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The importance of using models in the teaching and learning process of the nature of light

Ramirez Cindy Tatiana. [1], Grizalez Mendez Miguel Angel.[1], Torres García Luis Eduardo. [2]

[1] *programa de Matemáticas y Físicas: Grupo de Ciencia y Tecnología, Universidad de la Amazonia*

[2] *Grupo de Investigación CIEM-UA*

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Resumen

Análisis de experiencias recopiladas al dictar un curso – "el problema de la luz" - son presentados en este trabajo con el propósito de contribuir a superar fallas relacionadas con ideas erróneas tanto en los estudiantes como en los profesores. Al estudiante o futuro maestro se le orienta en el estudio de la naturaleza de la luz a través del conocimiento de los diferentes modelos o teorías que explican el fenómeno de la luz para que pueda tener un aprendizaje significativo y realice un cambio conceptual y metodológico y pueda aplicarlo en su trabajo de la educación básica, media o superior.

Palabras claves: Teorías, historia de los conceptos, modelos, naturaleza de la luz.

Abstract

Analysis of registered experiences on orienting a course –"the problem of light"- is presented with the aim at contributing to overcome failures related with wrong ideas both for teachers and students. Both the students and teachers are orientated in the study of the nature of light throughout the knowledge of the different models or theories explaining the light phenomena in order to have a significant learning and make a change both conceptual and methodological so it can be applied in their basic, medium or superior education work.

Key words: Theories, Concepts history, models, light nature teaching.

Introducción

Why a different didactic strategy for teaching and learning of physics? The traditional teaching and learning of science and particularly physics, in most cases has been restricted to develop the students' ability to solve numerical problems rather than to generate significant knowledge to enable them to properly explain the physical concepts from the simplest to the most complex. In the best of cases the teaching of physics has been limited to the macroscopic description of systems and their changes, omitting argumentation and reasoning strategies in which are involved their models, which have the effect of depriving the student the opportunity to understand how knowledge develops. This may lead students to invent "mysteries" to explain the material world, likewise thus often appear in their thoughts and interpretations, beliefs and alternative ideas that significantly determine their learning.

Einstein and Infeld in his book "The Evolution of Physics" point out the importance of the functional condition of physical theories and explanatory models as constituents of the same. They argue that "Physical theories are creations of the human spirit with their ideas, concepts and explanatory models freely invented. They try to give a picture of reality and to establish its relationship with the wider world of sense impressions. So, the only justification for our mental structures is the degree and the way that theories achieve such relationship".

Heisenberg said that physics is not a mere juxtaposition of findings and experimental observations at which its mathematical description is added. It is also the history of concepts. Consequently, Physics, at describing Nature by models, has certain characteristics that are instrumental in the methods to be followed in their learning. This should be a learning of concepts and theories of physics (i.e., models) taking into count that these evolve and we must place them in the history of physics stating their ranges of validity, the phenomena that they can explain and, at once, emphasizing the fact that theories are "representations" of Nature, but not Nature itself. That is, learning of physics can be

*Autor para Correspondencia: gotorresga@hotmail.com

conceived as conceptual and methodological change, without neglecting the students' prior conceptions and methodological inclinations to jump to conclusions based on qualitative observations.

Since theories evolve around one or more essential concepts, it is required then to use forms and different processes of teaching and learning of physics for students perceive the dynamic nature of knowledge and the role of physics in the understanding of the natural world.

A suitable didactic alternative to seek a meaningful learning of physics is undoubtedly the theory of models, since the use of physical models allow to predict the behavior of the system or the evolution of the phenomenon under study when modifying values variables or model parameters, in the same way the model theory facilitates understanding of phenomena or similar situations and facilitates scientific communication.

Therefore, in a physics course, it is required as the first didactic condition to introduce the suitable concepts, and to the extent that new phenomena are analyzed should incorporate new concepts in a clear and developed way, and then modify them, or replace them with better ones. Students must grasp the concept or idea of physical theory as a system of concepts, definitions and principles or laws that allow to describe and to represent mathematically a large number of phenomena. Physical theories are rooted in empirical facts through observation and experimentation and they have a very important feature to explain and to predict at the same time. Examples include Newtonian mechanics, thermodynamics, relativistic mechanics, Maxwell's electromagnetic theory and quantum mechanics. Regarding the topic at hand, the various theories of light, we must consider geometrical optics, wave optics and quantum optics.

As a result of pedagogical interaction between student and teacher, the student is required to understand that the various physical theories have a limited scope, whose borders usually are given by the conceptual models used in each.

The concept of model in Physics

What is a model in physics? Generally a model is an image or a conceptual representation of something real, is a figure of a substitute object. Models in physics are mathematical prototypes or paradigms, which means that the physical properties are represented by the quantitative variables in models.

Stephen Hawking and Leonard Mlodinow discussed in the Grand Design which should generally be a good prototype of a model [7]. Consequently a model is good if:

It is elegant

Contains few arbitrary or adjustable elements

Agrees with and explains all existing observations

Makes detailed predictions about future observations that can disprove or falsify the model if they are not confirmed.

By way of example, a mathematical model consists of four parts:

A set of names for the object and agents that interact with it and to any part of the object represented in the model.

A set of descriptive variables (or descriptors) that represent the object properties.

The model equations, describing its structure and its evolution over time.

An interpretation that relates the descriptive variables to the properties of an object representing the model.

There are three types of descriptors: object variables, state variables and interaction variables.

The first represents the intrinsic properties of the object. For example, mass and charge are subject to variables of an electron, while the moment of inertia and the specifications of size and shape are subject to variables of a rigid body. Object variables have fixed values of a given body, so they are actually variable from the point of view of the model theory.

The second representing the intrinsic properties with values which vary with time. For example, the position and velocity are state variables for a particle. A descriptor considered as a state variable in a model can be considered as an object variable in another model. Mass, for example, is a state variable in a particle model for a rocket, but it is constant in most model particles. Thus, object variables can be considered as state variables with constant values.

The third kind represents the interaction of an external object (called agent) with the object being modeled. The basic interaction variable is the mechanical force vector. Work, potential energy, and torque are alternative interaction variables.

For example, in the mechanics of particles, equations of a model typically are equations of motion (dynamic equations) for each of the particles in the pattern and also, if any, the constraint equations describing the interaction of certain types of interaction.

In some cases, it is convenient to change the equations of motion for the conservation laws related to the state variables at different times. This gives an alternative representation of the object, but it is a different model unless specified conservation laws have less information than the equations of motion, as often happens at times. In the equations of a model of the "internal variables of interaction", which describe the interactions between the parts of a composite object, they are expressed in terms of the state variables, so they are the dependent variables that can be eliminated mathematically. However, it is essential for the interpretation of the model.

Interpretations are treated so casually in physics textbooks that sometimes they become confusing for students. In fact, a common practice among physicists and mathematicians is the identification of the equations of a model with the model itself. This, of course, leads to the interpretation of the model; in fact it may be acceptable to scientists with experience, but not for students who need to recognize the performance as a critical component of a model, since without an interpretation of the equations, the model represent nothing, since they are only abstract relations between mathematical variables. Undoubtedly, this is what confuses physics students who have not developed the ability to acquire teacher's intuitive interpretation automatically.

In the inquiry that have made physicists and scientists all through history to discover the laws that govern the universe, there have been a number of theories and models, such as the theory of the four elements, the Ptolemy's model, the phlogiston theory, the theory of the Big Bang, and many other examples. As for the laws that govern the universe, we can say that: It seems that there is no single mathematical model or theory that can describe every aspect of the universe. But there seems to be a network of theories, and with each or with each model, our concepts of reality and of the fundamental components of the universe have changed.

Models approach to teaching and learning of Physics

What is the method of models for teaching and learning of Physics?

The models approach to teaching and learning of physics is a constructiv ist didactic strategy in nature, used for learning physics through inquiry; students are forging their own knowledge, design their experimental procedures, observe, formulate hypotheses, collect data, process and interpret information, contrast their hypotheses, communicate and share their ideas and results with peers and teachers. The models constructed are transferred to a variety of chosen situations, looking for generalization and consistency.

In this method the physics teacher becomes a designer of experimental environments, problems, activities and teaching strategies, he is itself a critical observer and facilitator of student's Socratic inquiry. The teacher interacts with the student in an atmosphere of warmth, trust and mistake tolerance.

The scientific concepts and principles most important are presented to students in this method that they should know and learn, showing at each stage of their development the general and specific objectives, a range of carefully selected content and models and specifying resources well teaching to be used to achieve the objectives.

The Modeling Method for teaching and learning of physics [9] consists of three phases, namely:

Building and developing the Model

Identification and Description. Under the guidance of the teacher, students describe their observations of the situation or phenomenon to treat, identify measurable variables, dependent and independent.

Discussion and Formulation: Autonomously students seek the proper relationship between the variables, discuss the experimental design and specify the details of a procedure.

Representation and Appropriation. Students construct graphs and math, prepare and socialize synthesis results and propose a model.

Confirmation and Consensus. Students defend their designs, results and interpretations constructed. Groups of students are selected to refute or validate results. The Socratic discussion focuses on seeking consensus for accurate interpretation of the model.

Defense and Model Validation

In validation activities, students learn to apply the model to a variety of similar and related situations, learn to identify the composition of the system and to represent its X structure accurately. Validate their understanding through oral presentations, guided by the teacher's questions that allow the understanding of the model achieved.

Model Application and Socialization

Students socialize the model presenting new situations for the same model, working in applied problem solving, defend and discuss the results.

A practical example: building models for teaching and learning theories about the nature of light. The following is an application example where the teaching and learning gravitate around the phenomenon in which light is involved, together with the experimental laws and principles that govern it, i.e. in terms of Geometrical Optics, Optics Wave and Quantum Optics.

The purpose of the activity is to use the method of models in the collection and analysis of experimental data to explain the reflection of a mirror or imaging lenses using the concepts of light ray and refractive index (Geometrical Optics), to teach the phenomena of interference and diffraction through the concept of wave (Wave Optics) and to teach the photoelectric effect using the concept of photon (Quantum Optics).

It is important to point to that the concepts and modeling used in the teaching of optics, either in the classroom or in textbooks (light beam, wavefront, electromagnetic wave energy quantized photon, etc.), by usually are not presented as models, i.e. representations constituted "calculable", more or less simplified, but as reality directly visible. Therefore, you can understand the problems and failures of students to devise theories as hypothetical constructs. That's why the dogmas resemble as definitive and closed.

Firstly, students are presented with readings related to the topics to be discussed, which are analyzed and discussed by students with accompanying teacher and try the concepts, definitions and results needed to build the model or final theory.

Students plan and conduct various experiments on the phenomena of light, previously defining the most appropriate experimental design, then they describes the observations made by determining the measurable variables and they construct graphs and charts, also they propose mathematical relationships that may characterize the observed phenomena, such as reflection, diffraction and refraction.

Next it is described, it is socialized taking the criticisms and suggestions to improve the work performed; subsequently, the model is built and proposed, presented and compared with already developed models for the study of light. The products to be obtained are equations for calculating the different variables and indices characterizing the study of the nature of light. The key to obtain learning relates to the ability to tailor the optical model to other experimental or theoretical situation natural phenomena of the same type of light each analyzed.

This paradigm is used to explain other experimental phenomena and to make predictions. It is required to compare different theories needed to understand the phenomena of light, trying to adapt it to the scientific method. This whole project should be considered as conceptual change to the level that we want, which in this case is a college or university degree.

From the standpoint of educational and training there is a range of possible models for use in studying the physical facts. These may be: iconic or scale models that offer a pictorial representation of the object, where this is usually presented through models, graphical models which are used in diagrams and components are drawn in simplified form with arrows pointing one's actions with others mathematical models which are types of scientific models that use some kind of mathematical formalism to expose relationships of events and situations difficult to observe in reality, conceptual or mental models that are structural analogues of states of affairs, events or objects world scientific model or conceptual model + physical laws is strictly corresponds to a theory.

The concept of a discourse model brings up all those who realize explanatorily descriptive of each of the fields of knowledge and research in the various working groups of specialists in science education from Nature [7]. Based on the model, you can perform analysis of how to run the basic, intermediate and higher education systems, the socialization of the historical development of scientific thought and activity among the younger generation.

Following this, the physics models are part of its body of knowledge and are committed to the description and explanation of the real world or in predicting situations. Therefore, learning in certain circumstances and depending on the age of the students is paramount to understand how we got to know what today is known in physics. However, rarely is seen to have opportunities to demand clarification on the design, evaluation and review of scientific knowledge, which is essential for the use of models [2]. It is necessary that students know how they are organized and how they are used.

The discussion suggests that it takes a logical and balanced curriculum development, so that students do not have difficulty learning and assimilating the different models on the nature of light have been developed; to know their limitations and to understand that one as well complement each other.

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