Presentation and consolidation of physical and chemical changes of substances through pupils' active work

Presentación y consolidación de cambios físicos y químicos de sustancias a través del trabajo activo de los estudiantes

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Abstract

The present paper shows an approach to the introduction of concepts: physical and chemical changes of substances. It was started from pupils' spontaneous knowledge about changes they had so many times experienced or seen in everyday life. Pupils' experience was a basis for a range of their activities in preparing for the class presentations, introduction and consolidation of the concepts. Each pupil was allowed to select autonomously substances and means of work and , the changes he was to conduct with substances, to carry them out, to observe them, to analyze them from the aspect of permanence, and to draw conclusions about scientific characteristics of those concepts. The level of knowledge acquired was evaluated by means of each pupil's drawing, where physical and chemical changes were presented. The drawings were analyzed, discussed and evaluated by pupils. The most frequent changes presented in drawings were those from each pupil's environment, analogous to changes performed through experiments in class. It was thus proved that pupils understood the scientific characteristics of the concepts taught, and applied and built them successfully into their knowledge of everyday processes. Such an approach to the teaching of concepts provides for developing creativity, independent decision-making and analytical thinking.

Key words: physical and chemical changes, active learning, education.

Resumen

Este artículo muestra un enfoque a la introducción de conceptos de los cambios físicos y químicos de las sustancias. La experiencia de los alumnos era una base para las actividades preparadas para las presentaciones de la clase, introducción y consolidación de los conceptos. A cada alumno le fue permitido seleccionar las sustancias y los medios de trabajo autónomamente y elegir los cambios, observarlos, analizarlos y hacer las conclusiones sobre las características científicas de esos conceptos. El nivel de conocimiento adquirido de cada alumno se evaluó por medio del dibujo, donde representaron los cambios físicos y químicos. Los dibujos fueron analizados, discutidos y evaluados por los alumnos. Los cambios más frecuentes presentados en los dibujos, son análogos a los cambios realizados a través de los experimentos en la clase. Fue demostrado así que los alumnos entendieron las características científicas de los conceptos enseñados, la aplicación y construcción con éxito en su conocimiento de procesos cotidianos. Tal acercamiento a la enseñanza de conceptos permite desarrollar la creatividad, tomar decisiones independientes y formar un pensamiento analítico.

Palabras clave: cambios físicos y químicos, aprendizaje activo, enseñanza.

INTRODUCTION

It is an axiom that natural sciences are indispensable for explaining and understanding a huge number of phenomena and changes all around us, and in our own bodies too. Chemistry can explain phenomena and changes in our kitchen, new materials used for space vehicle construction, and pheromone molecules that insects use to communicate. Due to abundant chemistry knowledge, a question is raised: what to select and when and how to offer it to pupils at the beginning of chemistry instruction?

It is certain that we will not start with a complicated formula of the latest generation cytostatic. We will not start with a complex formula of some protein, nor will we begin with composite materials used for manufacturing synthetic bones or skiing equipment. In selecting the material for initial learning of chemistry, answers to questions posed by CHIEH (1989) can be helpful: what should non-chemists know about chemistry, what teaching materials should be supplied to popularize chemistry knowledge among all citizens, what is to be done to improve laboratory learning, what is to be done to make laboratory learning less costly, what are basic skills for chemists, etc?

How should the learning of chemistry start? Contemporary school methods imply great activity on the part of pupils in all stages of the teaching process – during classes for presenting new material, experimental exercises, consolidation and systematization of teaching content (BODNER, 1986; HATCHER, 2002). However, it is often difficult to find active-learning techniques that are successful in large classes. To organize the teaching process where the pupil is an active participant, the teacher can make use of answers to the following questions: how can he/she help pupils develop their flair for chemistry, how to design chemistry knowledge to make it easy to learn, how to make fundamental chemistry knowledge relevant to everyday life, how to keep up with new findings in chemistry but still to retain what is most important, how to develop decision-making skill through chemistry, how to develop the way of thinking applied in chemistry, how to develop the ability of drawing conclusions through chemistry. Such an approach is a great challenge for all researchers of chemistry education at various levels.

Getting familiar with the school subject of chemistry should provide for developing pleasure in natural sciences (chemistry), the ability of careful observation, the attitude of asking questions about one's environment, the ability to plan the experiments, and getting acquainted with the basic concept of the school subject (STEINER 89). All mentioned goals are best achieved through experiments. The presentation of new topics in chemistry should begin with laboratory work, collected data, perceptions and conclusions being followed by discussion (RICCI, 1991). This paper presents an approach to the presentation of the concept of changes of substances (physical and chemical), where the said goals were accomplished through pupils' laboratory work with substances available in our environment.

METHODOLOGY

The paper shows a simple approach to presenting the concept of changes of a substance in the first year of chemistry instruction (age 13-14). This unit is taught at the very beginning of chemistry instruction, following the unit on substances and properties of substances. The concept of changes of substances provides for easy transfer from spontaneous to scientific concepts. Regardless of the fact that these are changes seen or performed by pupils countless times in everyday life, they were placed within the learning/teaching context, where they could reveal their scientific characteristics. It is previous experience that makes up the basis for numerous pupils' activities throughout presentation and systematization of the acquired knowledge about changes of substances. Pupils' activities proceeded through doing homework exercises and during classes involving presentation, systematization and evaluation of knowledge.

Homework:

Groups of three pupils each were assigned a task involving choosing, preparing and bringing in substances from their environment (home, yard, park, supermarket).

Pupils' activities during a class for presenting the concepts of physical and chemical changes

- Introduction to the task (given on a separate worksheet)
- Selection of changes to be performed through experiments with substances brought in
- Selection of equipment and utensils for carrying out the experiments
- Performance of experiments
- Perceiving, distinguishing and writing down the changes (reversible and irreversible changes)
- Presenting each group's report on changes performed
- Discussion about changes and their differences
- Drawing conclusions and defining concepts of physical and chemical changes

- Feedback about understanding of changes by means of problem-solving

Pupils' activities during classes for revision, consolidation and checking of the acquisition level of concepts of physical and chemical changes

- Preparing drawings where physical and chemical changes are presented
- Perceiving and describing changes in a drawing and feedback to/from
- Assessing how correct, genuine and artistic each drawing is (the jury consists of pupils and teacher)
- Selecting the three best drawings that will be kept in school as teaching aids

102 pupils participated in the experiment.

After the topic had been presented (a month and a half after the concepts of physical and chemical changes had been taught in the manner described), knowledge was checked using a paper-and-pencil test. The test also included tasks involving physical and chemical changes of a substance. Two tasks were assigned in the form of a drawing.

RESULTS AND DISCUSSION

The unit on physical and chemical changes of a substance allows for applying the method of experimental work where each pupil has an active role.

A class for presenting the concepts of physical and chemical changes

During this type of class, pupils were supposed to make their choices and through experiments carry out various changes with substances they had chosen and brought in. In their experimental work, they were guided by questions and instructions provided on a worksheet:

- What substances have you brought in for your experiment?
- Name two properties of each substance.
- Propose two changes with these substances and carry them out.
- After what type of completed changes can the substance reverse into its original state?
- What is going on when you light a match?
- Can you reverse a match into its original state after it has burnt?

The substances most frequently chosen by pupils were: salt, sodium bicarbonate, baking powder, sugar, vanillin, coffee, bark and paper. They have also chosen yeast, bread, water, oil, alcohol, preservative, metal wire, chestnut, stone, tobacco, sponge, India ink, chewing gum, leaf, shell, biscuit, red pepper, washing powder, rubber band, chalk, tea, pepper, chocolate and vinegar.

All groups have correctly identified two properties for each substance they brought in. They most often named or described color, smell, taste, state of aggregation, solubility, and magnetic attraction, which proves that the concept of a *substance's physical properties* has been properly acquired. This is of crucial importance because pupils arrive at a conclusion on the type of change on the basis of the substance's properties which are changing throughout the experiment.

Although pupils were asked on the worksheet to identify and perform two changes with each substance, 17.6% of the groups of pupils named two changes, while 61.8% named three, four and five changes. Other groups (20.6%) carried out one change each. They were dissolving substances in water (sugar, salt, sodium bicarbonate, flour, baking powder, coffee, pepper, tobacco…); heating (water, vinegar, tobacco, rubber band, paper, bark, leaf); painting (paper, bark); changing the shape (bending of paper and metal wire; ñhopping of paper, leaf, sponge, chewing gum; crushing in a mortar of shell, biscuit, chalk, pepper). To find out what changes pupils are most familiar with as spontaneous concepts; i.e., what spontaneous concepts they start from when forming scientific concepts, we calculated the per cent distribution of each single change carried out. Type and per cent of physical and chemical changes performed are given in Fig. 1. All groups were dissolving substances. Painting of various materials (paper, tea towel, bark) and removal of the paint was carried out by 47.1% of the groups; changes of the state of aggregation by 32.4 % (evaporation of water and vinegar by 8.8%, and melting of biscuit and chocolate by 23.6%) and changes of size and shape by 50.0% of the groups. It is surprising that all pupils were performing substance dissolving, the change less familiar than three other physical changes. They probably chose to experiment with this change because they were encouraged by the bottle of distilled water found among equipment and utensils.

Seventeen groups (50%) stated that apart from physical changes, it was also possible to perform a permanent change with chosen substances. They were heating the substances and noticed the change of color with some of them (caramel forming: 8.8%), release of gas bubbles when solutions of some substances were heated (sodium bicarbonate and baking powder: 5.9%). In particular, we should point out extraordinary perceptions of five groups whose members not only heated substances but also dissolved them before and after heating. Based on those experiments, they concluded that when some substances are heated, substances with other properties emerge and they develop a permanent change. Some substances were lit or burnt up by pupils (29.4%). Using their everyday experience, pupils also identified corrosion and rotting in substances (5.9 %).

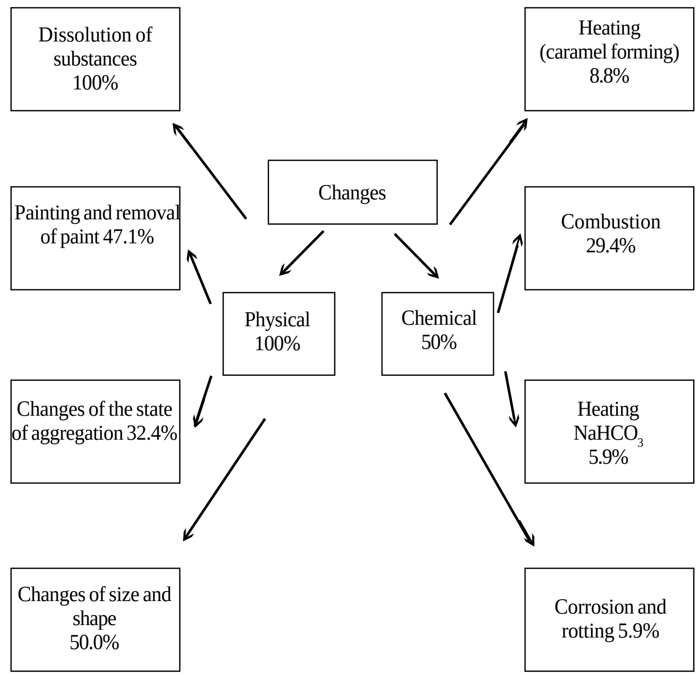

Figure 1. Type and per cent of physical and chemical changes pupils have chosen and carried out with substances from the environment. (The per cents obtained for physical changes are the consequence of the fact that pupils performed and noted more than one change).

The achieved results show that pupils are more familiar with physical changes from everyday experience, and therefore those are more recognizable than chemical changes.

Having performed changes with substances, pupils were assigned a task involving the possibility of substances' reversing into their original state. 70.6% of the groups correctly identified changes after which a substance can be reversed into its original state. The highest number (41.7%) thought that dissolving is a reversible change, while the change of color was identified by 12.5% of the groups; the change of the state of aggregation by 25%, and the change of size and shape by 25 %. Some groups named two and three changes.

Presentation of reports and discussion followed, and interpretation of responses given on worksheets. The great number and diversity of substances chosen and changes performed on the part of the pupils made the teaching of concepts interesting, dynamic, and clear, but also required a well-led discussion on the part of the teacher.

Similarities and dissimilarities between changes carried out with substances, properties of substances before and after changes were all brought up for discussion. Conclusions were drawn about characteristics, which were used to arrange all changes performed into two groups: reversible (physical) and irreversible (chemical).

At the beginning of learning/teaching chemistry, when the pupils meet with the concepts chemical and physical change for the first time, we think that for differentiation between these changes the following criteria are sufficient:

- Forming/non-forming of new substances (noted on the basis of the changes of the quality of the substances) and
- Ease of the return to initial substances after elimination of the conditions which caused the change (Chemical changes correspond to chemical

reactions. Of course, some chemical reactions are also reversible, but at this level of learning it could be neglected).

There were a great number of substances which pupils studied. Most of them were mixtures, which made the use of the mentioned criteria more difficult. However, there were a sufficient number of pure substances (salt, sodium bicarbonate, sugar, water and copper) and their changes could easily be classified using the suggested criteria.

After discussion, pupils had to characterize a single problem situation from everyday life: "*A player was injured during a match. His ankle was swollen. What kind of change took place in the player's leg? What kind of substance do we often use so that the swelling goes down?*"

The complex example of changes was chosen, which was well known to every pupil. The intention was to show to the pupils that very often chemical and physical changes happen at the same time in nature.

Pupils (85%) coupled the swelling with a change in the shape (size) of the ankle as well as with a change in the color of the ankle; i.e., with a physical change. They suggested that ice should be used for the swelling to go down.

The results indicated that the pupils mostly noted the phenomena, the consequence, and not the chemical or biochemical cause of the changes. When the pupils recognized that one of the criteria for distinguishing the changes was fulfilled, they considered that the problem was solved. Partial solution of the problem and the mistake of connecting the change of color with the physical change were suitable for the discussion about the cause of the change. With this approach the pupils learned that they should have a questioning attitude when the evidence and solution of some problem was considered.

Requirements set for pupils were not simple, considering the fact that physical and chemical changes are taught at the very beginning of chemistry instruction. The results show that pupils excellently applied empirical knowledge in comprehending and defining characteristics of the concepts of physical and chemical changes. This approach to the organization of the learning process enabled students to build chemistry concepts into their knowledge of everyday processes (Henderson, 1999).

Consolidation of knowledge about physical and chemical changes through pupils' drawings

At the end of the class, after the concepts of *physical and chemical changes* were presented, pupils were given an assignment. Their homework was to prepare a teaching aid (a drawing) for the next class, where three physical and three chemical changes, at the most, from everyday life would be presented. Each pupil's drawing was shown during the class for consolidating knowledge about physical and chemical changes. Organization of the class and pupils' activities are given in the scheme (Fig. 2).

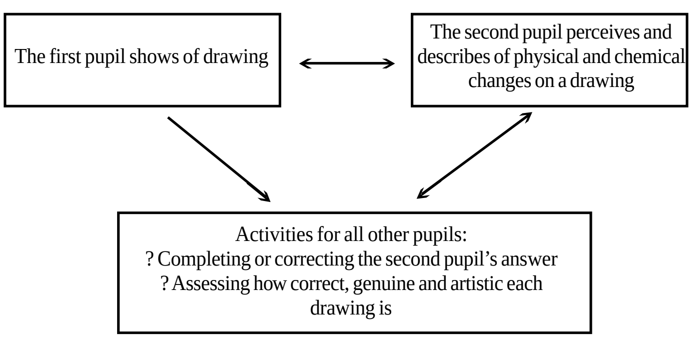

Figure 2. Organization of a class and of pupils' activities

Throughout the discussion, pupils received confirmation about the correctness of their drawings and took part in evaluating other pupils' work. Thus, the participation of each pupil was achieved and this contributed to the development of their communication skills.

It was interesting to note how the making of a teaching aid (a drawing) was influenced by the presentation of the concepts of physical and chemical changes through pupils' experimental work and discussion about the characteristics of these changes. Attention was especially directed to the choice of changes (changes performed during a class or changes from the environment) and to the distribution of each single change in the drawings. In the drawings, 57% of the physical changes and 43% of the chemical changes most common in nature were presented. The per cent distribution of the most frequently chosen changes is given in Fig. 3.

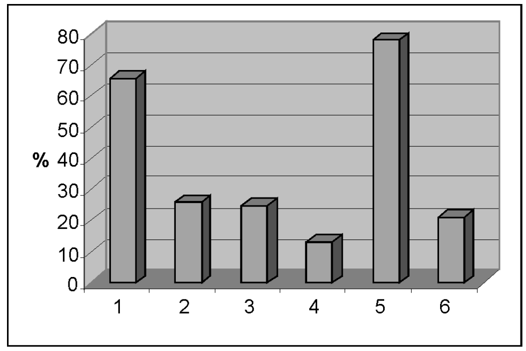

Figure 3. Physical and chemical changes presented in pupils' drawings: 1- change of the state of aggregation, 2 - sunlight distribution, 3 – rainbow phenomenon, 4 – thunderbolt, 5 – burning of various materials, 6 – changes in nature as a result of seasons' changing

Among physical changes, pupils largely opted for changes in water's state of aggregation (66%). They illustrated this change by rain falling (29%), the hydrological cycle (18%), water evaporation (15%), snow melting (4%). The per cent distribution of changes in the state of aggregation shown in drawings is twice as much compared to those types of changes carried out with substances during a class focused on presenting the topic. It is to be pointed out that in their drawings pupils presented changes from nature, which they recognized as analogous to changes performed through experiments during class, and that the experiments performed during class were not presented in the drawings. Dissolving as a physical change, performed by all pupils during a class of topic presentation, was found only in a few drawings presenting the river (river water – solution of substances). However, by the drawing of river water, pupils presented and perceived (identified) the change in the position of visible physical bodies (leaves, pebbles, fish…) more than the dissolving of substances. As other physical changes, they presented hair dyeing and cutting, and crushing of various materials.

As chemical changes, 78% of the pupils presented the burning of diverse materials (paper 26%, wood 19%, matches 14%, candles 12%, cigarettes 7%). Also, changes in nature were presented through changes of seasons: 21%. Pupils also illustrated the digestion of food, fermentation, and corrosion of various metal objects.

The drawings were very creative. Pupils did their best to present different changes in an interesting and accurate way. The results demonstrate that pupils understood and acquired the concepts of physical and chemical changes and by means of them identified and classified changes from everyday life.

Checking permanence of knowledge

After the presentation of the teaching topic, permanence and applicability of acquired knowledge was checked by the test that comprised multiple-choice, completing, and listing tasks. Two tasks in a drawing format were prepared by the teacher. The results achieved (from 67 to 89% correct answers) show that pupils have successfully acquired differences in characteristics of physical and chemical changes and applied them successfully in solving the tasks.

CONCLUSIONS

Pupils' motivation is one of the major tasks to be fulfilled at the beginning of school subject learning. It is best achieved in chemistry through independent laboratory work by relying upon pupils' spontaneous knowledge. In the approach presented for the presentation and consolidation of the concepts of physical and chemical changes, pupils independently and gradually perceived the characteristics of those concepts. They were active from the moment they started preparing substances, equipment and utensils for practical work, and performing the experiments, to drawing conclusions about those concepts, in discussion led by the teacher. The manner of work, the possibility of making one's own choices, independent decision-making, and the scheduling of one's own work were willingly accepted by pupils of this age.

The results demonstrated that such an approach to the presentation and consolidation allows for pupils to acquire the concepts at the level of understanding and application, and makes provisions for permanence of knowledge. Also, such an approach contributes to developing independence and critical thinking in pupils.

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Education in the framework of system theory
La educación con énfasis en teoría de sistemas

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Abstract

Education is being affected by the changes in the field of new technologies of Information and Communication (ICT). The cross-thematic approach (CTA), as a way of organizing curricula, attempts to approach school knowledge from a holistic point of view. We will use the multi-agent system's theory approach in which the cross-thematic approach is the basic process of the system. Under this perspective we focus on factors linking ICT with CTA along with the connection of ICT with teaching methods like: constructivism, discovery learning and problem based learning, which are considered to be the main activities of the basic process. The whole process is implemented by UML (Unified Modelling Language). This work can be extended towards object-oriented software for the educational system depicting its own characteristics.

Key words: system theory, activities, classes, UML, ICT, cross-thematic approach.

Resumen

Los cambios en las nuevas tecnologías de información y comunicación (ICT) influyen permanentemente en la educación. El énfasis cruz-temático (Cross-thematic approach, CTA), es una manera de organizar los currículos y acercar al conocimiento escolar desde un punto de vista holístico. Se aplica la variante de la teoría del sistema en donde el enfoque cruz-temático es el proceso básico del sistema. Los enlaces de los factores ICT con CTA se integran con la conexión de ICT con los métodos de enseñanza: constructivismo, aprendizaje por descubrimiento y aprendizaje problémico, los cuales se consideran como las actividades principales del proceso básico. El proceso total se lleva a cabo a través del idioma unificado para modelización (Unified Modelling Language UML). Este trabajo puede extenderse hacia el software orientado a objetos para el sistema educativo con descripción de sus propias características.

Palabras clave: teoría de sistemas, actividades, clases, UML, computadores, acercamiento cruz-temático.

INTRODUCTION - SYSTEM'S THEORY

A "system" is a collection of things with certain relationships among them. A system can be described from its inputs, outcomes, agents, activities, resources and control mechanisms. A diagram of a system is depicted below (GIAVRIS, A. & PSYCHARIS, S. (2003)).

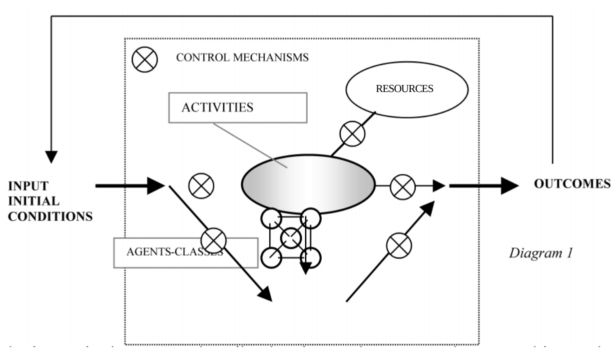

Diagram 1

The inputs in the system describe the aims and targets we have to achieve. The control mechanisms correspond to the ways we check the operation of the system and describe when and which activity is executed and the agents correspond to the entities with attributes considered useful in a particular domain of the Educational process. The outputs of the Educational System correspond to the expected results of the system. This definition of an agent is taken from descriptions by several authors, who describe agents as conceptual entities that perceive and act (FLORES-MENDEZ, R. (1999), RUSSELL, S.J. and NORVIK, P. (1995)) in a proactive or reactive manner within an environment in which other agents exist and interacting with each other. There are two kinds of activities: actions and interactions. An action is an activity, which the role carries out without interacting with others. After an action, a role moves from its present state to its next state. (GEORGAKOPOULOS, D. & TSALGATIDOU, A. (1998)). An interaction indicates a role's activity that is carried out in sequence with another activity or some other activities in another role (or roles). An interaction involves two or more roles, but is always driven by one of them. An agent and its role(s) are like a class in object-oriented design: it describes behavior, but when the process is enacted there are many instances of it. The study of multi-agent systems (MAS) focuses on systems in which many intelligent agents interact with each other, and their interactions can be either cooperative or selfish.

In a multi-agent system each agent has incomplete capabilities to solve a problem, there is no global system control and data are decentralized

A list of common agent attributes are: BRADSHAW, J.M. (1997) adaptivity, autonomy, collaborative behavior, knowledge-level, communication ability and mobility.

MODELING WITH UML

In many fields of science, a situation or a system is not studied directly but indirectly through a model of the situation or the system. Models are used throughout the lifecycle of a process, supporting the model's definition, re-engineering, implementation and continuous improvement. The UML (Unified Modeling Language) is a modeling language for object-oriented analysis and construction. UML is a famous way not only for describing and modeling software and non-software systems, but also for business modeling. Considering education as a system, we have to include the information system, which is part of an organization from a contemporary point of view. An Information System (IS) is that part of the organization which can be defined as the set of interrelated components that collect (or retrieve), process, store and distribute information to all the agents of the system, in order to support decision making and control of the organization. UML offers insight in modeling with use cases, depicts the different classes and objects of the system and reveals the different components of it. In this paper the following issues will be posed and analyzed:

1. What assumptions about education-related agents, underpin the application of system's theory to education, considering Education as a system and actually justifying our consideration?