A proposal for the Natural Sciences teaching plan in the Mexican basic level schools

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(Received 24 August 2011; accepted 13 December 2011)

Abstract
Physics teaching, at all educational levels, has been a constant concern within the Mexican physics community. Traditionally the contents and sequence of concept teaching of physics notions was proposed and decided by the teachers of the basic educational level. In 2009, however, the Ministry of Public Education signed an agreement with the National Autonomous University of Mexico in order to get involved university teachers and active scientists in a discussion about what and how to teach natural sciences in the ground educational level. We discuss in this paper our experience participating in that project.

Keywords: Science in school, teaching methods and strategies, curricula and evaluation.

Resumen
La enseñanza de la Física, en todos los niveles de educación, ha sido una constante preocupación de la comunidad de los físicos Mexicanos. Los Planes y Programas en Ciencias Naturales en Educación Básica, en Física en particular, eran discutidos y definidos principalmente por un círculo de los propios maestros de ese nivel. Sin embargo, en el año 2009 la Secretaría de Educación Pública firmó un convenio con la Universidad Nacional Autónoma de México, con el fin de que miembros de su personal académico analizaran y sugirieran cambios, tanto en el contenido como en la forma de lo que actualmente se enseña en ese nivel. En este trabajo se presenta la revisión de los contenidos temáticos de Física, de los planes y programas de la Educación Básica, así como una propuesta en cuanto a la forma de enseñanza de esos contenidos, que realizamos dentro del convenio mencionado.

Palabras clave: La ciencia en la escuela, métodos y estrategias de enseñanza, planes de estudio y evaluación.

PACS: 01.40.-d, 01.40.jh, 01.40.J-, 01.40.gb, 01.40.G- **ISSN 1870-9095**

I. INTRODUCTION

The teaching of sciences in Mexico, at all the educational levels, has been of permanent interest between the members of the scientific community, especially between the physicists. A proof of it are the following actions: i) The continuous presentation of papers on physics teaching in the Mexican National Annual Meeting of Physics; 2) The opening of a section on Education in the Mexican Journal of Physics, since the year of its foundation, in 1952, and 3) The creation of the Mexican Journal of Physics E (dedicated to education, see http://rmf.smf.mx/) in 2004, among other actions.

The concern about the improvement of science education is also common among others scientific societies, like those of the chemists, biologists and mathematicians. However, the actions of the scientific community towards the solution of the problems in science education have been, neither frequent nor systematic, despite of the fact that the increase in the amount of scientists is of a great benefit for the country. It is also well known that to increase the number of students interested on science it is necessary to start their motivation from early age.

In this context, it is important to mention that the Ministry of Public Education (SEP) and the National University of Mexico (UNAM) signed, in 2009, an agreement to involve academic staff of this institution in the evaluation of the Plans and Teaching Programs of the basic education that are in use. This agreement has offered a unique opportunity so that teams of biologists, physicists and chemists, can contribute to the improvement of the quality of the education of these sciences in the basic level.

Here we present the proposals which we consider essential to implement, in order to obtain a substantial change in the quality of the education of sciences. The proposals are related to the thematic content that the students (ages from 4 to 15) must minimally know of Physics, to the educational strategies that contribute to form them like curious, inquiring and critical individuals, and to promote abilities, skills and values that are necessary in the modern cultures. That is to say, our proposals aim at "the what and at the how", to teach physical concepts, with the purpose of developing scientific vocations from early ages.

II. MODIFICATIONS TO THE CONTENTS OF PHYSICS IN THE PLANS AND TRAINING PROGRAMS OF THE SEP

In Table I we present a comparison between the proposals of the SEP and ours, about what Physics concepts are suggested to be taught, as written in the Plans and Training programs for the basic education. Due to space limitations we only present the case from first to sixth degrees of primary school, although we have also developed a proposal for kindergarten and Mexican secondary school (ages from 12 and 15). The criteria that we have used to make the modifications take into account the following aspects:

i) The level at which the subjects are to be taught, must take into account the degree of intellectual development of the kids.

This requirement is based in the research done by Piaget [1]. Taking this into account, some concepts as those of “atoms” and “molecules” are first introduced in the Mexican secondary school. It is important to note that this aspect is also taken into account in the programs implemented by the SEP that are in use. As an example, we show in Table I the concepts of classical mechanics of the present plan and our proposal (discussed below).

ii) The teaching of the subjects must advance in degree of depth, in accordance to the school level. The proposal is developed around the concepts of motion, interaction and energy.

As an example of the mentioned approach, we introduce in first degree of primary school the subject of “Motion of objects”, before the subject of “Transport”, as suggested by SEP. “Motion of objects” allows to introduce the student to the “Transport” in vehicles in a natural way, and connects the student with problems that the society faces. It also serves as an introduction to the subject of motion in Mechanics.

As one sees in Table I, one touches later on other aspects of the mechanical motion, but now with increasing levels of depth. In second degree, the change in the state of motion appears, as a result of the interaction between objects, due to mechanical causes. The student is asked to haul and push different objects to perceive the forces.

These experiences are further developed in third degree, to connect the effect of deformation that forces produce, besides motion. In fourth degree the effect of friction is introduced by means of experiments of free fall. In addition, the analysis of a simple and revealing movement is set out, the pendulum.

In fifth and sixth degrees the study of simple machines is introduced with the aim that the students start to understand the concepts of work and energy. These concepts are also treated in the context of Electricity and Magnetism, opening thereby interdisciplinary knowledge.

It is only in the Mexican secondary school when the student will be introduced to the laws of Newton and their applications, for example to the case of Gravitation.

In a similar way, the subjects of Astronomy, Thermodynamics, Optics, Electricity and Magnetism and Acoustics are developed in increasing degrees of interconnection of the basic concepts of motion, interaction and energy.

In Table I, we present in bold face our suggestions of new subjects or those in which a change in the thematic order is suggested, whereas the subjects that we propose to eliminate are underlined.

iii) The possibility of having an interdisciplinary approach with other sciences, within all the levels of the basic education.

In the example presented in section ii) we have stressed that the subjects of Energy and Work can be understood from the point of view of Mechanics and Electricity and Magnetism. For this purpose one uses the three fundamentally interlinked concepts of: motion, interaction and energy. In a similar way, these three concepts also appear in Biology and other natural sciences of the curriculum, giving an interdisciplinary aspect.

iv) The possibility that the experiments, suggested in each subject of Table I, can be performed anywhere in the country, independent of its economic limitations.

Considering this criteria, we propose experiments that require materials of easy acquisition. Therefore, we are skeptical to include experiments that involve magnets to teach the subject of Magnetism (third degree). Nevertheless, since such objects can be obtained in urban areas, we keep an experiment with magnets.

III. A PROPOSAL FOR THE EDUCATION OF PHYSICS IN THE BASIC LEVEL, BASED IN THE QUESTIONING AND RESEARCH

In order to be successful in fostering the scientific attitude of basic level kids, the educational programs must include a strategy able to secure this objective. Congruent with this, we believe that one of the most effective ways of education of sciences consists of a strategy based on making questions and doing research; that is to say, it is necessary to teach science in the same way as it is practiced. This means that the classroom should be transformed in a kind of laboratory in which, through simple experiments of Physics, the students perform intellectual activities, guided by the teacher, the results of these investigations are discussed with their classmates, and finally they write a report of their findings.

TABLE I. Comparative physic contents between our proposal and SEP programs.

	Astronomy	*Mechanics*	*Thermodynamics*	*Optics*	*Electricity and magnetism*	*Acoustic*
1°	Day and night through the children activities. Notion of time. Solar light, air, **soil** and water like components of nature.	**Objects motion; the case of vehicles.** Transport	Notions of temperature; cold and heat. Objects that produce heat.	Light sources.	**Discharges and sparks**	Sound producing objects.
2°	Apparent movement of the Sun, dawn and dusk in relation to the cardinal points. Climate in the different seasons of the year.	Force notion and motion. **Temporal or permanent changes in objects.**	Limitations of the senses for measuring temperature. Materials that preserve temperature.	Light, color and shades. Primary and secondary colors. Translucent, **transparent** and opaque materials.	**Electrically charged objects**	**Sound (pitch, intensity and timbre, applications of sound)**
3°	Phases of the Moon.	Identification of mass and volume. Applied forces: deformation, flotation, and change of motion.	Uses of the thermometer to compare the temperature of different objects.	Light, opaque and transparent materials, shades. Technical applications of light.	**Attraction and repulsion.** Magnetism (magnets)	**Musical instruments.** Sound (Tone, intensity and timbre, applications of sound)
4°	Movement of the Moon around the Earth and her with respect to the Sun. Eclipses. The day-night sequence. Geocentric and heliocentric models.	**Effects of friction on the movement. The pendulum.**	Physical states and their characteristics. Cycle of water and its importance. Baking, conservation and decomposition of food. Different forms of heat generation and its effect on materials.	Reflection and refraction of light.	**Conducting and non-conducting materials.** Electrically charged objects	**Sound perception. Generation and voice transmission.**
5°	The Solar System, characteristics of planets turning around the Sun. Exploratory missions to Mars and Pluto. The Earth: characteristics of present gases in the atmosphere and its contamination. **Law of Universal Gravitation.**	Magnitude of applied forces. Notion of speed. Simple machines.	**Reversible and irreversible processes.**	**Mirrors and lenses. Image formation.**	**Classification of conducting and non-conducting materials by simple electric circuits.**	Communication systems. Transmission of sound in gases, solids and liquids. **Sound speed.** Generation and voice transmission.
6°	Universe, its main characteristics and the technological advances for its knowledge.	Forces and their effects in the operation of simple machines. Simple machines as output of technology.	Recycling of materials, changes of state. Permanent (combustion) or temporal (evaporation and condensation) deformation. Thermodynamic energy transformations and their impacts in the atmosphere. **Efficient uses of energy**. Energy savings. Alternative sources and their use for environmental preservation.	Mirrors and lenses. Image formation. Optical devices and their importance.	Environmental impacts of the production, **transportation** and use of electrical energy. **Efficient and rational use of energy.** Energy savings. Energy produced by alternative methods.	**Sound perception from sources in motion.**

In this table we write in bold the contents which we propose to introduce or to move in their order of presentation, and we underline the contents which we propose to eliminate.

The Inquiry Based Science Education (IBSE) strategy is an approach for teaching and learning science that comes from three interrelated aspects: an understanding of the process of student learning; the nature of science inquiry; and an appropriate content (in our case the contents described in Table I).

Are the children able to perform scientific research? The answer is affirmative, and is the base of the IBSE strategy, in agreement with the work of Piaget [1] and innumerable educators. The IBSE is based on two proposals; one developed since several decades ago in the University of Oklahoma in the United States [2], and other more recent, presented in the project "Pollen, Seed Cities for Science" [3], in Europe.

Important principles of the IBSE approach, as taken from Ref. 3 are: Direct experience is at the core of learning science; students must analyze and understand the question or problem that is the focus of their work; doing science inquiry requires that students learn many skills (one of the most fundamental is careful observation); learning science is not only acting on and with objects, it is also reasoning, talking with others, and writing both for oneself and for others; the use of secondary sources complements direct experience; science is a cooperative endeavor.

Some important pedagogical considerations in IBSE are in Ref. 3: Organizing the classroom as a research environment; creating and asking productive feedback questions, both by the teacher and the students; using student's prior experiences and ideas; holding group discussions; guiding student written recording.

Pedagogical strategies for specific stages of inquiry [3]: Guiding students as they design an investigation; helping students analyze their results to reach valid conclusions; comparing and contrasting with "established facts".

From these general considerations one can design learning experiences, sometimes called didactical sequences, for the teaching of the units forming part of the physics contents that the students are expected to learn. Their design must be compatible with the development of competences that the Mexican educative system is currently demanding to be part of the student's personalities.

We organized three workshops during 2009 and 2010 on IBSE and didactical sequences design. The participants were teachers from each one of the 32 states of Mexico. Each workshop lasted 40 hours, and was conceived in a way that the participating teachers could offer a similar workshop to their colleagues, back home. In this way it was expected a kind of trickle-down effect in which the students would be the last recipients of the learning experience of science.

Although we considered, in coincidence with the opinions of the attendant teachers, that the three workshops were successful, the expected educational after-effect produced by the teachers in their home state of the Mexican Republic, was not carried on. One of the main reasons for the non-occurrence of this positive feedback was, the lack of understanding of the physics contents by the teachers. This is mainly due to the fact that in most of the pedagogical schools where they study to be teachers do not include physics as such in the curriculum, nor any other of the natural sciences. In some schools the program includes physics or other natural sciences, but the emphasis is on pedagogical aspects rather than science by itself. Then, how to teach something one does not understand?

IV. CONCLUSIONS AND RECOMMENDATIONS

No doubt that the entire educational Mexican system requires a deep restructuring; this is so appreciated by almost everybody, including the official authorities responsible for that sector of the government [4]. It is in this context that the mentioned agreement between the Ministry of Education and the University of Mexico was signed in 2009. As physicists participating in the agreement, we consider important to make the following recommendations:

i) To continue the agreement between the University of Mexico and the Ministry of Education;
ii) To extend it to all the other institutions of higher education and scientific research in the country;
iii) To change the curriculum of the schools dedicated to prepare the teachers of the basic educational level, so that they learn natural sciences as such, together with their pedagogical background;
iv) To support the implementations of agreements between teacher schools and higher education institutions and scientific research, in order to organize many workshops, similar to the ones we have described here.

We are aware that to fulfill the recommendations it surely requires an effort of national proportions. However, although difficult, we strongly believe it is the only way to raise the quality of the scientific education of our students all over the country.

ACKNOWLEDGEMENTS

This work was supported by SEP-UNAM project.

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