Science Education International
Vol. 16, No. 4, December 2005, pp. 271-279

International Council of Associations in Science Education

The Teaching of Natural Sciences in Mexico: New Programs and Textbooks for Elementary School

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ABSTRACT *For almost a hundred years, basic education in Mexico has been mandatory, free and non-religious. Starting with the Basic Education Reform (which includes Kindergarten, Elementary and Middle levels, that is, students from 3 to 15 years of age) in the early '90s, there was a production of new free text books. This article reviews the characteristics of the Reform and the corresponding text books, and also presents a definition of the Mexican Education System.*

KEY WORDS: *Educational reform of natural sciences, textbooks, Mexican education system.*

Foreword

The study of different world traditions in the teaching of science has been gaining relevance in the face of the unyielding deterioration of its learning in many countries. For that reason, the past few years have witnessed the development of new projects; among these, "*Science for all Americans*" (Rutherford, 1990) and *2000+* (ICASE-UNESCO, 1993), both sharing an ambitious quest for total literacy, stand out. The goal of this article is the introduction of one of these quests.

For a long time, educational efforts in Mexico have been fundamentally focused on expanding the educational services in order to meet the demand posed by an increasing demographic rate that, with time, has been subsiding, as it is shown in Table 1. Over the last hundred years, population grew more than seven fold, not so the resources allotted to educational needs. An example: currently, the amount of money spent in the education of a primary student in Mexico is approximately 100 U.S. dollars, versus 600 dollars for an American student, 130 dollars for an Argentinian and 220 dollars for a Chilean pupil. In other words, we experience a shortage in the educational expense per student.

Table 1
Demographic Growth in Mexico.

Year	Population (millions)
1900	13.6
1921	13.3
1940	19.7
1960	34.9
1980	66.8
2000	97.4
2020 (estimate)	121.8

In Mexico, basic education (from Kindergarten up to Middle school, that is, from 3 to 15 years of age) is mandatory, free and non-religious. As of 1960, all students receive free text books that deal with their school grade subjects, and according to the single curriculum studied overall Mexico:

> *"... it is one of the most valuable structures of our Elementary education. It sets a common starting point for the formation of students and is an essential element for the fair access to opportunities in education (SEP, 1996)."*

Over the last forty years, the free textbook has been a key factor in the educational policies of the country, inasmuch as, because of its relevance and presence in the educational process, it has been the main agent of the educational reform. Moreover, given the great socio-cultural disparities, sometimes school texts are the only books available at homes. Each child in the country receives the books at the beginning of the school term (200 days starting in August). Each book costs a little less than a U.S. dollar (at year 2003 prices) and, from the time of the Educational Reform (launched in the early 90s), each student receives 40 different elementary school textbooks (39 books are federal, that is, exactly the same all over the country, and one corresponds to the state where the student lives).

The Mexican educational system serves a little more than 27 million people, 83% of them pursuing basic education. Next, we present data of the country's educational activity. Table 2 shows basic level Mexican educational system, extension and distribution. Table 3 shows the span of elementary school and Table 4 depicts free textbook production during the past years.

Table 2
Basic Education Students, Schools and Teachers (2000-2001)

Level	Students' age	Total register	Teachers	Schools
Kindergarten	4-5	3 456 096	155 777	72 650
Elementary	6-11	14 808 199	545 717	99 176
Middle School	12-14	5 348 026	307 763	29 007
Total		23 612 321	1 009 257	200 833

Table 3
Percentage of Registered Students in Elementary School

6 to 12 years	1970	1990	2000
Boys	66.1	89.2	93.9
Girls	65.4	88.8	93.8
Total	65.7	89.0	93.8

The Teaching of Natural Sciences

Previously to the 1993 Educational Reform in Mexico, as in other parts of the world, it was common belief that if students reproduced scientific activities, they would achieve the corresponding knowledge. This situation favoured the performance of experiments to confront the student with natural phenomena (Bonilla, 1997). Empirical knowledge seemed essential. The intention of this type of teach-

Table 4
Free Text Books Production

Year	No. of Issues	No. of Titles
1960	17 632 000	19
1970	57 707 000	37
1980	48 413 000	27
1990	75 890 000	27
2003	200 000 000	105

ing was "to form little scientists" (Black, 1996), and it paid particular attention to scientific method seen as a discovery process. The deficiency of this approach to science teaching was evident in few years. The students did not learn the empirical aspects of scientific knowledge, mainly stemming from the experimental work they did not perform, neither did they grasp matters related with the process of such a complex and abstract reality as science, or its simple appreciation:

> *"... this ability to understand is, as we have seen, very independent from "speaking and writing well." And if it cannot be taught or transmitted by adults to children, it can be achieved by the child, provided that he grows in a favourable environment. This means that adults are able to understand his curiosity and desire to act in first person, and he is not forced to repeat what has been done, said or thought " (Ceccarelli, 1985).*

Educational research about the way children learn has set the basis to restate the teaching of natural sciences (Driver, 1989; Claxton, 1994). The need to consider the experience of children, as well as their conceptions regarding phenomena, has become evident as a starting point for teaching strategies:

> "*If I had to reduce all education psychology to a single principle, I would state this: the most important factor influencing learning is what the student already knows. Find out what that is, and teach accordingly*" (Ausebel, 1976).

Therefore, the intention of this new paradigm, as indicated in Table 5, was to achieve an approach to scientific thought, so that the student might use it to expand his understanding of the world, starting with his daily-life phenomena. But that is not all. There is also an aspiration to change the learning strategies, so students must put their thoughts into conflict (Giordan, 1995); therefore, *ad hoc* activities must be designed and carried out. Regarding experimentation, the combination of two strategies is accepted. One that allows clearance of certain concepts or general laws based on traditional experiments, as done previously, and another one that promotes the creation of knowledge by the student, starting with the consideration of his ideas against the results of simple experiments. In other words, the objective is for people to learn well (Claxton, 1994).

Usually, common citizens do not have to apply sophisticate scientific or technological knowledge, so it is convenient to promote the understanding of the essential part of scientific activity by the basic education. Thus, the citizen of the future will be able to develop skills, capabilities and attitudes that will enable him, at least, to get a basic knowledge of his body and the surrounding environment.

Table 5
Comparing the Objectives of Science Curricula at Different Decades

1960-1980	1980-2000
Preparation	Propagation
Generation of Knowledge	Application of Knowledge
Disciplinary Emphasis	Emphasis on Society
Controling Content	Seizing Content
Right/Wrong	Risk/Benefit
The Class as a Unit	Small Work Groups
Individually-solved Problems	Cooperatively-solved Problems
Model Construction	Decision Making

Ultimately, this formation must let the information he receives in the future help him to make crucial decisions about different problems and start personal actions arising from these decisions. This approach is considered to come close to the indications made by the UNESCO about the need to form scientifically literate citizens (UNESCO, 1993).

The New Programs and Textbooks

A new educational reform was started back in 1993, aiming at the modernization of learning in basic education, in all its modes. Particularly in the case of natural sciences in elementary education (students from 6 to 12 years of age) the following guiding principles were requested:

- To link natural world knowledge achievement with the formation and practice of scientific attitudes and skills.
- To relate scientific knowledge with its technical applications.
- To pay special attention to themes related with the preservation of the environment and health.
- To promote the relationship of learning natural sciences with the contents of other subjects, particularly language (Spanish) and mathematics.

These guiding principles are integrated in five thematic axes grouping contents and that, according to the importance established by these orienting principles, are:

1. Human body and Health (HBH)
2. The Environment and its Protection (EP)
3. Living Beings (LB)
4. Matter, Energy and Change (MEC)
5. Science, Technology and Society (STS)

The interrelation of these five thematic axes is consolidated in the textbooks in five blocks. This first division obeys the peculiar Mexican school calendar. Usually, from the beginning of classes until Christmas, two 2-month periods (bimesters) elapse, and this is equivalent to studying the first two blocks. Subsequently, from Christmas until the Holy Week, another two bimesters elapse and two more blocks

are studied, leaving the fifth and last block until the end. As we will see, this block does not contribute to new information, but only integrates that already reviewed.

Each block conjugates more than one thematic axis with the guiding principles, thus showing the integration of science, starting with daily environmental phenomena, or those related with the human body and health. The first four blocks of each book consist of eight lessons, and classroom debate takes one week. The first seven lessons of each block are a corresponding part of the program, while the eighth summarizes and integrates it. On the other hand, the first four blocks present the program, while the fifth (called *Pongamos Todo Junto* [Let's put it all together]) summarizes and integrates it. On this double round, at the end of each block and each course, knowledge is collected and integrated into more complex knowledge (Table 6).

Table 6
Index of Text Books

Block	Name	Thematic axis
	THIRD GRADE	
Block 1	We all use and discard things	EP-STS
Block 2	Water, Air and Living beings	LB
Block 3	Feeding and Nutrition	HBH
Block 4	Movement	MEC
Block 5	Let's put it all together	HBH-EP-LB-MEC-STS
	FOURTH GRADE	
Block 1	Our relationship with the World	HBH
Block 2	Living beings and their environment	LB
Block 3	Things change	MEC
Block 4	Let's protect our resources	EP-STS
Block 5	Let's put it all together	HBH-EP-LB-MEC-STS
	FIFTH GRADE	
Block 1	We Living beings are part of the Ecosystems	EP
Block 2	The microscopic World	LB
Block 3	Human Diversity	HBH
Block 4	Energy to transform	MEC-STS
Block 5	Let's put it all together	HBH-EP-LB-MEC-STS
	SIXTH GRADE	
Block 1	Where do we come from?	LB
Block 2	How do we live?	EP-STS
Block 3	How are we?	HBH
Block 4	Where do we go?	MEC
Block 5	How do we know?	HBH-EP-LB-MEC-STS

Among the many innovations, curricular change promotes equity of gender; the intention was to integrate it in textbooks. Special attention was paid to the iconographic handling eliminating stereotypes and presenting women performing tasks traditionally destined for men and viceversa.

Lesson structure shows the following characteristics:

1. Starting from previous educational research about what children know, the Bachelardian principle about the importance of making questions (Bachelard, 1979) is assumed as a fundamental premise:

   "For a scientist, all knowledge is an answer to a question. If there was no question, there cannot be scientific knowledge."

2. Besides the main text, each lesson includes at least one of these three types of activities:

i	Open up your eyes	(Abre bien los ojos)
ii	Let's explore	(Vamos a explorar)
iii	Let's get to work	(Manos a la obra)

All activities try to develop different capabilities, not all of them specifically scientific, such as, writing, pattern or guideline identification (*Open up your eyes*), manipulation of objects and/or experimentation (*Let's get to work*), problem solving and/or research (*Let's explore*). In Figure 1, a facsimile page of sixth-grade textbook showed one of these activities related with the soil.(*Let's get to work or Manos a la obra).*

3. On each lesson, there is another type of parallel information identified with panels, and this can be of two kinds:

i.	*Did you know that...?*	With qualitative information related with the main text.
ii.	*Compare*	This fundamental scientific activity introduced quantitative information.

Furthermore, students elaborate a scientific dictionary (bottom of Figure 2), learn to estimate, are initiated into dealing with conceptual maps, make decisions (Figure 2) by means of a specific activity (in fifth grade), and are challenged (in sixth grade) to integrate all their knowledge into the last activity of the program.

Special mention must be made of the last blocks of each book, because they contain an additional analysis proposal (in the third and fifth grades with the execution of a small research project) and synthesis (in the fourth and sixth grades, with an adventure in an uninhabited island following the prints of the past).

Moreover, the intention of the sixth-grade book is to integrate the previous three (it would be the equivalent of block number five of each book) and debating about time, with the didactic use of a "history line" on each bottom text page (see Figure 1) in the last lesson of each block.

In spite of the difficulties encountered among different groups of Mexican society regarding the discussion of taboo-themes, particularly those referring to sexual education that generated a strong public debate, this ambitious reform project concluded, on a first stage, with the distribution and use by more than 12 million children of the four textbooks during the 1999-2000 term.

¿Cómo es el suelo?

Uno de los componentes más importantes de los ecosistemas es el suelo. Para aprender cómo son sus características, tendrás que trabajar con muestras, es decir, con pequeñas cantidades de suelo. Realiza en parejas la siguiente actividad.

Necesitas por pareja:

una lupa, lápices de colores, tres muestras de suelo de lugares diferentes, tres hojas de papel

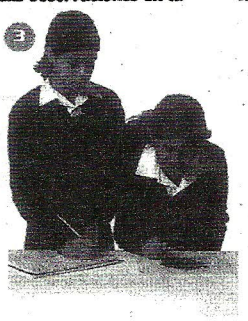
1. ***Copia en tu cuaderno una tabla como la siguiente:***

Muestra	Lugar de donde se obtuvo	Color	Dibujo	Otras observaciones
1				
2				
3				

2. ***Con cuidado, distribuye sobre una hoja de papel una muestra de suelo. ¿De qué color es? Regístralo en la tabla.***
3. ***Observa la muestra de suelo con la lupa y dibuja en la tabla lo que observaste.***
4. ***Toma un poco de suelo entre los dedos, apriétalo y contesta: ¿Cómo se siente? ¿Se pegan entre sí las partículas o permanecen separadas? ¿Observas algún ser vivo en la muestra? Registra tus observaciones en la última columna de la tabla.***
5. ***Repite cada uno de los pasos con las otras dos muestras de suelo. Completa la tabla con tus observaciones.***

Junto con tu maestra o maestro, propón y lleva a cabo un experimento para investigar cuál de las muestras absorbe más agua y reflexiona acerca de qué suelo sería el más adecuado para cultivar y por qué.

Anota los resultados en tu cuaderno.



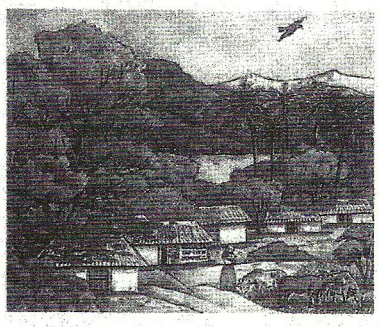
En Asia hace 5 000 años, la invención del arado incrementó la producción agrícola. Su uso hizo vulnerable el suelo a la erosión.

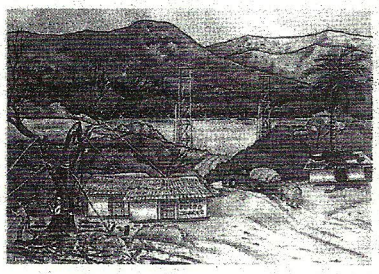
Los chinos inventaron su escritura hace 3 500 años.

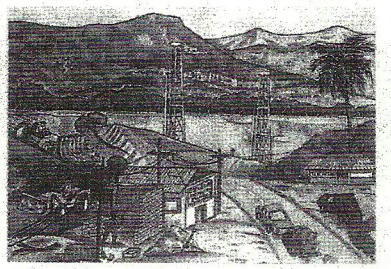
Figure 1. Facsimile of a Sixth year book

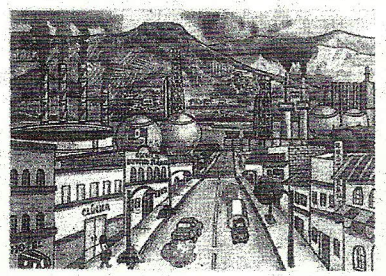
TÚ DECIDES

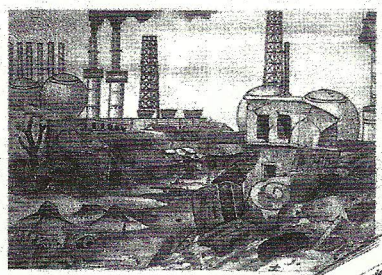
Imagina que en la comunidad donde vives se descubre un yacimiento de petróleo. Parte de la gente está feliz porque su explotación permitirá contar con más y mejores servicios.
Otras personas piensan que es mejor no extraer ni utilizar el combustible porque esto provocará problemas ambientales. ¿Qué hacer? Para tomar una decisión, organízate en equipos.
Haz dos listas: una con los posibles beneficios que tendría la explotación del yacimiento, y otra con las desventajas. Analiza las dos listas y toma una decisión sobre lo que conviene hacer. Escribe una carta que le enviarías a las autoridades de tu comunidad donde expreses tu punto de vista.











No olvides completar tu diccionario científico con las nuevas palabras que aprendiste en este bloque. Algunas de ellas son las siguientes:

conductor eléctrico	decantación	mezcla homogénea
electroimán	mezcla heterogénea	trabajo mecánico

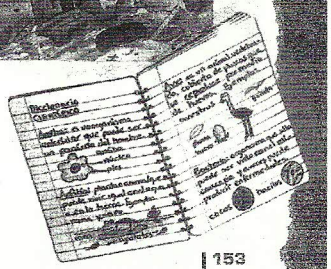


Figure 2. Facsimile of a Fifth year book

It has been said that (Vargas, 1997):

> *"There is no need to make an exhaustive review of the new free textbooks to verify that the Public Education Ministry (SEP) has assumed the importance of this fact. Graphic quality was substantially improved in the edition of the new materials, with a clearly higher level than most textbooks marketed by private publishing houses. And the relevance lies on the fact that the SEP improved the quality of the material not as a market-competition move, but obeying a strictly educational need: to encourage the children of the country to experience an enriching approach to the world of books".*

Conclusions:

The Spanish poet Antonio Machado says in one of his best known poems:

Walking makes the path, the path is made by walking...

The path of the Educational Reform of natural sciences in Mexico has just begun. There is much to do, particularly regarding teachers' formation inside the new paradigm. We want and hope to make it.

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