Teaching models and learning experimenting with chemistry: possibilities to promote Brazilian youngster and adult's learning with meaning

Modelos de enseñanza y aprendizaje de la química: posibilidades de promover el aprendizaje significativo del joven y del adulto

Marcelo Franco Leão, Eniz Conceição Oliveira, Cecília Guerra, José Claudio Del Pino

Departamento de Ensino, Instituto Federal de Mato Grosso, Mato Grosso; Centro de Ciências Exatas, Univates, Rio Grande do Sul, Brazil; Centro de Investigação em Didática e Tecnologia na Formação de Formadores (Laboratório de Supervisão e Avaliação), Departamento de Educação e Psicologia, Universidade de Aveiro, Portugal; Centro de Ciências Exatas, Univates, Rio Grande do Sul, Brazil
josepino@univates.br, marcelo.leao@cfs.ifmt.edu.br, eniz@univates.br, cguerra@ua.pt

Abstract

This paper reports a teaching intervention developed for promoting chemistry learning of 1st year of medium education at the Youngster and Adult Education Center (YAEC), in the city of Barra do Bugres, state of Mato Grosso, mid-western Brazil. The research involved 21 women at YAEC. The research methodology adopted is qualitative, allowing us to analyze the results subjectively and interpretatively. The data gathering instruments were one questionnaire applied before and after performing the course activities, as well as observations recorded in a logbook developed by the students. The results were analyzed through a content analysis technique. The categories of analysis were: youngster and adult's levels of interest, meaning and transposition of the chemistry knowledge for the resolution of problem situations. The study allowed us to identify and develop teaching strategies that would make possible contextualized chemistry teaching.

Key words: *youngster and adult education, teaching and learning of chemistry, teaching intervention.*

Resumen

El siguiente artículo narra una intervención educativa desarrollada para promover el aprendizaje en química en el 1er. año de secundaria, en el Centro de Educación de Jóvenes y Adultos, en la ciudad de Barra do Bugres, Estado de Mato Grosso, Centro-oeste de Brasil. En la investigación participaron 21 mujeres del CEJA. La metodología de investigación adoptada ha sido la cualitativa, permitiendo analizar e interpretar subjetivamente los resultados obtenidos. Los instrumentos utilizados para la recolección de datos fueron: un cuestionario, aplicado antes y después de la realización de las actividades y las observaciones registradas en un diario. Los resultados han sido evaluados por medio de la técnica de análisis de contenido. Las categorías analizadas fueron: interés, significación y transferencia de los conocimientos estudiados para la resolución de situaciones problema. El estudio ha permitido identificar y desarrollar estrategias didácticas que posibilitan una enseñanza de química contextualizada.

Palabras clave: *educación de jóvenes y adultos, aprendizaje en química, intervención didáctica*

INTRODUCTION

Chemistry is a subject that involves scientific abstract concepts which are sometimes difficult for students to understand and learn (Chassot, 1993). Chemistry is the science that studies matter, its physical-chemical transformations and energy variation that occur during those processes. It represents a major portion of all natural, basic and applied sciences. Thus, it is important that educators encourage the perception of daily, observable, measurable situations, since the concepts that are brought into the classroom, according to Freire (1996), originates from their reading of the world, where the meanings are pertinent to them.

The structure of matter, the properties of chemical compounds and the articulating of these scientific concepts with the natural phenomena and technological advances of societies should be developed in schools (Coringa; Pintel; Ozaki, 2007). Consequently, it is important to develop innovative teaching and learning strategies to stimulate students' interest, reasoning and understanding of Chemistry concepts. Chemistry teaching should play an important role of retrieving, in a dialogical fashion, the different meanings attributed to Chemistry knowledge within a physical and social reality (Chassot, 2011).

Chemistry is interlinked with other sciences (e.g. Biology and Geology) and is present in citizens' daily routine, for instances, production and conservation of food. Towards that sense, the Brazilian National Curricular Parameters (BNCP) (Brasil, 2000) recommends that teaching practice should focus on the development of students' competences through significant and contextualized knowledge of science. Also, the Curricular Instructions for the Brazilian Medium Education Nature Sciences Area (SEDUC/MT, 2010) indicate that the construction of Chemical knowledge should be established by means of problematic and challenging situations to students.

Chemistry daily routine should lead to an understanding of the social and economic relations in society (Luft, 1988). Students' daily knowledge is constructed by adult men, who convey it successive generations, making it a part of the culture (Lopes, 1999). Towards that sense, relating 'scientific knowledge' with 'daily knowledge' requires a significant intermediation through education.

Chemistry is a scientific area that allows us to understand how nature, its rules and its interactions relate with society. Students need to develop competences which allow performance of many jobs (e.g. Medicine, Chemical Engineering). Nevertheless, the most relevant weaknesses in traditional curriculum of chemistry are: a lot of new scientific concepts; social, industrial and ecological outdated problems; the ways and methodology of teaching modern chemistry are not contemplated (Orlik, 2002, 2013).

According to a Science-Technology-Society (STS) perspective of science education, the scientific concepts that are brought into the classroom should emerge from students' interpretation of the world (Santos, 2012; Bazzo, 2012; Mansour, 2009; Vieira, Tenreiro-Vieira, & Martins, 2011). Thus, under this constructivist perspective, experimental activities should be organized taking into consideration students' previous knowledge about scientific concepts (Giordan, 1999). This way, dialog between teacher and students take on an important role in classroom. This approach for Chemical education is, thus, aligned with international recommendations of scientific community of science education (Cachapuz, Lopes, Paixão, Praia, Guerra, 2004).

The Salters' Chemistry has been developed, covering biology, chemistry, and physics for the high school age range (11–18 years) in England and Wales. Salters' describes the development and key features of one of the major context-based courses for high school students (Bennett & Lubben, 2006). However, when employing experimental activities in classroom, care should be taken for our classes not to become soaked in positivist thinking. Its fundamental characteristic consists on founding all knowledge on sensory data and stating that only probable relations may be established between things that are likely to be confirmed through repeated observations, without the certainty that they are universal or necessary (Del Pino, 2013).

Contemporary positivism stands on Comte Positivism from the 19^{th} Century. Comte restricted scientific ambitions to pure and simple description of phenomena and relegated to the domain of metaphysics any attempt on the primary causes. The true positivist conception in science starts from the fact it deems neutral and primordial, that observation is the only material from which science is constituted and should develop. Whether a statement is true or false may only be established by resorting to experience, testable by the senses, that allows perception of reality (Del Pino, 2013).

This study was related to the development of a teaching proposal on 'food' involving Youngster and Adult Education students (up to 18 years old) from a public school in the interior of Mato Grosso state, in the mid-western region of Brazil. The teaching proposal was aligned with the national curricular base of knowledge in Chemistry, and in consonance with the history of Chemistry science development. The teaching proposal included conceptual aspects that allow for the students' understanding of the constitution, properties and transformation of materials, with their models explained and highlighting the social implications related to their production and use (SEDUC/MT, 2010).

The main aim of this study was to evaluate whether the teaching and learning proposal contributed (or not) to youngster and adults' Chemistry learning.

THE STUDY

Outline of the intervention

This study was developed during the third school trimester of 2013 (from October to December month) with a class from the 1st year of Medium Education at the Youngster and Adult Education Center, in the city of Barra do Bugres, state of Mato Grosso, mid-western Brazil. The participants were 21 students, all female, with ages between 18 and 46 years old. Among them, 6 students perform operational activities in different services (e.g. sugar mill, refrigerating plant construction, civil construction, commerce), and the other ones were housewives (some of them make handicrafts to complement their family income). Their time out of school varied between 2 and 25 years.

The theme "Food" was chosen for Chemical education course, as it is believed to be a potentially meaningful subject for these students' social context. The teaching methodology employed during classes was from a constructivist perspective (Coll, Martin & Mauri, 2006), with a STS approach (Santos, 2012; Bazzo, 2012; Mansour, 2009; Vieira, Tenreiro-Vieira & Martins, 2011).

These STS approach was integrated in the proposal developed in the following indicators: A) Explores the chemistry topics as a function of their social usefulness; B) Presents situations for daily routine application, for new knowledge, where STS interaction is present at the end of the proposed activities; C) Presents proposals that lead to student involvement in projects that promote critical thinking skills about issues where STS interaction is manifested; D) Proposes diversified activities for reality simulation that has students place themselves in others' places, solve problems, carry out debates, discussions, research about issues where STS interaction is manifested and the explicit appeal of critical thinking skills.

Adapting Santos (2008) approach to Chemical teacher action, the following activities were designed and implemented by the researcher of this study, who was also the teacher of this course: i) give sense to the content (setting off from the contextual and emotional meaning); ii) specify (after contextualization, lead to the perception of specific characteristics); iii) understand (concept construction and use in several contexts); iv) define (clarify a concept); v) argument (spoken, written, verbal and non-verbal text); vi) discuss (reasoning and arguing); and vii) bring it to life (intervention in reality). Table 1 presents the main topics that were selected for discussion in the course.

The course involved discussions between the teacher/researcher and the students about the 'atomic models', a theme that was covered under the topic "Voyage into food: from macro to micro". To work on the structure of the matter, a questioning methodology was implemented. The initial motivation for the development of studies about Chemical Elements was the question: "What constitutes foods?" The following questions emerged during the discussions between the teacher and students about this theme: 1) What constitutes the materials? 2) How are the substances that surround us formed? 3) What is the name of these parts that make up a whole? 4) What is the meaning of atom, and is it still valid? 5) What charges do atoms feature? 6) Where are they located?

For the 'atomic model evolution time line exposure', the following experimental activities were proposed: A jar completely filled with jaboticabas (large, purple berry) represented 'Dalton's model' for the constitution of matter. The students were requested to remove all the jaboticabas from the jar and put them back in to understand the model proposed by that scientist.

To understand 'Thompson's model', chopping paper and rubbing a plastic pen on their scalps was proposed. Once the phenomenon was observed, it was explained that the rubbing caused the electric charges to dislocate, after that, the attraction of the pieces of paper by the pen material, which at that moment would be electrically charged.

For the 'Rutherford-Bohr atomic model', the proposal was to represent the atom using plates, eggs and pieces of paper to identify the electrosphere and nucleus, and where the protons, electrons and neutrons are located.

Table 1. Curricular proposal developed for Youngster and Adult Education (YAE)

Teaching models	Topics covered	Related contents	STS indicators
Assembly of the food pyramid with daily foods.	The importance of food, their origins and main characteristics.	Concept of food and its origins; Study of materials; Pure and mixed substances; Food Groups and Food Pyramid.	A, B
Separation of the foods used in the food pyramid into two groups: animal and vegetable origin.	Diet and caloric value of food.	Food classification; Balanced food diet; Food wheel; Caloric value of food; and Benefits from a healthy diet.	A, C, D
Activity to demonstrate hand sanitization using water soluble dyed ink instead of detergent.	Good practices in food preparation.	Good practices in preparation; Hygiene; Types of contamination; Contaminating agents, Preparation of solutions and vitamins.	A, B, D
Assessment of each student's fridge pictures including a discussion to identify what is correct and incorrect when organizing the fridge.	Food conservation through refrigeration: organizing the fridge.	Food conservation; Correct way of storing food; Packaging; Characteristics and validity; Conserving with cold and thermal convection.	A, D
Preparation of stuffed chocolate bonbons for selling.	Food processing and trade.	Food processing; Changes in physical states; Product appearance and aesthetics; Production standardization.	A, B
Press release about bovine milk tampering by adding Hydrogen peroxide and practical activity about the substances basic acid character.	Chemical reactions that occur in food	Types of chemical reactions; Evidence of the occurrence of a reaction; Identification of reagents and products; Indicators, catalysts and reaction medium; Enzyme inhibition.	A, D
Visit a water treatment plant.	Water as a substance and the process of making it potable	Functions of water in the body and in food preparation; Water treatment and potability; Processes of blend separation; and Chemical analyses for quality control.	A, B
Construction of cellular models with foods.	The relation between nutrients and cell composition.	Organic and inorganic cell molecules; Chemical composition of cells; Prokaryote and eukaryote cells; Organells and their functions; Animal cells and Vegetable cells	A, C
Elaboration of the periodic table with foods.	Chemical composition of food	Mineral salts; Chemical elements; Percentage of elements that make up the human body and food; and Periodic Table of elements.	A, C
Jar with jaboticaba fruit: Dalton's model; a plate with a raw egg and pieces of paper with the + and - signs representing protons and electrons.	Voyage into food: from macro to micro.	Material structure and organization; Dalton's, Thomson's and Rutherford-Bohr's atomic models; Electrosphere and nucleus; Protons, electrons and neutrons.	A, D

The electrons were represented by minus signs (-) in red, laid out on the egg white, representing the empty electrosphere. The protons, in turn, were symbolized by plus signs (+) in blue, laid out on the yolk, representing the solid atom nucleus. The neutrons were also added to the yolk and were represented by the color orange, as they are located in the nucleus. The result was surprising, as can be observed in Figure 1.

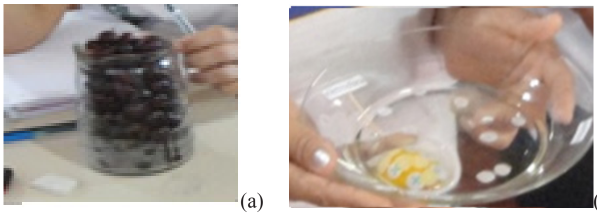

Figure 1. Dalton (a) and Rutherford (b) atomic model

From the experiments with jaboticabas in the jar, chopped paper attracted by the electrified pen through friction on the scalp and the representation of the atomic regions and charges with eggs, it was possible to provide a view of an invisible world (Chassot, 2011).

METHODOLOGY

This study is characterized as research-action method, which according to Thiollent (1985), is an empirical research performed through planned actions and in which everyone, researchers and participants get involved cooperatively. Research-action is understood as being where the investigator interacts in a different manner with the investigated individuals aiming at a planned action in the face of the problems identified (Coutinho, 2011).

The methodological approach of the research is qualitative allowing us to analyze subjectively and interpretatively the results obtained. Lüdke & André (2013) advocate that the qualitative aspects allow understanding the intricate aspects that occurs within a micro social situation, by placing the researcher in the middle of the research scene to, then, take a position about the results obtained. Table 2 presents the participants, the data collection and analysis instruments used in this study:

Table 2 – Participants, data collection and analysis.

Participants	Data collection	Course development			Data analysis
		Beginning	During	End	
21 students	questionnaire 1	x			Content analysis
	questionnaire 2	x		x	
	Logbook of activities developed by students		x		
	questionnaire 3			x	

Questionnaire 1 had the following aims: to characterize the sociocultural and economic profile of the participants. Questionnaire 2 was applied twice, at the beginning and at the end of the course. The aims of this instrument were: to identify previous knowledge of participants about the theme of the course (pre-conceptions…); and to evaluate and compare the participants' learning developed in the classroom concerning the concepts of the course. The logbook notes served to describe the actions developed the course. Questionnaire 3 was applied at the end of the course in order to evaluate the teachers' pedagogical practice effectiveness. This questionnaire had five questions: How do you evaluate the chemistry lessons this semester? What did you enjoy or learn during the chemistry lessons? What could be improved in next chemistry courses? What should be continued? What were the contributions for your daily life?

All students involved in the research signed 'Consent Forms' and committed themselves to voluntarily take part in the proposed activities and authorized the use of the data, including the use of images. To ensure the anonymity of the participants, their names have been replaced by S1 (Student 1), S2, (Student 2), and so forth.

Data collected were analyzed using content analysis technique (Bardin, 2015). Bardin (2015) defines Content Analysis as: "a set of communications analysis techniques that employs systematic, objective procedures to describe the message contents" (p. 38). This technique seeks to learn the message that hides behind words and reveal other realities the messages contain. Data analysis aimed to understand the positive and negative aspects in the execution of the course, as well as to identify which contributions and learning EXPERIENCES were observed in this group of students before and after the development of the pedagogical practice.

RESULTS AND DISCUSSION

Discussion took place under the light of the theoretical/conceptual referential, constructed from different bibliographical sources referenced herein.

Students' perceptions about their learning during the course:

Data collected through the questionnaire allowed analysis of students' interest and/or willingness to learn Chemistry. Figure 2 illustrates this category results.

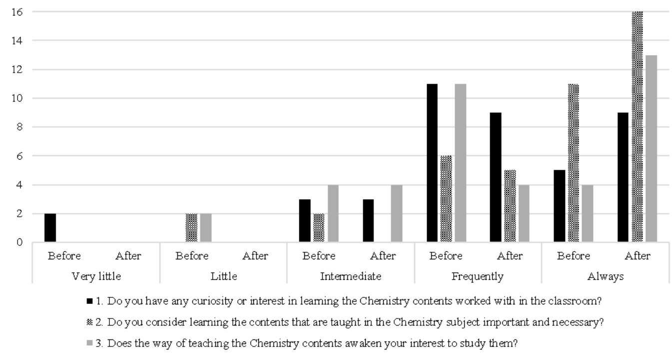

Figure 2 - Answers from students to questions 1, 2 and 3, listed under the "interest" category.

Upon questioning whether students feel curiosity and interest to learn the Chemistry contents worked with in the classroom (question 1), the data reveal that the subject contents are interesting and intensify when worked with in a contextualized fashion. These data corroborate what Santos (2008) thinks about how important interest and motivation are as a driving force to activate the learner's cognitive structures. Also clear is the requirement to create the conditions for that initial individual's impulse translates into a will to learn the contents. Furthermore, it is worth remembering that the interest contributes to students' attention in the study object.

In question 2, the answer "Always" had the most significant increase. This increase in how important learning Chemistry is also associated with the motivational factor, since the latter is an impulse towards pursuing to meet a need (Santos, 2008). Question 3 raises the issue of whether the way of teaching was stimulating, motivating, and whether it had any influence in learning the content. We point out the fact of a high rate of interviewees changing their options from "Frequently", which went down from 11 to 4 answers, to "Always", which went up from 4 to 13 answers. It can be perceived, from the data obtained, that the teaching methodology has an influence in learning. This reveals that a differentiated teaching methodology has an influence in the development of classes. As Santos (2008) states, motivation may be activated by internal factors (needs, interest) and external ones, such as encouragement and incentives. This characteristic reinforces Freire's (1996) idea that simply reproducing lessons is not enough, but creating teaching situations that allow for the production/construction of knowledge. It also shows that the teaching methodology may benefit from exciting and diversified strategies at the right moment (Antunes, 2001).

The second predefined category for analysis refers to students' meaningfulness about…. Questions 4 and 5 seek to asses this aspect. Figure 3 illustrates this category results.

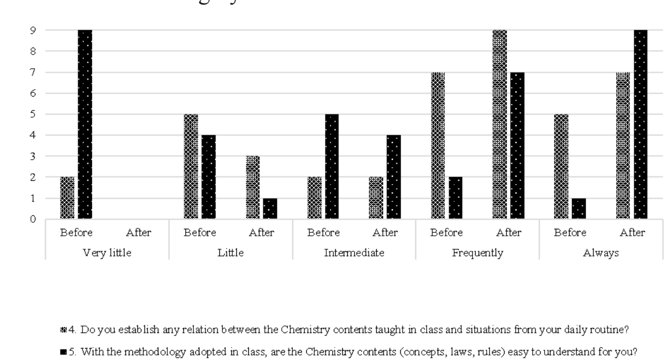

Figure 3 - Answers from students to questions 4 and 5, listed under the "meaningful" category.

From the answers to question 4 it can be perceived that there was an increase among the students who considered such content meaningful and relate them not with compulsory study items, but as something relevant for their lives. Working with "food" allowed us to establish relations between the school contents and daily situations. This finding corroborates Ausubel's (1982) theory when advocating that the logical meaning of the study material is transformed into a psychological meaning for the student throughout meaningful learning situations.

From the data assessed in question 5, it can be seen that most interviewees improved their understanding where Chemistry studying is concerned. Such a finding serves to confirm the teachers' mediator role in the dialectic conception, where the interaction between teacher/students/content occurs, oscillating between actions, reflection and action. It is also perceived that, in order to attribute meaning or understand certain content, the cognitive level must be mobilized so that the pre-existing knowledge schematics serve as a support for the new learning (Coll, Martin & Mauri, 2006; Antunes, 2001).

In question 6 that covers where chemistry exists, 3 students thought Chemistry would be present in the books and in classroom, that is, they were harnessed to the traditional thinking of the bench school that Freire (1983) criticized for not managing to establish any relation between school knowledge and their daily lives. This was one student's option after applying the teaching proposal. There was an increase in the number of students who deemed chemistry contents meaningful, as something relevant for their lives. Working with "food" allowed us to establish relations between the school contents and daily situations. The meaning of the contents studied in Chemistry is harnessed to their establishment with the daily routine, which corresponds to one of the conditions for meaningful learning to take place, as defined by Ausubel (1982): the contents being considered as potentially meaningful for the learner.

The third predefined analysis category referred to the transposition of the knowledge studied to solve problem situations. Questions 7, 8 and 9 consider such category for analysis. Table 3 shows the results from this analysis category.

Table 3 - Students answers to questions 7, 8 and 9 related to the third category.

	Correct	
Question	**Before**	**After**
7. What processes are required to separate a blend containing sand, salt and iron filings?	6	10
8. Sucrose (C12H22O11), known as table sugar, is an important carbohydrate that comprises our diet. Soda pop contains phosphoric acid; whose chemical formula is H3PO4. By analyzing the formulas of those foods, which alternative correctly presents the chemical elements present in these substances?	8	19
9. Heartburn is caused by a high concentration of hydrochloric acid in the stomach. From the substances below, which one would be capable of neutralizing stomach acidity?	9	18

In question 7, we found that less than half of the class answered correctly the processes required to separate the blend of substances presented. However, we found that there was an increase from 6 to 10 when compared to the data from before the intervention. This finding reinforces the idea that a problem situation may only be solved when it meets the intellectual development and knowledge level of the students (Brasil, 2000). We chose to ask about something different from the issue being studied to corroborate the conceptual difficulty in the area of chemistry and that further encouragement is required for learning of that knowledge to occur in future studies.

To answer question 8, students had to apply all the knowledge constructed throughout the pedagogical practice in problem situations. It was noticed that meaningfulness of the contents studied occurred, since the number of correct answers regarding the knowledge of the Chemical Elements and use of the Periodic Table increased significantly, from 8 to 19 students. In a similar fashion to the studies of Branca (1997), there was a transposition of the learned knowledge in solving this specific problem. Once the referred proposal was applied, it was possible to develop cognitive frameworks necessary to solve such situation, which increased the rates of correct answers.

Question 9 brought the transposition of the knowledge constructed to solving life problems. The rate of correct answers in this question was impressive (it doubled). This shows that there was a development in the ability to identify/recognize the objects from the constructed learning and that the differentiated proposal followed the fundamental principles of YAE as stated by Kalman (2004): contextualization, the starting point being what the students already know and the heterogeneity of those involved.

Table 4 shows the categories and subcategories that arose from the material collected during the development of this teaching practice, particularly the analysis of the responses to the questionnaire 3.

Table 4 – Evaluation of the teachers' pedagogical practice effectiveness

Categories	Subcategories
Difficulties that CEJA "15 de outubro" students presented while studying Chemistry.	Difficulty understanding the teacher's explanation; Content complexity; Not understanding the formulas or calculations involved.
Student's assessment of the teaching proposal.	Favoring learning; The theme made understanding easier; It covered interesting things.
Aspects deemed most significant in the study.	The experiments performed; The contents developed; The practices with daily elements.
Suggestions for changes to future practices.	The teacher be more patient; Improve the physical structure of the school.
Contributions from the pedagogical practice experienced.	Learning for life; Changes to daily practices.

The gathered data were analyzed to gain support from theoretical references that discuss the teaching and learning processes, STS approach and meaningful learning. During the analysis, some authors who have been mentioned on the research were revisited. Results revealed how significant the pedagogical intervention was while studying Chemistry through foods.

To assess how much of the proposal was assimilated by the students, they were requested to write down in their logbook what learning was made possible from the development of the activity. Ausubel (2003) believes that assimilation involves a particular type of meaningful learning process that is closely linked to the main theses in the constructivist conception. Below is the transcription of answers from two students:

> *"I learned many things, for example, one experiment with magnetic attraction from a pencil, piece of paper and the scalp e rub on the pieces of paper and it sticks because it is a magnetic attraction. And the egg experiment, the yolk representing the nucleus that contains protons and neutrons, with the white being the electrosphere with a negative charge, the electrons. I found it was very interesting, a learning experience that I will keep for the rest of my life, it was a great experiment, like those in other days" (S6).*

> *"I learned a lot in Chemistry class, because I used to think that Chemistry was only about medicines, but the teacher taught us that we use it in everything we do, what we eat, drink and do has chemistry" (S17).*

The results also indicate that learning with meaning occurred, it being a process through which new knowledge pertaining to this stage in schooling relate to the pre-existing cognitive framework of the learners (Ausubel, 1982).

CONCLUSIONS

The study allowed identifying and developing teaching and learning strategies that would make possible an involving Chemistry teaching. It can be observed that there were countless advantages linked to contextualization in chemistry teaching: greater involvement of students, incentive to research, establishment of relations between chemistry and daily routine, exchange of experiences, interaction of the participants in the development of the activities, better understanding of the chemical concepts and the construction of learning for life.

The exchange of experiences that occurred during the development of the activities served to emphasize the social importance of each citizen in the pursuit of life quality. It also showed that shared knowledge is a means of social transformation, as it served to modify the reality of those who experienced it.

The use of concrete materials contributed to the understanding of chemistry concepts, which oftentimes are abstract. Socialization of more meaningful learning to elaborate conceptual maps showed that the proposed actions allowed for a wealthier conceptual construction. The chosen referential, i.e., planning of activities, strategies and resources employed assisted for the success of this educational process. This differentiated teaching methodology is positive for Youngster and Adult Education by providing for meaningful learning.

We believe that Chemistry teaching through 'food topics', as presented in chart 1, could be a possibility to promote Scientific Literacy of Youngster and Adult Education. Results showed that there was an increase in motivation and interest of students during the course, as well as the knowledge construction for solving practical problem situations. This way of action is to bet on Chemistry teaching not as a fragmented subject, but as teaching that seeks for solutions to the problems of this natural world.

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Falling temperatures: a simple estimation of the absolute zero

Bajando las temperaturas: una estimación simple del cero absoluto

JORGE PINOCHET, WALTER BUSSENIUS CORTADA, DANIEL ROJAS-LÍBANO

Facultad de Educación, Universidad Alberto Hurtado, Erasmo Escala 1825, Santiago Centro, Santiago, Instituto de Matemáticas y Física, Universidad de Talca, 2 Norte 685, Talca, Chile, japinochet@gmail.com

Abstract

When teaching an introductory course on thermal physics, one of the important challenges that a college physics teacher faces is to introduce to his/her students to the idea of an absolute minimum for the temperature, the so called 'absolute zero'. Indeed, given that the experiments used to determine the absolute zero temperature are usually performed in advanced thermodynamics courses, the usual procedure in introductory levels consists of passing on the notion based on the authority of a textbook. The aim of this article is to present a straightforward and low-cost experiment that allows introducing the notion of an absolute minimum temperature. The values obtained for the minimum temperature are in excellent agreement with the actual value of -273.15°C.

Key words*: absolute zero, school-level experiment, ideal gas.*

Resumen

Uno de los grandes desafíos que enfrenta un profesor de física de pregrado que imparte un primer curso de física térmica, es introducir a sus estudiantes en la idea que existe un valor mínimo para la temperatura, el denominado cero absoluto. En efecto, dado que los experimentos para determinar el cero absoluto suelen realizarse en cursos avanzados de termodinámica, el procedimiento habitual en los niveles introductorios consiste en transmitir la noción de temperatura mínima apelando a la autoridad de un texto. El objetivo de este artículo es presentar un experimento simple y de bajo costo que permite introducir la noción de temperatura mínima. Los valores encontrados para esta temperatura se encuentran en excelente acuerdo con el valor aceptado de -273.15 °C.

Palabras clave*: cero absoluto, experimentos de nivel escolar, gas ideal.*

INTRODUCTION

One of the important challenges for a college physics teacher, when teaching an introduction to the topics of heat and temperature, is to present to the students the idea of an absolute minimum temperature. This is the so-called *absolute zero*, which corresponds to the temperature of -273.15°*C* (0 *K*). Indeed, given that the experiments used to determine the absolute zero temperature are usually performed in advanced thermodynamics courses, the usual procedure in introductory levels consists of passing on