, a new sense for the humanity and specific objectives for the communities.

Discussing the idea of the university, the authors show that the medieval university was a teaching university, while the university of Berlin, founded in 1809 was the first to introduce the concept of university of the investigation, in which research and teaching were separated. Such a model was followed by most of the universities before the 20th century, but along that century the integration of research and teaching was the main characteristic of the university, so named research and teaching university. To oppose to this model and look for a new function to the university of the 21th century, Bowden and Marton develop an extensive essay about several aspects of the academic work. Their argumentation is developed along four sections.

In the first one, titled "The learning university", the idea of the university is presented within a general scenario to be detailed in the following sections. Thus, in the second section, titled "Learning aspects", the authors discuss what is required to learning, learning in different contexts, learning conceptions, learning and research, among others.

The aim of the third section is discuss the students' university. What would be necessary to learning, based on competence approaches? How to stimulate the learning? How evaluate the learning?

Finally, the last and longest section is dedicated to the main objective of the book, that is to say it is dedicated to present the authors' view about a learning university. What it means collective conscience and ethic of the learning, and what is their role on an educational environment? How can the learning quality be defined? How can the learning be organized in the university?

As a conclusion, we can say that this book is, at the same time, an extensive argumentation to change the present university paradigm, and a complete manual to provide the transition from the university with three objectives (teaching, research and communitarian services) to an university with a sole objective: learning.

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