Previous physics knowledge of new entry students in the School of Physics, UAZ, Mexico

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Abstract

The objective of the present work is the evaluation and analysis of previous knowledge regarding certain aspects of physics of new entry students in the School of Physics (UAF) of the University of Zacatecas (UAZ), Mexico. In order to determine the new entry students' previous physics knowledge, we applied an evaluation consisting of 10 questions relating to some basic concepts of physics. The results obtained confirm the main hypothesis of our investigation: students do have previous knowledge of physics but it is not necessarily accurate.

Keywords: Conceptual errors on force, Physics Education, Classical Mechanics teaching.

Resumen

El objetivo de presente trabajo es el análisis y la evaluación de los conocimientos previos en aspectos de mecánica en los estudiantes de primer ingreso de la Unidad Académica de Física (UAF) de la Universidad Autónoma de Zacatecas (UAZ), México. Para determinar los conocimientos previos de física de los estudiantes de primer ingreso, aplicamos una evaluación consistente en 10 preguntas relacionadas a conceptos básicos de física. Los resultados obtenidos confirman la hipótesis principal de nuestra investigación: los estudiantes de física tienen conocimientos previos de física pero no necesariamente correctos.

Palabras clave: Errores conceptuales sobre fuerza, Educación en Física, Enseñanza de Mecánica Clásica

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I. INTRODUCTION

The knowledge and analysis of students' previous ideas are necessary if we wish to prevent the information that we teach our students from being influenced by erroneous mental concepts that they already have. There are four basic ideas of learning psychology [1, 2] that may help us understand the relevance of previous knowledge.

From a constructivist point of view, the interpretation of phenomena and the explanations that the students give of the concepts clearly depend on what previous mental images they have and in addition, will be a condition which influences the acquisition of new knowledge.

Another basic idea consists of assimilating that what we teach the students must be related to what they already know and to what they learn from their everyday experiences and environment so that two types of unconnected parallel knowledge do not exist, but rather uniform knowledge with multiple ramifications. When something is learned, it must be significant. That is to say, students construct new knowledge if they are conscious that it is new knowledge and if this new knowledge is in agreement with their previous experiences and concepts. This idea is fundamental when considering new methodologies of learning that result in the correct construction of the scientific knowledge.

Students are responsible for their own learning, since they are the ones who must look for the meaning of the new learning situation. The work of the professor must be focused on being a motivating factor for what he/she wants the students to learn. From classroom experience, it is easy to recall examples of answers to questions which reveal the deep lack of understanding of some key concepts. Simple questions not requiring simple memorization and repetition such as " if a stone falls from a certain height in one second, how long will it take another stone of double the mass to fall from the same height?" This type of question allows us to detect a lack of understanding of fundamental, repeatedly-taught concepts. For this particular question, the answers given revealed that high school students, university students, and a very high percentage of secondary students consider double the mass to equal half the fall time in spite of having previously done numerous exercises on the free fall concept and even in some cases, after having done experiments. These types of answers, contradictory to effective scientific knowledge, are widespread and rooted, usually occurring quickly, with certainty, repeated very insistently and are related to interpretations of diverse scientific concepts (gravity, force, intensity of electrical current, etc.). They are frequently referred to as “intuitive ideas,” “child’s science,” “conceptual errors,” “alternative frames,” or “spontaneous representations.” The ideas that lead them to commit errors are often referred to as “alternative concepts,” “previous ideas,” etc. [3].

As a result of multiple didactic investigations, the empirical evidence shows that before entering the university, students already have their own conceptions of natural phenomena and of what they will be taught [4, 5, 6, 7]. This may lead to deficient learning of the main concepts, scientific principles and models that are used to interpret natural phenomena, particularly if the professor does not pay attention to the previous ideas of the students, and does not consider them at the time of programming the educational activities. A professor’s role must firstly be heavily concentrated on detecting previous ideas and creating appropriate didactic strategies to deal with them. If indeed they are erroneous, they must be corrected and replaced by the adapted scientific concepts. This is not only applicable to students in basic education but also to students in superior levels [8].

Different investigative works [6] have tried to identify the origin of previous ideas. According to the works Osborne [9], their origin is related to: a) the experiences and observations of daily life; b) the habitual lack of precision of common language and knowledge especially that reflected in the beliefs and practices of their surrounding influences such as family, friends and school. These factors, among others, could be the origin of some spontaneous ideas that are reinforced by inadequate learning in social contexts [10, 11, 12].

Perhaps the most worrisome aspect of erroneous preconceptions is not their existence, but their persistence and insistent repetition throughout various academic levels with no correction or contradiction. All results obtained in the most recent investigations show students’ steadfast resistance to change mental structures they have already constructed. It has been proven that even a simple discussion of the correct scientific concepts has little effectiveness in generating a change in the students’ erroneous preconceptions which usually remain unaltered despite having completed several levels of education [13]. It is important to emphasize that students will not assimilate a new conceptual scheme if they are not aware of their own limitations regarding their previous knowledge and if they do not understand the need to modify it. Therefore, the significant learning of sciences will not occur by the accumulation of transmitted information, but rather by a conceptual change.

II. INSTRUMENT FOR THE DETECTION OF ALTERNATIVE IDEAS

The Diverse techniques exist to identify, clarify and quantify the incidence of alternative conceptions that the students have in the different scientific fields. For our investigation, we used an evaluation (Annex 1) [14], in which the questions were designed so that students with alternative concepts may express them and thus help us to identify the degree of the problem. The questions are multiple choice and true/false. By means of this system, the variables are more able to be significantly controlled.

Following the evaluation, a work session was held where students had the opportunity to explain why they decided on the answers they chose.

III. RESULTS

In order to objectively analyze the answers, the evaluation questions were classified into two categories: Category 1: Questions answered correctly according to the accepted opinion of the scientific community. Category 2: Questions answered incorrectly, questions that were difficult to classify due to confusing answers and questions that were left blank.

Based on this classification, the data from the answers was collected and is shown in Table I.

When analyzing the evaluation answers, the existence of many errors may be verified. These errors have some common characteristics of the type mentioned in the introduction. Following are some of these characteristics in order of importance: a) The distortion of the concept is insistently repeated throughout the different educational levels with no correction or contradiction.

TABLE I. Mean Percentage of answers classified within the defined categories.

Grinding time (min)	***Mean size (µm)***
2.5	315
5	185
8	128
30	46
45	34
60	27

b) Frequent errors occur regarding certain interpretations of a given scientific concept such as gravity, force, intensity of current, among others. c) Generally, we found that these answers were answered quickly with no hesitation or doubt as to their being correct. d) These mistakes that are made by a great number of students from a variety of different backgrounds and, even by some professors. Some of the alternative ideas that they may be behind the conceptual errors committed when answering the evaluation and which are in agreement with other investigations are: 1) there is no gravity in a vacuum. 2) Relating force to movement instead of relating force to the change of movement. This alternative idea of force causes them to think that on anybody in movement there must be a net force acting in such a way that if the force on the body is annulled, the body is stopped and that the greater the speed, the greater the value of the force. In addition, that the movement will always be made in the same direction and sense as the net force; and that if, at a given moment, the speed is worth zero, the resulting force on the body at this moment will have to be zero.

The previous idea the students have regarding force as the cause of the movement, is coherent with that which implies that heavy objects have to hit ground before lighter objects (when they are dropped from the same height) or more precisely, with the idea of an inverse proportion between the weight (or the mass) and the fall time (that, for example, with double the weight it falls in half the time). This idea of force as the cause of the movement leads them to, for example, in question 5, indicate option b) as correct in a great percentage of cases and at practically all educational levels (option b) states that as the iron block moves more and more slowly it exerts less and less force). These alternative ideas (erroneous concepts) induce the students to attribute "macroscopic" properties to atoms in order to explain a series of phenomena like dissolution, state changes state, expansion, etc. They may think if iron melts it is because the iron atoms melt or that if a gas is compressed it is particles that are reduced in size, etc.

Other alternative ideas include that electrical current is spent when it goes through a light bulb, that light is something that can be seen (just as we see the ordinary objects), that global movement of electrons which make up the continuous electrical current in a wire happens with enormous speed.

VI. CONCLUSIONS

In this work we have analyzed concrete examples of preconceptions relating to fundamental concepts and principles of physics such as force, gravity, electrical current intensity, and action/reaction, among others. The origin of these preconceptions, as well as the extent to which some of them are so deeply ingrained, can be explained if we consider the role played by the students' daily life experiences with physics, how badly it is understood and explained, the common language used in their social environment (Madrigal 2006, [12]), different mass media, the conceptual errors of some text books, and various different methodological aspects. Nevertheless, the main interest of research done on alternative conceptions does not reside in identifying in detail all of these conceptions in every single scientific field, although this knowledge continues to be essential for effective teaching. The fecundity of this line of research lies in the search for and elaboration of new models for teaching scientific concepts and the study of sciences in general conclusions must notice the new and remarkable contributions of the paper. Also the suggestions and shortcomings of the manuscript must be pointed out.

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REFERENCES

[1] Driver, R., *Psicología cognoscitiva y esquemas conceptuales de los alumnos*, Enseñanza de las Ciencias **4**, 3-15 (1986).

[2] Driver, R., *Un enfoque constructivista para el desarrollo del currículo en ciencias*, Enseñanza de las Ciencias **6**, 109-120 (1988).

[3] Carrascosa, J., *Errores conceptuales en la enseñanza de la física y la química: una revisión bibliográfica*, Enseñanza de las Ciencias **3**, 230-234 (1985).

[4] Brown, D. E., *Using Examples and Analogies to Remediate Misconceptions in Physics: Factors Influencing Conceptual Change*, Journal of Research in Science Teaching **29**, 17-34 (1992).

[5] Clement, J., Brown, D. E., Zietsman, A., *Not all preconceptions are misconceptions: finding 'anchoring conceptions' for grounding instruction on students' intuitions*, International Journal of Science Education **11**, 554 – 565 (1989).

[6] Driver, R., Gaalen, E., *Theories-in-Action: Some Theoretical and Empirical Issues in the Study of Students' Conceptual Frameworks in Science*, Journal Studies in Science Education **10**, 37 – 60 (1983).

[7] Wandersee, J. H., Mintzes J. J. and Novak, J. D., *Research on alternative conceptions in science*, en Gabel D.L. (ed.), Handbook of Research on Science Teaching and Learning, (MacMillan Pub Co, Nueva York, 1994).

[8] Repetto, E., *Programa de entrenamiento de la carrera. Cátedra de Orientación Educativa*, (UNED, Madrid, 1990).

[9] Osborne, R. J., *Towards modifying children's ideas about electric current*, Research in Science and Technological Education **1**, 73-82 (1983).

[10] Viennot, L., Reasoning in Physics: *The Part of Common Sense*, (Kluwer Academic Publisher, Dordrech, The Netherlans, 2001).

[11] Campanario, J. M., Moya A. y Otero J. C., *Invocaciones y usos inadecuados de la ciencia en la publicidad, Enseñanza de las Ciencias* **19**, 45-46 (2001).

[12] Madrigal, J., Enciso, A., *Teoría, métodos y técnicas para la enseñanza de la lengua*. Actas del IV Encuentro sobre Problemas de la Enseñanza del español en México, *Dra. Marina Arjona Iglesias*, Zacatecas, México, 2006.

[13] Furió, C. Guisasola, J., *La enseñanza del concepto de campo eléctrico basada en un modelo de aprendizaje como investigación orientada*, Enseñanza de las Ciencias **19**, 319-334 (2001).

[14] Carrascosa J. A., *El problema de las concepciones alternativas en la actualidad (parte I). Análisis sobre las causas que la originan y/o mantienen*, Revista EUREKA

sobre enseñanza y Divulgación de las Ciencias **2**, 183-206 (2005).

APPENDIX

Following are a series of questions related to some aspects of physics. Indicate the best answer.

1. Let's suppose that the atmosphere surrounding the Earth has completely disappeared, leaving the planet surrounded by the emptiness. In these conditions it can be affirmed that the body weight on earth: ( )
(a) will fall.
(b) will become zero.
(c) will increase.
(d) will not change.

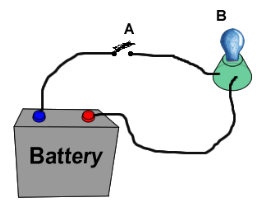
2. A stone is sent vertically upwards reaching a height of 6 meters off the ground. If there is zero air friction, what height will another stone reach sent with the same speed but whose mass is half that of the first one? ( )
(a) 3 meters.
(b) 6 meters.
(c) 12 meters.

3. It has been experimentally verified that when iron is heated it becomes red hot and finally melts. This phenomenon takes place because :()
(a) the iron atoms move away from each other debilitating the connections that join them, breaking many of them, etc.
(b) the initially hard iron atoms become softer and softer with the increasing temperature.

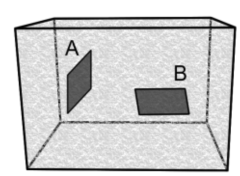
4. A piece of paper is inside a closed transparent sphere. By means of a magnifying glass, we cause this paper to burn until it completely burns up. If we weigh the sphere and the paper before (1) and after (2) burning the paper, it can be said that: ()
(a) (2) will weigh the same as (1).
(b) (2) will weigh less than (1).
(c) (2) will weigh more than (1).

5. An iron block has been sent towards the right on a smooth and flat surface without friction against an elastic spring, as shown in the figure. When the block hits the spring, the block continues moving towards the right and will push the spring: ()
(a) with more force.
(b) with less force.
(c) with the same force.

6. In the electrical circuit shown in the figure, it can be observed that when switch A is connected, light bulb B ignites. This happens so quickly because: ()
(a) the electric charges that constitute the current (electrons) move through the wire at the speed of light.
(b) the electric charges move through the cable at an enormous speed but without reaching the speed of light.
(c) although the electrons advance very slowly, the speed at which electric energy propagates is practically equal to the speed of light.

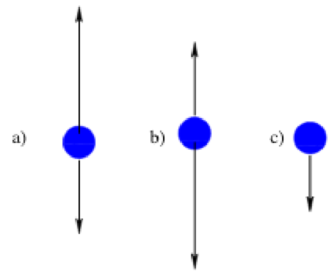


7. Two flat sheets are almost at the bottom of a pool of water. Sheet A is perpendicular to sheet B, as shown in the figure. It is possible to affirm that the pressure
on the center of sheet B will be: ()
(a) less than the value of the pressure on the center of sheet A.
(b) equal to the value of the pressure on the center of sheet A.
(c) greater than the value of the pressure on the center of sheet A.



8. If the velocity of a body is zero, the resulting force on the body at the same moment is also zero?
(a) True
(b) False
(c) I don't know.

9. An object is sent vertically from the ground upwards. Considering zero friction in the air, indicate which of the schemes correctly represents the forces that act on the object shortly before it reaches its maximum height? ()
a) b) c)



10. Indicate which of the following situations best describes what happens to the electrical current:
(a) The current leaves one battery pole, goes through the light bulb, and returns with less current to the other battery pole.
(b) The current leaves one pole, goes through the light bulb, and returns with the same current to the other battery pole.
(c) The current leaves both battery poles at the same time and is consumed in the light bulb.
a) b) c)