Evaluating a didactic strategy to promote atomic models learning in High School students through Hake´s method.

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Abstract
The didactic sequence relates atomic structure concepts (matter structure) with the different models that have been proposed to improve its study, making use of didactic elements that are related to students´reality where they become responsible of constructing knowledge by means of significant learning. Results were analyzed with Hake´s gain factor, which show that there has been a significant change in students´ performance, improving their attitude and interest towards the topic.
Key words: atomic models, constructivism, significant learning, Hake factor

1. Introduction

Matter representation from the submicroscopic dimension is approached through models, which according to Galagovsky (2014), when they are taken to the classroom students become confused since they have to consider different representations to explain submicroscopic particles. Learning concepts as states of matter (which is typically based on Dalton´s atomic model), or emission spectra (based on Bohr´s atomic model) are typical examples of this confusion which lead to misconceptions, as stated by Guevara and Valdez (2014).
Taking this into account and motivated by the learning and teaching context, the following questions arise: How can learning and teaching of atomic models be improved? Is modelling a competence that could improve the learning and teaching process of atomic models?
Learning Chemistry is difficult since it requires that the students relate the macroscopic world they perceive with a submicroscopic world based on atoms and molecules that can not be perceived (Deboer, 2000). What is more, the students need to learn a symbol system that are needed for its repesentation. Regardless this difficulty, it is important to teach chemistry to non-specialists as a knowledge that will enable them to be informed about technological and scientific developments that affect our daily lives. The teacher´s task is to adapt scientific knowledge in such a way the student can connect it to previous knowledge so as to reach significan learning. It is also important to transmit Chemistry´s evolving traits by showing the challenges that can be encountered.

It has been observed that students are not interested in the subject, or can be confused and do not handle basic concepts, not being able to relate these concepts to their reality. This can occur since Chemistry is usually presented through theory and abstract concepts that are not necessarily connected to students´reality, added to the fact that symbolic specific language that is hard for students to understand is typically used. These facts also apply for matter structure.

According to Mosquera, C., Mora, W., and García, Á. (2003), the main conceptual difficulties related to matter discontinuity are, among others:

- Students perceive matter as seen by their eyes. This sense dependence makes it more difficult for them to understand the world at an atomic and molecular level.
- There is a tendency to interpret the world in terms of the macroscopic one, which is not always correct.
- A difficulty to assume that matter is discontinous and that there is a void space between particles that comprise it is present.
- Students interpret matter as continuous and static, in contrast to the dynamic perspective of atomic models (in movement).
- Classic atomic models are mixed without taking account the validity limits of each one.

2. Learning Strategies

Recent interest in learning strategies, understood as the way in which students are taught by taking the most advantage of their possibilities in an efficient and constructive way, has been promoted by new psychopedagogical routes. Several studies indicate that successful students differ from less successful students in that they know and use more sophisticated learning strategies rather than mere mechanical repetition. It is actually more academically profitable to apply strategies that improve instructional techniques or learning materials. Many of the given definitions for academic strategy rely on the following:

- They are procedures or sequences of actions
- They are conscious and voluntary actions
- They can include several specific techniques, operations or activities.
- They follow a specific purpose: learning and solving academical issues.
- They are instruments that with their help learning activities and problem solving are fostered (Kozulin, 2000).

Learning strategies are procedures that students use in a conscious, controlled and intentional way as flexible instruments to learn significantly and solve problems (Diaz Barriga, Castañeda and Lule, 1986). Three of the learning strategies most characteristic features are (Pozo and Postigo, 1993):

- Its application is not automatical, it is controlled. They need planning and execution control, being related to metacognition or knowledge of students´ own mental processes.
- They imply a selective use of students´ own resources and available capacities. For a student to carry out a strategy, he/ she must have his/her own resources at hand,

deciding which one he/she should use based on which one is more adequate according to the tasks´demands.

- Strategies are made up of simpler elements, such as learning techniques and abilities. In fact, the effective use of a strategy hugely depends on the techniques it is composed of. All in all, mastering learning strategies requires, besides ability on certain techniques, a deep reflection on how to use them. In other words, the use of these strategies should not be mechanical or automatical

Learning strategies are executed by the apprentice, no matter who he/she is, so long as he/she is required to learn, remember or solve problems from specific learning contents.

3. Learning strategies classification

Learning strategies can be classified according to their specificity extent, the knowledge domain in which they are being applied, the type of learning they favor, their objective, the type of techniques they integrate, etc.

Recirculation strategies: they are considered as the most primitive ones used by any apprentice which consist on repeating once and again the information to be learned until association is achieved to be stored in the long term memory.

Production strategies: they suppose integrate and relating new information to be learned with previously acquired knowledge. It allows treating and coding information in a more sophisted way since they focus on meaning rather than superficial aspects of information.

Organization strategies: permiten una reorganización constructiva de la información que ha de aprenderse, haciendo posible organizar, agrupar o clasificar la información, con la intención de lograr una representación correcta de ésta.

4. Models in Chemistry

Chemical knowledge uses various models. Due to this, models take an essential role as modelling substances and their transformations. They allow to make ideas bigger, such as representing a situation where a parallelism exists between the theoretical systematic changes of the model and the experimental situations (Halbwachs, 1975).

Bunge (1976) defines a model as "*an imaginary construction (therefore arbitrary) of objects or processes that replace an aspect of reality with the aim of making a theoretical study through usual laws and theories*". It is a simplified representation – a device, a prototype, a plan, a drawing, an equation, software - that allows a better comprehension of what is being modelled to explore, describe and explain scientific and mathematical ideas, contributing to make science more relevant and interesting (Obaya, Vargas, Montaño and Giammatteo, 2019).

Models have the following characteristics (Chamizo, 2010):

1.- A model is always related to an object, a system or a process.

2.- A model is an instrument to respond scientific questions. In other words, it is used to obtain information of something that cannot directly be obtained.

3.- Models present certain analogies to the object, system, phenomenon or process they wish to represent. They are similar, but not entirely, so hypothesis can be derivated from

them and be subjected to testing. Results of this test provide new information about the model.
4.- Models differentiate from the objects, systems or processes they represent. Generally, they are simpler and what has been eliminated has no explicit interest on what they actually represent.
5.- Constructing a model is a commitment between analogies and the differences they have with the objects, systems or processes they represent.
6.- Models are developed through an iterative process in which empiric evidence allows revising and modifying the basic assumptions of the first. A model is generally one, in a hystorical sequence in a particular area of scientific knowledge.
7.- A model is accepted as scientific knowledge when it has been published in a specialized journal. Its hystorical pemanence depends on empirical evidence that supports the model through time.
8.- Models can be iconic and conceptual. The first ones make reference to scale images or objects. The latter ones are related to language through formulas or symbols.
To test whether a model is valid or not, it should be able to explain movements and when possible, predict others. Because of this, models are constructed using scientific methodology to attempt explain a phenomenon or situation and predict events from them. Scientific models are useful to communicate, explain phenomena or set solutions found at a particular time in history. Didactic models foster school science (Obaya, 1995; Chamizo, 2013), which is a science reconstruction of scientists helping students learning, simplifying teachers´explanations and being expressed in text books.
A model is a representation that helps the world achieve a better understanding of the observed phenomena. Its use in the classroom is benefitial since it helps construct and reason students´mental models. In this way, they are able to describe, explain and predict natural phenomena or complex scientific ideas.

5. Methodology

Didactic sequence was used for CCH Azcapotzalco High School students from the first year enrolled in Chemistry II. The experimental group, 204-A was made up of twenty students, being 7 women and 13 men between 15 and 16 years old. It is important to note that before the sequence is applied, a diagnostic test is needed to analyze students situation. In such a way, both students and teacher are aware of the starting point. A questionnaire (annex 1) containing 20 questions evaluating essential concepts from the topics were applied, calculating Hake´s gain score.

5.1 Didactic strategy

The didactic strategy is a means to favor students´ learning, so long as interaction with the given activities demands an active response from them which involves intelectual, procedural and attitudinal abilities for a significant learning to take place.
Three moments were considered to structure the didactic sequence: introduction, development and wrap-up. Introduction activities allowed the teacher to detect previous

knowledge, contextualize the topic and motivate students. Development actions were focused on learning concepts, abilities, attitudes, values and new knowledge, as well as reinforcing and deepening previous knowledge. Wrap-up activities allowed the integration of a synthetic and critical view, and knowledge transfer to other concepts where results analysis and feedback is considered (Suárez, 2017).

The following didactic strategy was carried out in five sessions. The time alloted, objective and activities description, techniques and resources used for each one are shown below.

Didactic Strategy (Lesson Plan)

TOPIC: Atomic Models

Topic: What is a model?	**SESSIÓN:** 1 **TIME:** 70 min
Topic´s Objective: ➢ Identify students´previous knowledge on atomic models that are necessary to prevent, rectify, modify or improve the didactic sequence to be used.	
Learning Outcomes: ➢ Learn and identify the concept of model, as well as its relevance in science, transforming the information given by the teacher into knowledge	**Previous Knowledge Pre-test:** • Atom, Neutron, Electron, Proton • Electron, Proton, Neutron mass • What is a model? Why are models useful? • Dalton and Bohr atomic theory • Atomic models
Activities	

Introduction Phase

Sharing Objectives (Time/ 10 min) ➢ Teacher´s presentation with students ➢ Present the topic, objectives, learning outcomes and activities to carry out	Technique: Provide students with tags to write their names on it Material: Adhesive tags, markers, projector, computer.
Agenda: **1.-**Pre-test questionnaire (Time/ 20 min) ***Purpose of the activity:*** Identify students´previous knowledge regarding atomic models by means of a pre-test	Technique: Solving a questionnaire Material : Printed questionnaire (**annex 1**).

Development Phase

2.- Mysterious box (Time / 15 min) ***Purpose of the activity:*** To prove whether the used technique influences or not students understanding to create a concept on atomic model ▪ Make teams of five students ▪ Each team will be provided with a closed box which contains different objects inside. Boxes will be passed around and team members should use their senses to solve the following:	Technique: Identify unknown objects, comparative chart Material: Carton boxes covered, with different objects inside, printed chart.

1. Fill out a comparative chart with their answers, identifying similarities and differences from each box´s content 2. Write a hypothesis related to the content inside the five boxes 3. Which properties of the content would you like to know that are not easily perceived?	
3.- Results analysis and feedback (Time /15 min) ***Purpose of the activity***: Students deduce the definition for model, what it is and what its usefulness is, taking in context atomic models. The teacher provides the concept of atomic model with the aid of a PowerPoint presentation, having the following in mind: ✓ The idea that a model is an ideal representation of reality, considering only certain attributes, helping understand and explaining how it works is presented. ✓ The same reality can be portrayed with different models, being more detailed or deep when more knowledge is known	Technique: Power Point presentation (**Anexo 2**). Material: computer, projector, board

Wrap-up phase

4.- Conclusions (Time / 10 min) ***Purpose of the activity:*** As a group, come up with one definition of what a model is and provide examples of daily life models.	Technique: Team work to produce a concept Material: markers, board

Topic: The atom	**SESSIÓN:** 2 **TIME:** 45 min
Topic´s Objective: Reafirm students´knowledge of the atom as the main constituent in matter, knowing the subatomic particles that compose the electron.	
Learning Outcomes: ➢ Identify that matter is made up of atoms. Hence, it is discontinuous. ➢ Identify how subatomic particles were discovered. ➢ Know the mass of subatomic particles.	**Previous Knowledge:** • Historical precedents of the atom definition • Electric charges present in the atom • Levels of organization in matter • Matter concept and classification
Activities	

Introduction Phase

1.- Introduction (Time / 10 min) ***Purpose of the activity:*** Contextualize students in the topic by watching a video, which has been modified, called "Matter and its physical states", retrieved from https://youtu.be/Cr236r2Wb0c	Technique: Audiovisual Material: Computer, projector, board

Development Phase

2.- Subtopics to develop (Time / 25 min) ➢ Levels of organization in matter ➢ Atom concept and structure ➢ Discovery of subatomic particles with their most relevant characteristics ➢ Electron importance in chemistry ***Purpose of the activity:*** By means of a PowerPoint presentation, provide the basic elements to understand the relevance and behavior of an atoms, which will be also useful to define atomic models.	Technique: PowerPoint presentation (**Annex 3**). Material: Computer, projector, board, markers

Wrap-up Phase

3.- Conclusions (Time / 10 min) ***Purpose of the activity:*** Come up with the most important ideas expressed by students associated with the atom and note them down on the board. • *Ask students to bring books related to general chemistry, chemistry one or one that contains information regarding atomic models*	Technique*:* Brainstorm Material*:* Markers, board

Topic: Atomic models	**SESSIÓN:** 3 **TIME:** 55 min
Topic´s Objective: ➢ To distinguish scientific contributions that helped establish the current atomic model ➢ To construct models from the different atomic theories	
Learning Outcomes: ➢ To appraise the contributions from each atomic model as part of a historical process that helps understand the current atomic model	**Previous Knowledge:** • Atom, neutron, electron, proton • What is a model? What is a model useful for?
Activities	

Introduction Phase

Agenda: (Time / 5 min) **1.-** Indicate students the activities that will take place during this session ✓ Make 6 teams ✓ Assign each team with an atomic model ✓ Come up with each model´s characteristics and explain the given model to the whole group	Technique: Material:

Development Phase

2.- Atomic models reading (Time / 20 min) ***Purpose of the activity:*** Identify the different Atomic models proposed throughout history, as well as their main limitations and contributions with the help of books that students bring	Technique: Reading in teams Material: Textbook on chemistry topics.

Wrap-up Phase

3.- Conclusions (Time / 30 min) Team work to make a comparative chart. ***Purpose of the activity:*** To identify the main contributions and limitations of each atomic model ➢ Each team will present the assigned atomic model base don information retrieved from the books. ➢ The teacher will complement and correct information if necessary. ➢ In a graph organizer and based on the information given by the teams, students will include the following: ▪ Scientist that proposed the theory and year of publication ▪ Experiment that supported the model ▪ Main contributions and limitations ▪ Model representation ✓ Using students´information, the teacher will make a PowerPoint presentation to clarify information that turned out to be confusing or mistaken. This presentation will be used on the following session.	Technique: Presentations in teams Material: Comparative chart handout (**annex 4**).

Topic: Feedback	**SESIÓN:** 4 **TIME:** 50 min
Topic´s Objective: ➢ To confirm acquired knowledge in regards of atomic models.	
Learning Outcomes: ➢ To identify in chronological order how atomic theories arose and evolved as well as the main postulates and limitations	**Previous Knowledge:** • Atom, neutron, electron, proton • Electron, proton and neutron mass • What is a model? Why is a model useful?
Activities	

Introduction Phase

Agenda: (Time / 5 min) **1.-** To make up teams and retrieve the information from the activity carried out in session 3 (comparative chart).	Technique: Graph organizer Material: White sheet of paper with graph organizer

Development Phase

3.- Feedback (Time / 30 min) ➢ The teacher will recall information on the topic, using the comparative chart as a guide and the presentation when needed. This presentation should be ready one class before.	Technique: Collaborative work and PowerPoint presentation (**annex 5**) Material: Projector, computer, board.

Wrap-up Phase

4.- Conclusions (Time / 15 min) ➢ Students´ participation for solving doubts ***Purpose of the activity:*** ✓ At the end, students will distribute a list of required materials that will enable them to make the atomic model they were assigned for the following session.	Technique: Audiovisual resource Material: Projector, computer, board.

Topic: Creating atomic models	**SESIÓN:** 5 **TIME:** 60 min
Objective ➢ To create atomic models from the physical phenomena they were established	
Activities	
➢ Ask students to make teams and organize themselves to create their atomic model. In the cases that apply, they will also have to make the prototype of the experiment that gave birth to the model. ➢ When each team is ready, they will explain their 3D model as if they were a group of scientists making an experiment and proposing a scientific model. ➢ In pairs, students will integrate the information of an atomic model in an infograph by using ICTs, which should be sent by email and presented on the following session to the whole class.	
Post-test ➢ Students answer a questionnaire that will evaluate acquired knowledge and will serve as an instrument to determine Hake´s gane score (Hake´s factor) at the end of the used didactic strategy.	**TIME:** 30 min

Results and Observations

Session "Mystery box"

From the activity carried out with the written answers from students and the class observations, the following information was obtained:

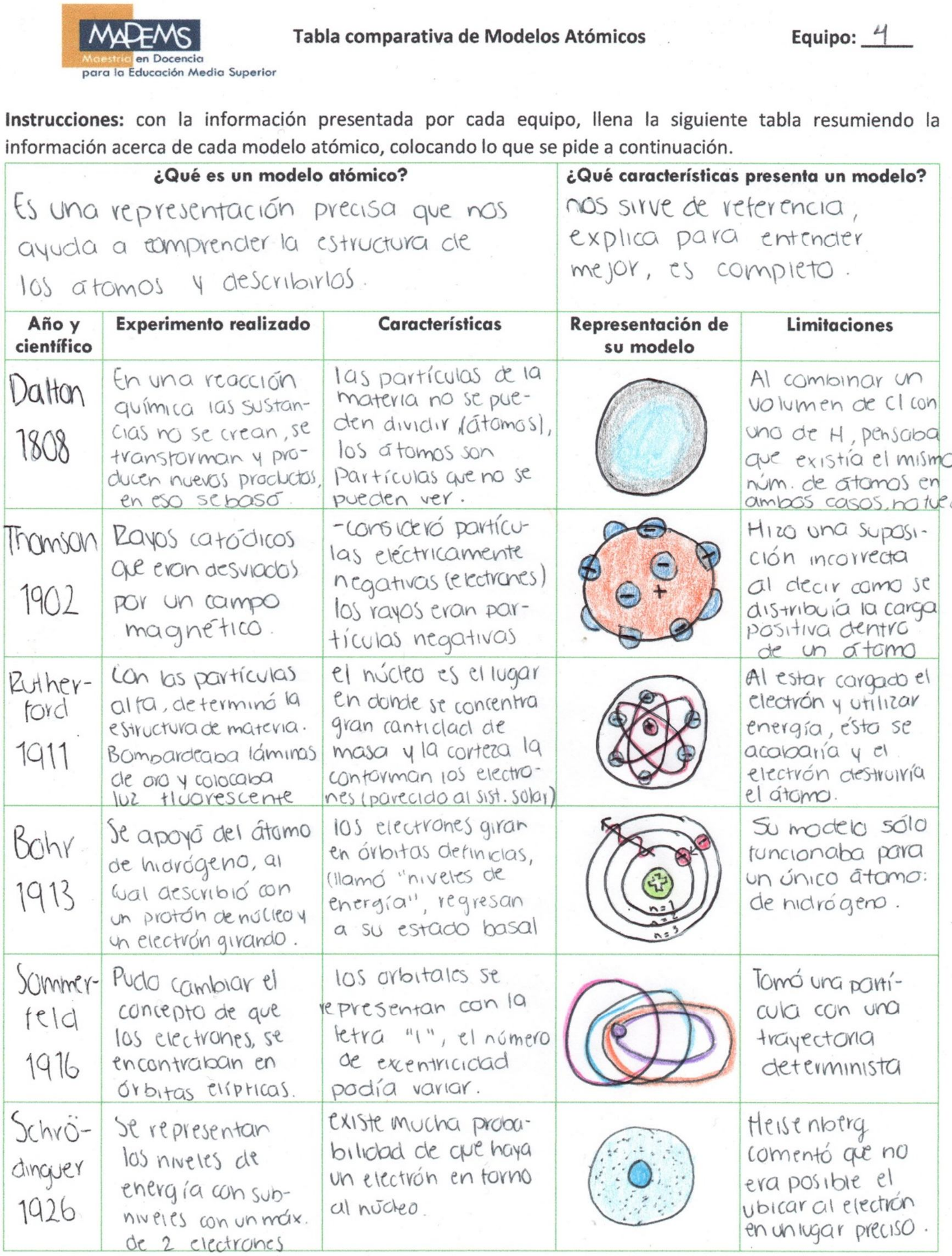
Table 1. Results from the activity "Mystery box"

ACTIVITY 2: Hypothesis from properties of the boxes´content					
Box 1	Team 1	Team 2	Team 3	Team 4	Team 5
1 Small locks	Dices and stones More of the tiny object Non - spherical	There might be two dices. Hard plastic	Heavy and small	Slightly heavy and metallic	Rectangular plastic
2 Domino pieces	Dices Non-spherical	It has many edges. Non-spherical Light-weighted	Squared and light-weighted	Light-weighted Made out of plastic	Tiny things
3 Clips and Keys	Coins, keys, rings. Tiny and somewhat light-weighted	Light metal Squared and small	Key chains with small keys	Metallic, small and light-weighted	Keys
4 Styrofoam cubes and wood	Objects covered by something Irregular objects	Squared wood Big and heavy	Erasers	Two different objects	Big and heavy objects
5 Screws	Screws Nails Keys	Tiny metals held together Irregular	Metal rings Light weighted	Metal chips	Circular as coins
Properties from the content that cannot be perceived					
	Shape	Shape and color	Flavor, color, shape, texture	Color, flavor, aroma, texture	Texture, smell, color
Group definition: *" A model is a way to represent a phenomenon or fact that we could see or not, making it easier to study it and therefore understand it. "*					

Observations: They were also asked to give examples of models, to which they answered the DNA double helix, the terrestrial globe, and water cycle to name a few.

Session "Atomic models"

In this session, each team was supposed to cover a specific atomic model. For this, information from several books was used – Reading, analyzing and discussing the information. At the end, conclusions were presented to their classmates. With the information provided by one of the teams, the rest of the students noted down information on a chart (see Figure 1 corresponding to different teams).



MADEMS Maestría en Docencia para la Educación Media Superior

Tabla comparativa de Modelos Atómicos **Equipo:** 4

Instrucciones: con la información presentada por cada equipo, llena la siguiente tabla resumiendo la información acerca de cada modelo atómico, colocando lo que se pide a continuación.

¿Qué es un modelo atómico?	¿Qué características presenta un modelo?
Es una representación precisa que nos ayuda a comprender la estructura de los átomos y describirlos.	nos sirve de referencia, explica para entender mejor, es completo.

Año y científico	Experimento realizado	Características	Representación de su modelo	Limitaciones
Dalton 1808	En una reacción química las sustancias no se crean, se transforman y producen nuevos productos, en eso se basó	las partículas de la materia no se pueden dividir (átomos), los átomos son partículas que no se pueden ver.		Al combinar un volumen de Cl con uno de H, pensaba que existía el mismo núm. de átomos en ambos casos, no fue así.
Thomson 1902	Rayos catódicos que eran desviados por un campo magnético.	-consideró partículas eléctricamente negativas (electrones) los rayos eran partículas negativas		Hizo una suposición incorrecta al decir como se distribuía la carga positiva dentro de un átomo
Rutherford 1911	Con las partículas alfa, determinó la estructura de materia. Bombardeaba láminas de oro y colocaba luz fluorescente	el núcleo es el lugar en donde se concentra gran cantidad de masa y la corteza la conforman los electrones (parecido al sist. solar)		Al estar cargado el electrón y utilizar energía, ésta se acabaría y el electrón destruiría el átomo.
Bohr 1913	Se apoyó del átomo de hidrógeno, al cual describió con un protón de núcleo y un electrón girando.	los electrones giran en órbitas definidas, (llamó "niveles de energía", regresan a su estado basal		Su modelo sólo funcionaba para un único átomo: de hidrógeno.
Sommerfeld 1916	Pudo cambiar el concepto de que los electrones se encontraban en órbitas elípticas.	los orbitales se representan con la letra "l", el número de excentricidad podía variar.		Tomó una partícula con una trayectoria determinista
Schrödinger 1926	Se representan los niveles de energía con subniveles con un máx. de 2 electrones	existe mucha probabilidad de que haya un electrón en torno al núcleo.		Heisenberg comentó que no era posible el ubicar al electrón en un lugar preciso.

Figure 1. Atomic models comparative table – Team 4

Session: “Feedback”
Observation: It is important to highlight that omissions in information from the presenting teams was enriched with participations from the other students. This provided a deeper analysis, as shown below:
Student 1: *“ When Rutherford bombarded a gold sheet with particles, he realized most went through and only a few bounced on the same direction they came from. With this, the atom nucleus was discovered”*
Student 2: *“ The gold sheet was bombarded with alpha particles, which have positive charge. The few particles that bounced back were due to the fact that the particles were rejected since they had the same charge. This allowed scientists to know the atom had a positive nucleus.*

5.2 Use of ACT´s

As a reinforcement activity, each student was asked to make an infograph. In order for the students to be able to make it, they were informed of the Infograph´s characteristics, the elements that make up one, how to make them and some free access software were mentioned. In Figure 2, an example of such work elaborated by a group of students is presented.

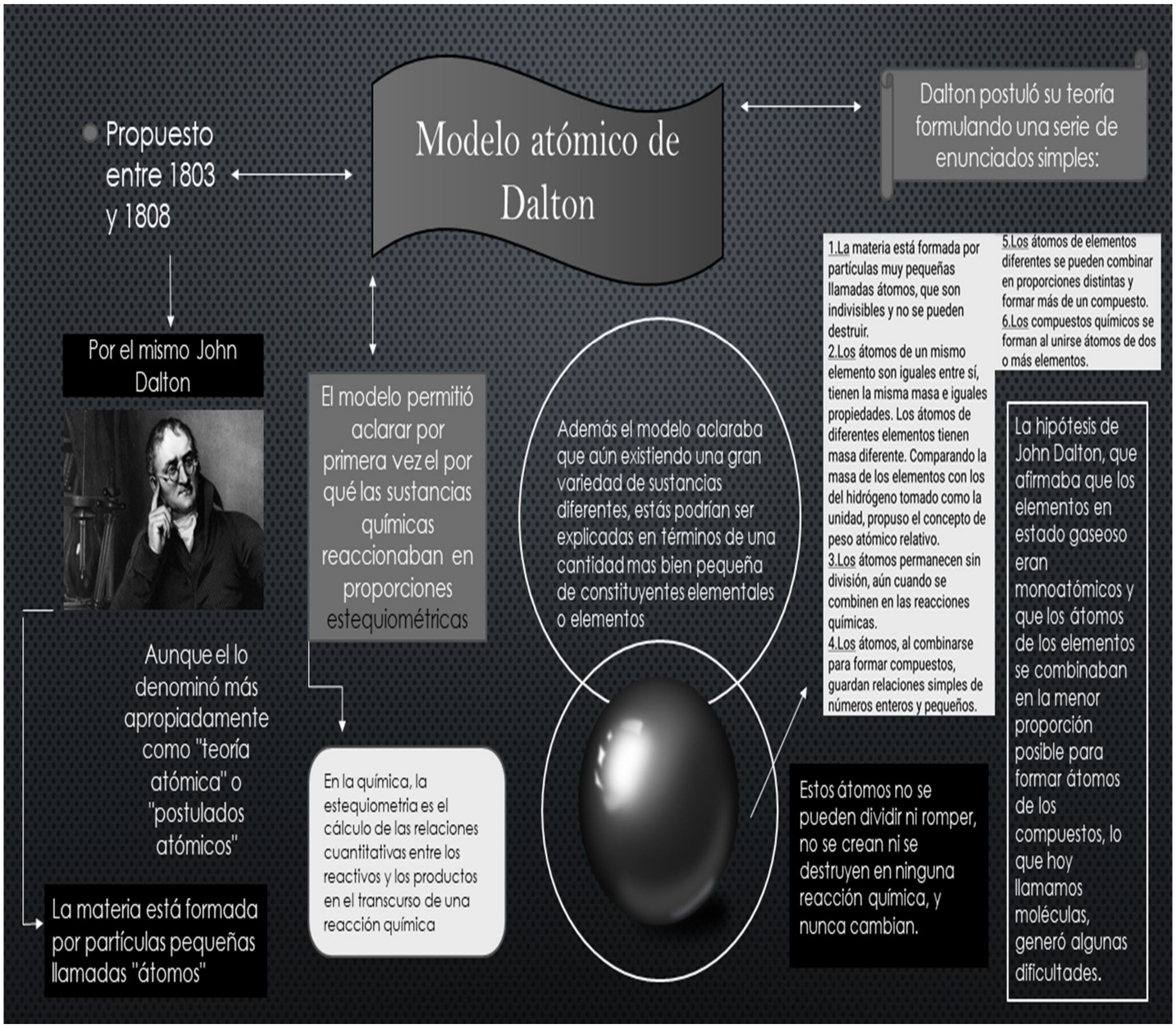


Figure 2. An infograph created by a group of students is shown.

6. Pre-test and Post-test results analysis

A pretest was applied before starting with the didactic strategy, and a post test was applied in the end. Results were analyzed using Hake´s gain score, which show a significant change in students´development, improving their attitude and interest towards the topic.

Hake´s Factor

Obtained results from the two evaluations (pre and post test) are easily interpreted by using Hake´s normalized gain, which allows for conceptual developed gain to be measured and compared (Hake, 1998) before and after applying the didactic sequence. Such factor is reported as a number that represents the increased ratio between the pretest and the post test in the beginning and at the end of the didactic strategy, with a value that covers the interval (0-1) and is calculated with the following formula:

$$\boldsymbol{g} = \frac{postest\,\% - pretest\,\%}{100 - pretest\,\%}$$

Hake uses the gain score to determine three achievement levels as shown below:

a) **g high**. When g value is ≥ 0.7
b) **g average**. When g value is between 0.3 ≤ g ≥ 0.7
c) **g low**. When g value is ≤ 0.3

The results shown in Table 2 are part of the students response average, taking the percentage of correct answer for each question to determine Hake´s factor by using the equation (1).

Table 2. Hake´s gain score values obtained for each question in the test.

Question	Questionnaire	Number of correct answers	% of correct answers	Hake´s gain score (g)
1	***pretest***	13	65	*0.71*
	postest	18	90	
2	***pretest***	18	90	*1.00*
	postest	20	100	
3	***pretest***	18	90	*0.00*
	postest	18	90	
4	***pretest***	18	90	*1.00*
	postest	20	100	
5	***pretest***	15	75	*0.80*
	postest	19	95	
6	***pretest***	13	65	*0.29*
	postest	15	75	
7	***pretest***	6	30	*0.79*
	postest	17	85	
8	***pretest***	13	65	*0.14*
	postest	14	70	
9	***pretest***	4	20	*0.88*
	postest	18	90	
10	***pretest***	6	30	*0.86*
	postest	18	90	
11	***pretest***	6	30	*0.93*
	postest	19	95	
12	***pretest***	4	20	*0.75*
	postest	16	80	

13	*pretest*	5	25	*0.73*
	postest	16	80	
14	*pretest*	10	50	*0.90*
	postest	19	95	
15	*pretest*	14	70	*0.83*
	postest	19	95	
16	*pretest*	13	65	*0.57*
	postest	17	85	
17	*pretest*	8	40	*0.75*
	postest	17	85	
18	*pretest*	10	50	*0.80*
	postest	18	90	
19	*pretest*	9	45	*0.91*
	postest	19	95	
20	*pretest*	6	30	*0.79*
	postest	17	85	
			Average	**0.72**

In the graph analysis made before, the percentage of correct answers in both the pre and post tests are shown. As it could be seen in Table 2, besides this average, Hake´s gain score is shown for each value. It is evident that most answers have a high conceptual gain ($g \geq 0.7$) and only answers to questions 3, 6 and 8 are low ($g \leq 0.3$). This indicates students were able to acquire and/or reinforce knowledge, but there are still certain concepts that should be explained in more detail in order for students to appropriate this particular knowledge. Lastly, it is shown that Hake´s gain score average for the group 0.72, which it indicates according to Hake that the learning was achieved. It indirectly shows that the didactic strategy used for this topic is effective.

7. CONCLUSIONS

After designing and implementing a didactic strategy to teach atomic models in Chemistry for first year High School students, it can be affirmed that :

- By developing this didactic strategy, students were curious and imaginative – the intention of discussing when they didn´t agree with their classmates was fostered. Undoubtedly, these atittudes help students in their learning process.
- Based on the results obtained from the evaluation instrument and the comments received from students, a significant improvement in students´knowledge was achieved for atomic models. The achievement levels indicated by Hake´s gain score are related to a high conceptual gain ($g=0.72$). Therefore, Hake´s gain score indicates how effective techniques used were when a didactic strategy is based on constructivism and significant learning.

- Having discussed and analyze the information from each atomic model as a group, and coming up with the most outstanding physical representation allowed students to establish connections between macroscopic observations as a consequence of their submicroscopic characteristics.
- Technology has nowadays a very important role, since it has taken part in our daily lives. Hence, it should be taken into account by the teacher in the learning and teaching process. Nonetheless, time needs to be devoted to software use so that the produced material has the correct characteristics and the objective for which they were created is met
- The teacher assumed a role as a facilitator in the scaffolding process in order for the students to acquire new knowledge. Students and teacher established emotional condittions that fostered learning. By being motivated in the activities made, an assimilation level was achieved that created the expected learning in each student.

Having said that, it is essential to promote research in the educational field to implement didactic strategies according to our students economical status and technological resources in order to achieve higher learning levels. The teacher task is to adapt scientific knowledge so that the students can connect it to their previous knowledge, achieving in such a way significant learning and taking into account the circumstances and conditions that are constantly changing such as place, historical moment and types of students.

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ANNEX 1. Initial and Final Evaluation (Pre and Post – Test)

UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
Maestría en Docencia para Educación Media Superior
Topic: Atomic Models

Student´s Name: **Correct answers:_____ / 20**

Instructions: Answer the following questions by underlining the correct answer and/or making a sketch.

1.- A model allows us to:
a) represent real life phenomena
b) represent only what another person thinks
c) represent only scientists´thoughts
d) represent unreal and imaginary situations
e) I don´t know

2.- A characteristic of a model is that:
a) they are discovered in nature
b) they are shown in laboratories
c) they are chosen among several options
d) they are converted into mathematical equations
e) they are constructed to show a specific aspect of the world

3.- Which of the following phrases best describes your idea of a model?
a) They represent an object, idea, system, phenomenon or process created with a specific objective
b) It is a person who poses for paintors, sculptors, photographers, etc.
c) It indicates attitudes of what is trying to imitate
d) It is a brand of a mexican drink
e) Theoretical scheme, usually as a mathematical expression, of a system or process

4.- An atomic model is:
a) a mathematical equation of the movement that protons have
b) a graphical representation of the atom´s structure
c) a nature explanation – these are never modified and are used as a basis for scientific work
d) related to phenomena observations that occur in the laboratory
e) a quantitative or qualitative representation of an atom´s nucleus

5.- The following image represents:
a) an atom
b) an element
c) a compound
d) a mixture

6.- The atom is defined as:
a) the tiniest particle that exists with life
b) very similar to the size of a cell
c) a particle that can be observed with a microscope
d) the tiniest particle that comprises matter
e) I don´t know

7.- The windows from your home contain glass. How do you think the atoms that form glass are arranged?
a) The atoms in glass are always static, without movement
b) The atoms that make up glass are constantly vibrating
c) The atoms that make up glass only move when the glass is agitated
d) The atoms that make up glass only move if there are air bubbles pushing through them

8.- How many molecules are found in a drop of water?
a) Trillions of water molecules
b) Centennials of water molecules
c) Thousands of water molecules
d) Millions of water molecules

9.- When bombarding a thin sheet of gold with alpha particles (α), it was observed that many of them went through the sheet without being deviated. Only some of them, deviated or bounced back, proposing that the nucleus had a positive charge. This is a characteristic of ______________´s model:
a) Dalton **b)** Thomson **c)** Rutherford **d)** Bohr **e)** Schrödinger.

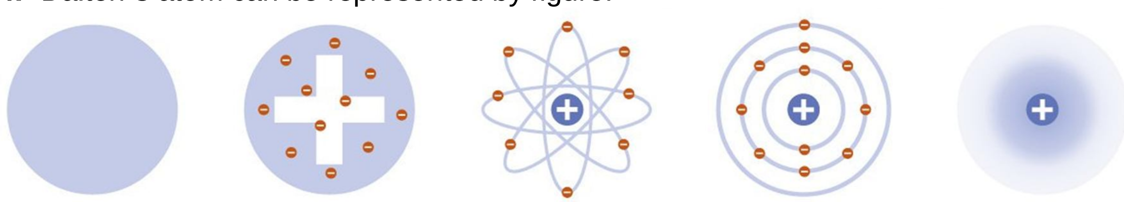
10.- By applying high voltaje to two electrodes within an evacuated glass tube, an electric flow is generated that travels from the cathode to the anode. This experiment is characteristic of ______________´s atomic model:
a) Dalton **b)** Thomson **c)** Rutherford **d)** Bohr **e)** Schrödinger.

11.- When two chemical elements react to form a compound, they always do it in the same mass ratio. This refers to ______________´s atomic model:
a) Dalton **b)** Thomson **c)** Rutherford **d)** Bohr **e)** Schrödinger

12.- There is a zone that surrounds the nucleus where it is highly likely to find electrons. This describes ______________´s atomic model:
a) Dalton **b)** Thomson **c)** Rutherford **d)** Bohr **e)** Schrödinger.

13.- When an electron moves from a higher energy level to a low one, the energy difference between both levels is emmited as electromagnetic radiation. This is a characteristic of ______________´s atomic model:
a) Dalton **b)** Thomson **c)** Rutherford **d)** Bohr **e)** Schrödinger.

14.- Dalton´s atom can be represented by figure:



a) **b)** **c)** **d)** **e)**

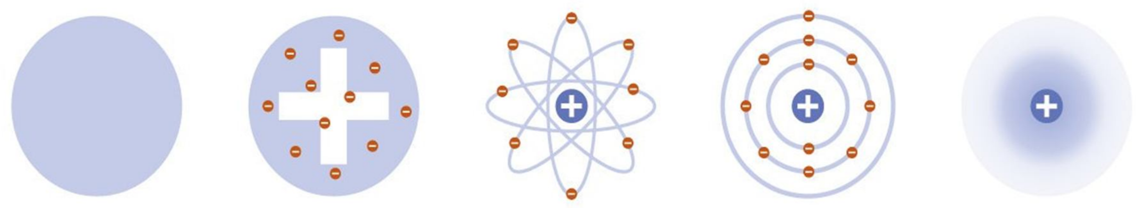
15.- Bohr´s atom can be represented by figure:

a) b) c) d) e)

16.- Thomson´s atom can be represented by figure:

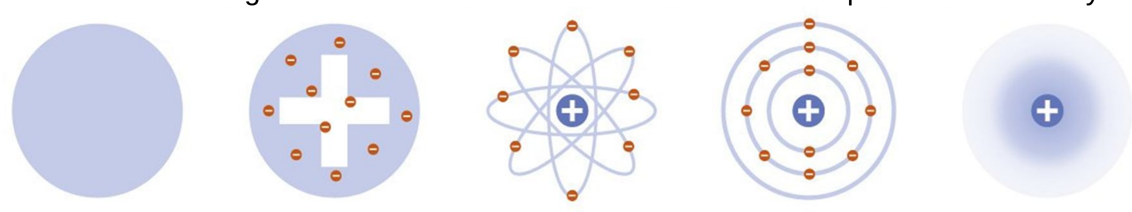
a) b) c) d) e)

17.- Rutherford´s atom can be represented by figure:



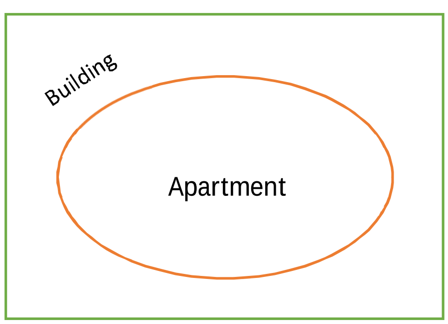
a) b) c) d) e)

18.- Schrödinger´s atom can be represented by figure:



a) b) c) d) e)

19.- With the following words: appartment, bed, livingroom, bedroom, building, kitchen, table complete the following diagram grouping words according to their organization.



20.- Create a similar diagram as the one above for a drop of water, from the macroscopic level to the submicroscopic.

Key words: nucleus, electron, molecule(s), proton, atom, drop of water, neutron