The planetary motion and science history

Torres, Y. I.[1,3] Arévalo, J. R.[1,3] y González, M. H.[2,3]
[1]*Group of Teaching Research Science and Astronomy.*
[2]*Group of Scientific Instrumentation & Teaching.*
[3]*Faculty of Sciences and Education, Distrital University, Carrera 3 No.26 A-40, Bogotá, Colombia.*

E-mail: jotorres.fis@gmail.com

(Received 25 July 2011; accepted 28 November 2011)

Abstract

Some authors suggest that traditional paradigms are incapable of achieving an appropriation of concepts, requiring rethinking the teaching and learning of science as demonstrated through some distorted view of scientific knowledge and science. We present the analysis of educational experience developed from the perspective of incorporating elements of contemporary approach to history of science in teaching and learning of physics. In the development of experience, we studied problems and explanatory models of planetary motion, placing them in the context in which they were produced and highlighting elements of the nature of science. The experience was ahead with students in the first half of the Curriculum Project Degree in Physics from the University Distrital in 2010. The experience contributed to the characterization of alternative visions of the nature of science and scientific knowledge.

Keywords: Science history, physics education, teacher training, teaching methods.

Resumen

Algunos autores indican que los paradigmas tradicionales se muestran incapaces de lograr una apropiación de los conceptos, requiriéndose replantear el proceso de enseñanza y aprendizaje de las ciencias puesto que se evidencian algunas visiones deformadas del conocimiento científico y de la ciencia. Se presenta el análisis de una experiencia pedagógica desarrollada desde la perspectiva de incorporar elementos del enfoque contemporáneo de la historia de la ciencia en la enseñanza y el aprendizaje de la física. En el desarrollo de la experiencia, se estudiaron problemas y modelos explicativos sobre el movimiento planetario, ubicándolos en el contexto en el que se produjeron y destacando elementos relativos a la naturaleza de la ciencia. La experiencia se adelantó con estudiantes de primer semestre del Proyecto Curricular de Licenciatura en Física de la Universidad Distrital en el año 2010. La experiencia contribuye en la caracterización de visiones alternativas de la naturaleza de la ciencia y el conocimiento científico.

Palabras clave: Historia de la ciencia, física educativa, enseñanza y aprendizaje, métodos de enseñanza.

PACS: 01.65.+g, 01.40.-d, 01.40.J-,01.40.gb, 01.40.Ha **ISSN 1870-9095**

I. INTRODUCTION

Initially, studying the planetary motion from the perspective of incorporating elements belonging to a contemporary approach to *Science history*, transforming the current standpoint on the science nature requires three aspects. In firsthand, we need to clarify the elements from science history to be involved. Secondly, it is essential to investigate what image of science nature appears as prominent in the group. And thirdly, we have to define the science history contribution in the notions of science nature construction according to the contemporary viewpoint.

Thereby, addressing natural phenomena teaching and learning from the science history may favor 5 aspects. One has to do with the construction of problems underpinning the accepted theories in the scientific community. Another one deals with both, the wise moves and miscalculation of sciences. A further one is related to knowledge changes and difficulties in its development. The next one involves the study and understanding on the science (physics) constituents by students. And the other is connected to the transformation among future teachers of both, the current image shared on the science nature and their teaching methodological designs.

Within the foundations of the activity developed, the science history contributions coincided with the physics didactics` findings. In this precise case, four categories of analysis were constructed with the purpose to examine the phenomenon considering them.

II. STATEMENT OF THE PROBLEM

In the pedagogical practice, diverse ideas about the sciences learning meet. These ones in turn are influenced by conceptualizations regarding the science nature and scientific knowledge. At the same time, those conceptualizations constitute an epistemological basis as they define the knowledge construction process from both, the physical and pedagogical knowledge which seem to be founded on two features that characterize the conventional manner of physics teaching.

The former shows the teaching process as the result of a given knowledge transmission model. And the latter includes the actions in the classroom as based on the Aristotelian-empirical epistemology which comprises various premises: "the experience is the only knowledge source", "the observation and theories are divergent processes", "the physical science logics has to do with the confirmation of theories" and "the science history employment is limited to the sporadic use of biographies or anecdotes telling".

Accordingly, the science curricula are focused on contents development. Thus, these curricula are led by an inner science logics, missing out aspects reoffering to the science nature such as: external influencing factors and how they have had an impact on their construction, the methods utilized for their validity, the scientific community`s nature, links between technological systems, their contributions to the culture and vice versa [1, 2]. In this fashion, the scientific activity is reduced to textbooks and catalogues where the theory stated as the effective discovery is the one that matters instead of the ideas toward those discoveries.

III. BACKGROUND

To begin, the experience here presented stemmed from a broader study intended for analyzing three elements. Primarily, the didactic potentialities of science history in the physics teaching/learning process are examined together with Bogotá teachers` concepts and notions a propos the science image and nature [3]. And the last one comprises an inquiry into the methodological strategies exploited in the Physics teaching and learning process within the Bachelor degree in Physics at the District University.

With the intention of carrying out the experience development and analysis, two categories according with [4]. were taken into account namely, the phenomenon and problem nature, explanatory models. In effect, the chart 1 presents a description and characterization of each category from the traditional and contemporary perspectives on the science history.

IV. METHODOLOGY

The present experience embraces students` conceptualizations on science nature and history. Those results showed that there was a lack of science history foundations as well as a deep misunderstanding on the science nature (specially physics) and its possibilities around classroom practices [5].

TABLE I. Characteristics of Analysis categories from both, the traditional and contemporary standpoints on science.

Category (utilized for the analysis)	Category's description from the Science history traditional view	Category`s description from the contemporary vision on science history
The phenomenon character and problem within science.	Neither phenomena, nor problems are constructed; instead they seem to exist without breakings or changes. Then they are considered an additional approach of human reasoning to the nature. At the same time, they do not depend on the scientific communities or each epoch interests, having then a universal character.	The phenomenon as well as the problem keeps a constructed character. Both of them are subjective and mediated by socio cultural interests relative to the given epoch. Also, situations that produce questions commonly accepted in a historical moment are addressed. Neither of them has a universal character and is constructed in agreement by the scientific community. [7]
Explanatory models	These concentrate on the narration of external facts to the subject. This one in turn emerges as quantitative, isolated and ahistorical. Furthermore, one single model is deemed as true characterized by linear, ongoing and validated by the experimental method. By the same token, it is presented as finished and unique in textbooks.	In this case, the explanatory models spring from the constructed character from the phenomenon and problem. They also link the different models, their ruptures and controversies. There is not a unique valid explanatory model. The results of the experience are connected to the subject.
Science notion	It is unique, linear, continuous, determined-prescriptive and realistic. The truth is one and universal, the scientific truth. That is why this notion does not recognize other knowings` validity. In addition, the experimental method supports it. Furthermore, this notion is positive or ascending; therefore, "mistakes" are not seen as contributing to the construction process, but as obstacles to the goal.	In contrast, this notion is not linear, continuous or universal. Then it is not absolute, but relative. The subject participates in the phenomena and problems construction. In chorus, this notion is not determining or prescriptive. The reality and natural phenomena are the result of human experience. [8]

The experience was developed for three months with the two hours per week-intensity and unfolded in the qualitative approach along with the methodology known as *Case study*. In that regard, the activity concentrated on the analysis in deep of a 5 students-participants group from the course. Correspondingly, the activity covered two stages including the exploratory and the implementation ones. In respect to the former, students` conceptualizations and questions plus problems derived from the phenomenon studied were expressed. On the other hand, the latter entailed an analysis of the phenomenon from the perspective already pointed out, drawing on the bibliographical revisions and discussions.

1. Exploratory stage.

In accordance with Bachelard [6] "any knowledge is the response to a question". Thus, the exploratory stage attempts to identify and explore students` prior ideas as well as contributing to the problems identification and construction on the phenomenon called: Planetary motion. As a result, three points needed to be considered specifically, a) Motivation as a factor involved in learning, b) The importance of connecting knowledge construction to problems, and c) The inclusion of cognitive conflicts understood as the extension work in which some ideas or hypothesis are changed into others appearing as valid as the earlier ones.

2. Implementation stage.

At this level, the phenomenon is addressed not only for elucidating its reach and implications in the physics learning and teaching context, but also trying to reinterpret its contents taking the categories elaborated from the science history. In this opportunity, a study of related texts was performed with the aim to identify the problematic state of affairs that intervened in the appearance of explanatory models designed by science in different historical moments. Consequently, a myriad of works were studied; for example: On the Revolutions of the Heavenly Spheres. N. Copernicus. The world or Treatise on the Light. R. Descartes Sidereal Messenger, Galileo. The System of the World., Isaac Newton. Works and Context.

Moreover, tasks for observation comprehended as a process with theories and pretheories or concepts and preconcepts through which the subject constructs not just problems and questions to solve, but also his/her environment or phenomenon.

V. FINDINGS INTERPRETATION

In this section, the results obtained in the development of the experience are presented, highlighting the registers occurring with evident frequency and relevance for the group.

1. Findings exploratory stage

The above questions illustrate then the difficulty that existed between participants in the problems and questions elaboration. This is owing to the lack of the hypotheses statement, showing that problems and questions are in the need of an explanatory framework or model. Indeed, those questions are made as fragments of concepts, equations or laws responding to predetermined queries. Subsequently, it is feasible to assert that students share an idea on science only consistent in a set of scientific results without problems and questions.

Along these lines, within the ideas and conceptualizations made by students around the planetary motion, the subsequent ones stood out:

- "The universe was originated as a result of the big-bang, a big explosion of matter so that appearing when the space and time were created, followed by planets that move around the sun for the gravity among them."
- "Planets move in the space as if they were in whirlwinds, as when a Stone falls on the water, producing a wave"

This means that they had not been addressed, having a limited conceptual development. Likewise, the terms utilized reflected what had been listened to or read in classes. On the other hand, the second fragment above demonstrated the influence of Descartes` ideas about the starts` motion given in the form of whirlwinds. As a consequence, it is viable to observe how students` prior ideas related to those provided by science.

In spite of being this chance for students to state hypotheses, they did not emerge in the written text or in the discussions. In other words, students are being prepared to learn concepts, equations, and laws to answer preformulated questions rather than actively questioning. As a result, it is worth noticing the notion of science privileged in this case according to which it is finished and only constituted by scientific wise moves. Similarly, it appears progressive and without mistakes. For that reason, science in this view comes out as being a problematic and a historical. This aspect in turn does not correspond to the current statements concerning the science nature.

2. Findings implementation stage

The planetary motion phenomenon was studied and analyzed following the categories defined. In this manner, its most outstanding tenets were pointed out.

Through the lectures and discussions carried out, certain problems recognized by students appeared, including the next ones:

- "The sun and planets formation by means of the circular trajectory and motions"
- What motion do we have to bear in mind to explain planets motion?
- Why does a planet move following the observed trajectory?
- Did a planet`s speed depend on the distance from the sun?
- What is the shape of the orbits?
- What is the relationship between the revolution period of a planet to the orbit`s radius?
- Number, magnitude and motions of starts.
- Hooke posed a problem for Newton: how can we find a mobile`s trajectory that moves for the force of gravitation varying with the distance square in inverse towards the center?
- Halley visited Newton in 1684to discuss a problem he had been thinking of together with Hooke and Wren: what is the trajectory of a planet appealed towards the sun with a force changing with the distance square in inverse?

Initially, it was observed how students were not able to identify the singular problems that motivated the study despite lectures and discussions developed. In effect, there was a misunderstanding on what a problem referred to. Nevertheless, it was possible for students then to discover different and multiple problems that pushed the phenomenon study. Consequently, students realized about the fact that there were still problems without solution, becoming also the source of explanation that seemed to be better comprehended when approaching its problems

Some explanatory models identified:

Explanatory model 1:

"The whirlwinds or vortices theory. There is not emptiness; every space is full of a subtle substance: ether. This one moves in whirlwinds around the sun and other stars from which the earth divides the sky for each of them. Surrounding the sun, floating in ether and pulled by their vortices, the planets turn around. The universe expands indefinitely and what unifies it is the ether net.

Explanatory model 2:

"Planets move in elliptic orbits with the sun in one of their foci–it answered Kepler`s question on what orbits` shape was…" Besides, Kepler`s laws seemed not be invented by Kepler at once. On the contrary, the first and the second ones were published in 1609 unlike the third one relating the rest that was published in1618. In consequence, the sky constitution in the form of a circle got broken, showing an elliptic trajectory.

Explanatory model 3:

"The law of Universal gravitation. This is another explanation constructed to understand planets motion. *Thus,* it studies mathematically stars motion taking into consideration basic principles. By the same token, it rejects and questions the Cartesian idea on the whirlwinds, having Kepler`s laws as guiding axes. As a result, a new universe conceptualization emerges inasmuch as its unity does not depend on the geometrical stars constitution or a substantial net that connects them, but on a much more mathematical and geometrical principle namely, the Universal gravitation theory".

Keeping in mind this, it becomes feasible to interpret the previous fragment claiming that students were finally able to recognize the foremost explanations and relate the explanatory models to reconstruct that one from Newton.

VI. CONCLUSIONS

By means of the activity intended, inquiring into the planetary motion from the contemporary perspective on science History –following the problems and explanations construction- provided foundations for the concepts and theories comprehension.

In summary, the crucial aspects that were prominent once the activity finished were the following:

- It is worth noticing the role of doubt and invention as a creative and constructive factor in the epistemological, ontological and conceptual breakings.
- Carrying out activities where the science "mistakes" become apparent let participants know the diverse paths through which they went for their construction. Besides, this showed the human character in this activity. Furthermore, it shed light on the fact that knowledge was not constructed with the expected facility by which students were thought to acquire it.
- There is a commonality between students` explanations and historical conceptualizations that have been replaced by today`s accepted knowledge in the scientific community.
- The historical analysis indicates that the change of an explanatory model into another or conceptual and methodological adjustments in science do not occur easily and quickly. Hence, it is viable to think that the same will happen with students` conceptualizations and cognitive structures.

REFERENCES

[1] Acevedo, J. A., Vásquez, A., Martin, M., Oliva J., Acevedo, P., Fatima, M., Manassero, M., N*aturaleza de la ciencia y educación científica para la participación ciudadana. Una revisión crítica,* Revista Eureka sobre enseñanza y divulgación de las ciencias **¿vol.?**, 121-124 (2005).

[2] Matthews, M., *Historia, filosofía y enseñanza de las ciencias,* Revista de Enseñanza de las ciencias **12**, 255-277 (1994).

[3] Arévalo, J., Torres, Y., Ortiz, J., López, D. G., *Identificación de Tendencias Metodológicas en el Proceso de Enseñanza Aprendizaje de la Física Experimental en Algunas Universidades de Bogotá y Colegios Distritales,* Letras con ciencia Tecnológica. Revista Científica y tecnológica Instituto Técnico Central ET **1**, 29-38 (2006).

[4] Granes, J., *Gramática de una controversia científica,* (Unibiblos, Santa Fe de Bogotá, 2001), pp. 2-25; 97-143.

[5] Arévalo, J., Torres, Y., *La historia de la ciencia como recurso didáctico en el proceso de enseñanza y aprendizaje de las ciencias,* VIII Taller Internacional ENFIQUI, *La enseñanza de la física y la química*, y I Taller *La enseñanza de las Ciencias Naturales* Matanzas Cuba. Junio (2010).

[6] Bachelard. G., *La formación del espíritu científico,* (Siglo XXI Editores, México, 1984), p.p. 8-9, 17-26.

[7] Khun, T., *La estructura de las revoluciones científicas,* (Ed. Fondo de Cultura Económica, México, 2007), p. 29, 50, 57-58, 281, 284.

[8] Solbes, J. y Traver, M., *Resultados obtenidos introduciendo historia de la ciencia en las clases de física y química: mejora de la imagen de la ciencia y desarrollo de actitudes positivas,* Enseñanza de las ciencias **19**, 151-161 (2001).