Chapter 69
The History and Philosophy of Science and Their Relationship to the Teaching of Sciences in Mexico

Ana Barahona, José Antonio Chamizo, Andoni Garritz, and Josip Slisko

69.1 Introduction

Why is science so important in today's societies? Science (along with technology) is one of the salient endeavours of the contemporary world and, more than any other human activity, distinguishes the current period from previous centuries. According to Stehr, it is a widely shared assumption among contemporary social scientists that the immense impact of science and technology on society has become one of its defining characteristics (Stehr 1994).

Nowadays, we are experiencing the fourth, postindustrial, technoscientific revolution, where science and technology play an increasingly important role in most spheres of life and where our dependence on knowledge-based occupations is considerably growing (Böhme 1988). Contemporary society may be described as a knowledge society, based on the penetration of all its spheres by scientific and technological knowledge (Stehr 1994).[1]

[1] Some authors consider the first of the technoscientific revolutions to be the agricultural revolution; the second, the industrial revolution, (these two revolutions emerged from applying new sources of energy to mass production of goods and the transfer of information theory to industrial processes); the third the informatics and robotics revolution; and the fourth the postindustrial revolution. These revolutions were manifestations of the ever-increasing capacity of human beings to

A. Barahona (✉)
Departamento de Biología Evolutiva, Facultad de Ciencias,
Universidad Nacional Autónoma de México, UNAM, México
e-mail: ana.barahona@ciencias.unam.mx

J.A. Chamizo • A. Garritz
Seminario de Investigación Educativa en Química, Facultad de Química,
Universidad Nacional Autónoma de México, UNAM, México

J. Slisko
Facultad de Ciencias Físico Matemáticas, Benemérita Universidad
Autónoma de Puebla, México

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Advances in science and technology deeply influence natural and social processes. Science and technology as an instrument of mediation between nature and society have transformed people's lifestyles and their relationship with the cultural and natural environment.

Now we know more about the way the world and the universe work; in matters of health many diseases have been eradicated, and many therapies have been found for others. On the technological side, modern agriculture and industry have been developed to cover the needs of more and more inhabitants of the planet, as well as increasing the possibilities to access information in real time with worldwide coverage. Modern societies cannot function without the products of science and technology; they are now so commonplace that they have become largely invisible.

Changes due to science and technology have generated transformations in the way knowledge is organized and have transformed societies into knowledge societies, where information is manifold, decentralized and available to more and more people around the world. This is why it has become essential to modify the current education system regarding science and technology in countries like Mexico. In order to do so, the inclusion of reflections produced by historical and philosophical studies has been a cornerstone over the last three decades.

The first part of this chapter is about the relationship between the history and philosophy of science and the teaching of science. It will allow us to emphasize the value that recent studies on the history and philosophy of science have had in science education in Mexico. On one hand, in it we stress the importance of the history and philosophy of a discipline in the teaching of science, and on the other, we insist in the role of science in modern societies and encourage science teaching within a historical and philosophical perspective. In the second part we will review the latest Mexican educational reforms in 1993 and 2006 and acknowledge the advances regarding the teaching of biology, physics and chemistry in basic education (elementary and junior high school) as well as the inclusion of the history and philosophy of science.[2]

69.2 The History and Philosophy of Science and Their Relationship to the Teaching of Science

Science, like other human activities, is a complex and social one (Longino 1990). We can say that science is a way of knowing about and explaining the world around us. It differs from other forms of knowledge in its particular ways of observing, thinking, experimenting and testing, which constitute the fundamental aspects of its nature. From a scientific perspective, things and events in the universe

control and manipulate their environment and resulted in important social and political changes (Hirschhorn 1986; Stehr 1994).

[2] A more broad approach had been boarded by two of the authors (Chamizo and Garritz 2008).

present consistent patterns which can be understood by means of systematic study. Scientists attempt to make sense of the observation of phenomena by formulating explanations based on scientific principles accepted by the community that are compatible with these phenomena.

Science can be understood as a process of knowledge production that not only has instruments which expand the senses and allow careful observations and interventions in phenomena but also establishes the theories which make sense of them (see, e.g. Golinski 1998; Hacking 1983).

Science has a history of elucidating many processes; the way human beings have observed and explained nature has changed through history. At the beginning of the nineteenth century, for example, the existence of genes was unknown, though it was known what happened when one crossed certain plant varieties. Nowadays we have the sequence of the human genome. Change in knowledge is evident and inevitable. Scientists reject the idea that one goal of science is to reach the absolute truth and agree that there is some uncertainty that is part of its nature and modification of knowledge is one of its norms; however, it can be said that most of scientific knowledge is long-lasting. What we know now can be modified or rejected by future observations or theoretical proposals. Therefore, stability and change are integral parts of the nature of science.[3]

Science is not only a collection of data. Concepts, scientific theories and methodologies, along with goals, values, aptitudes and abilities (which are handed down from generation to generation), are an integral part of science. When one teaches or learns science, one does not only teach or learn 'scientific knowledge' but also goals and values (objectivity, honesty, collaboration, conservation of nature), abilities (to observe, manipulate, calculate, measure, estimate) and aptitudes (curiosity, openness to new ideas, confrontation of different positions before problems, informed scepticism, communication). Scientific education can and must contribute towards enhancing people's knowledge as well as to develop scientific values and/or social values in general positive aptitudes and abilities that help improve quality of life. In this sense, schools have an unavoidable social duty, as they are in charge of distributing scientific knowledge to the population.[4]

What is the importance of teaching science? Human beings have everyday principles, which allow them to interact with the world. However, science enables us to have a better quality interaction. In modern societies, active participation and a

[3] Thanks to recent studies on the history and philosophy of science, it can be said that the different ways in which humanity has explained phenomena, i.e. the different patterns of scientific explanation, have been modified over time (see, e.g. Martínez 1993).

[4] Values have been basic elements of the twentieth-century educational perspective in Mexico, for they have social, political and pedagogical content that expresses the standards of comprehensive human education. For this reason, values have been considered an asset whose conveyance and quality must be promoted. Their presence in the social milieu has been linked to the development of the Mexican educational system since the end of the nineteenth century (Latapí 2003). Nevertheless, as Wuest Silva and collaborators (1997) mention, the study of the role played by the values associated with science and pedagogy did not begin until the 1980s.

sense of critique[5] are essential before the magnitude of the problems we face. For example, in nuclear power, climate change, the loss of biodiversity, atmospheric pollution, serious diseases such as AIDS or cancer, to name a few, scientific knowledge has become valuable in itself, and these issues have caught our attention regarding the relationship between science and society (Shortland and Warwick 1989). The teaching of science and the acquisition of scientific knowledge have value because knowing science allows us to have explanations about natural or social phenomena and develop the capacity to solve problems with efficiency (Matthews 1994/2014).

Over the last three decades, the importance of the history of science in scientific education has been gaining recognition. Below are a few of the most important reasons. The study of the history of science:

- Helps us understand the nature of science as a complex cultural enterprise that can be presented as part of a wider cultural heritage (Jenkins 1989) and therefore helps place professional education appropriately within a broader cultural context. It is not about forming scientists at an early age (which may be a positive effect), but to form informed citizens with the capacity to decide, observe and manipulate their surroundings.
- Gives us a better understanding of the methods and concepts associated with goals and values which are characteristic of different times and that remain stable for long periods.
- Can enable future scientists to improve their response to the challenges posed by the rapid globalization of science and technology (Wilson and Barsky 1998); according to Gooday and collaborators (2008), the history of science has particularly important forms of knowledge and understanding concerning science that cannot be obtained so effectively by any other means, like the ability to read and interpret primary sources and formulate and defend a cogent argument (see also Solomon 1989).
- Allows us to understand how scientific goals and values go beyond disciplinary boundaries and contribute to the reorganization of disciplines and the development of technological advancement, important to the understanding of modern science. For example, the Human Genome Project would have been impossible without the participation of the most important technological firms in charge of making the sequencers, the big philanthropic foundations in charge of financing, the universities and higher learning centres where scientific knowledge is produced and disseminated, etc.
- Allows us to find suppositions which are shared by students and whose critique and abandonment are associated with important scientific advancements. The teaching of the history of science will allow students to locate these presuppositions (or previous ideas) and be in a position to abandon them rationally. For example, a serious

[5] The role of critical discourse in science is not a peripheral feature, but rather it is at the core of its practice, and without it, it would be impossible to construct reliable knowledge; for authors like Osborne (2010), scientific education must include critical discourse in the teaching of science to foster the ability to reason and argue scientifically.

problem in students at a higher learning level is their lack of post-Lamarckian evolutionary thought. Many explanations of evolutionary processes in these students are those that correspond to Lamarckism which explained, in the nineteenth century, that species were modified due to the needs imposed by the environment: the necks of giraffes were very long because these animals had to continuously stretch them in order to reach the foliage of trees, wisdom teeth do not come out because we do not use them, etc. This kind of Lamarckian thought, where the need creates the organ, is an idea no longer shared by scientists after the theory of evolution by natural selection that Charles Darwin proposed in 1859 in *On the Origin of Species* (see, e.g. Ayala 1977, 1994, 1994b; Ruse 1979, 1996).
– Enables the idea that students put forward their explanations and are in a position to modify them to acquire modern scientific knowledge. In this way, the study of the history of science will help them understand that some of the explanations they provide, though inaccurate, can provoke a conceptual change.
– Constitutes a strong source of suggestions about how the contents and concepts of a course must be organized according to their complexity and can be used to define the pertinent didactic sequences in the development of a topic.
– Finally, allows us to locate scientific and technological developments within the general outlook of the history of humanity, which is useful for understanding the link between a scientific approach and social problems (UNESCO 1999).

One of the authors of this chapter has promoted an initiative to include the history of science in the basic education curriculum of Latin America schools (Chamizo 1994, 2007).

69.3 The 1993 and 2006 Reforms and the Transformation of Science Teaching in Mexico

Mexico has constructed a significant and high-quality scientific and technological system over the last 20 years. However, this system is insufficient before the new challenges imposed by novel problems and international competition. For these reasons, our scientific and technological system must be consolidated and expanded in a very particular way: through the teaching of science and technology in the early stages of individual development. We must emphasize that the development of science and technology in Mexico has public institutions at its foundation. Any project that comes from the State will have as a starting point the cultural, scientific, professional and historical capital generated in said institutions.

Until a few decades ago, basic-level student education regarding science was concentrated on presenting a rigid structure of subjects which tended to promote the idea that science is a great deal of information that, when processed, offers scientifically correct answers about the phenomena in our surroundings. Thanks to the development in historical and philosophical studies of science, it is now thought that the disciplines that make up science were historically formed through posing problems, not the other way around.

69.3.1 The 1993 Reform

During the presidency of Carlos Salinas de Gortari (1988–1994), the Educational Modernization Programme (Programa para la Modernización Educativa) was proposed and enacted in 1993 (known as the 1993 Reform). It contained a diagnosis of the country's situation and proposed a deep structural change. This model implied radical structural changes and the innovation of practices to modify educational content, the ongoing training of teachers, the organization of different educational levels and the integration of basic education in one cycle that would include preschool and basic education (elementary and junior high).[6] All this in order to elevate the quality of education, to reduce backwardness and decentralize the education system.[7,8]

Methodological, conceptual and epistemological aspects were included in the 1993 Reform of the science curriculum and the study programmes for elementary and junior high schools, which meant an advance regarding the conception of modern science in national curricula. The new natural sciences programmes were based on a formative perspective according to the goal of helping students 'to acquire knowledge, capacities, attitudes and values that can be expressed by the development of a responsible relationship with the environment… and to educate children not as scientists in a disciplinary and formal way; instead, students are encouraged to observe, question, and formulate simple explanations about what happens in their surroundings' (Barraza 2001).

Thanks to this reform, there was progress regarding the teaching of science in basic education,[9] for not only elementary and junior high school curricula were modified but also new textbooks[10,11] and new materials were prepared for the

[6] Elementary or basic education includes compulsory preschool, primary and junior high education. Preschool lasts for 2 years (4–5 years old), primary education lasts for 6 years (6–11 years old) and junior high education lasts for 3 years (12–15 years old).

[7] On March 4, 1993, the Article 3 of the Constitution was amended, assigning a mandatory character to junior high school. This fact provoked one of the most important changes in the 70-year life of junior high school since its foundation. This reform was incorporated into the General Education Act (Ley General de Educación), enacted on July 12, 1993. In this way the government, through the Ministry of Public Education (Secretaría de Educación Pública, SEP), together with the states, committed to the decentralization of education, to 100 % coverage and to raising its quality levels.

[8] The SEP was founded in 1921 by the Mexican government. Since then, this ministry has designed the content of the national curricula for all subjects for basic education.

[9] The teaching of science in elementary school includes biology, physics and chemistry.

[10] In 1959 the SEP launched a new program, the Free-Text Program (Gilbert 1997), which established the National Commission for the Free Textbooks (Comisión Nacional de Libros de Texto Gratuitos, Conaliteg), and the production of the national textbooks for all basic education subjects, which are based on the national curricula. These textbooks, official and distributed for free, are still being handed out to every basic-level student, teacher and school (private and public, urban and rural) in the country, giving access to all basic-level students to education. These textbooks provide specific guidelines for each grade and are considered excellent sources of information.

[11] It is worth mentioning that some science educators were engaged in the production of the elementary textbooks around 1996 and added a good deal of history and philosophy of science to them.

teachers, with a focus that attempted to centre the teaching of science according to the modern ideas of the history and philosophy of science mentioned above.

Bonilla and colleagues (1997a, b) and Chamizo (2005) have documented this reform. The natural sciences' programme for primary school included five major topics: living beings; human body and health; environment and environmental protection; raw material, energy and change; and science, technology and society (STS). The STS dimension of teaching science corresponds to a large need of innovation in science education. As early as 1971 Jim Gallagher proposed a new goal for school science: 'For future citizens in a democratic society, understanding the interrelationships of science, technology and society may be as important as understanding the concepts and process of science' (Gallagher 1971, p. 337).

As is it outlined by Aikenhead (2003) in his synopsis on the origins and dispersion of this new approach of teaching science, the name STS was coined by John Ziman (1980) in a book titled *Teaching and Learning about Science and Society*. In spite of its title, the book consistently referred to STS in its articulation of the rationale, directions and challenges for STS in school science. It is important to mention that Aikenhead mentioned the following sentence about the relationship of history and philosophy of science with the STS scheme: 'A more comprehensive treatment of STS includes the internal social context (the epistemology, sociology and history of science itself) as well as the external social context of science' (2003, p. 63). It must be emphasized that the recent inclusion of STS in Mexican education means recognition of the importance of history and philosophy of science (Garritz 1994).

Peter Fensham (1985), in his famous paper *Science for All*, contributed directly to the evolution of STS by forging links between science education and technology education, embedded in social contexts relevant for all students. Fensham (1995) has mentioned in the Mexican *Chemistry Education Journal* that in 1984 the Science Council of Canada reported on a 4-year study of school science in that country. The title was 'Science for Every Citizen'. A year later the Royal Society in London published a manifesto, 'Science for Everybody', as part of a larger report on the public understanding of science. In 1988, Australia's Curriculum Development Centre put out a national discussion document entitled 'Science for All', and in 1989 the American Association for the Advancement of Science summarized phase 1 of its Project 2061 under the title *Science for All Americans.* Finally, before the Mexican reform, UNESCO and ICASE had launched 'Project 2000+: Scientific and Technological Literacy for All' (ICASE 1993).

In the Mexican reform of junior high school, the diverse methodologies of each one of the sciences (biology, physics and chemistry) were acknowledged, and the curriculum changed from 'natural sciences' to 'biology', 'physics' and 'chemistry'.

69.3.2 Biology: The Teaching of Evolution

For natural sciences in elementary education, it was established that biology (its first three topics: living beings, human body and health, environment and environmental protection), from the third to the sixth grade, should be taught from an evolutionary perspective. Evolution itself became a subject in the sixth grade.[12]

> Diverse themes with an evolutionary focus were introduced in the beginning of the third grade. For example, there is a discussion of plants' capacity to nourish themselves and how this relates to the oxygen that we breathe today, which comes from photosynthesis of plants that existed thousands of years ago […] Throughout the development of themes regarding the study of plants and animals, there are multiple references to the importance of adaptations that are a result of the evolution of the species […] In the fourth grade, the study of evolution is reinforced when, among many examples, students learn about the role of human beings in changing ecosystems. In the fifth grade the subject of "cells, one-cell and multi-celled organisms" is introduced. Fifth-graders also learn about the first grand division between one-celled organisms with a nucleus and one-celled organisms without a nucleus or bacteria. (Barahona and Bonilla 2009, p. 16)

The sixth-grade programme extensively included evolution: the origins of the earth, the transformation of ecosystems (throughout time and due to continental drift), fossils, the extinction of species, geological eras, Darwin and his book *Voyage of the Beagle*, the concepts of natural selection and adaptation, among others. This resulted in a fundamental transformation of the curriculum and textbooks, as previous materials had discussed knowledge about the origin of species in a purely descriptive manner. This change constituted a great challenge for the design and elaboration of the new third-to-sixth-grade Mexican textbooks (Barahona and Bonilla 2009).

As Shortland and Warwick (1989) have shown, historical case studies draw attention to the failures and disappointments that often follow long years of work or to the communal effort that goes into the production of new scientific knowledge. This viewpoint was particularly crucial for the teaching of evolution in elementary and junior high schools. The inclusion in the six-grade programme of Darwin's Voyage of the Beagle is an example of how historical case studies can show not only on evolution and Darwinism but also on the teaching of the nature of science, the scientific method and the role of evidence in science.

In sum, the 1993 curriculum and textbooks were an important leap forward and indeed a great advance over other educational systems that still question the value of including the Darwinian theory in elementary school.[13]

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[12] This was already a requirement in the 1970s but only as a junior high school subject among many. For example, the discussion was limited to the study of fossils as evidence of life in the past, with illustrations that showed the gradual evolution of horses as well as the differences between contemporary humans and their ancestors; the references to Darwin were minimal (Barahona and Bonilla 2009).

[13] According to the 1993 Reform, the federal authorities launched a new curriculum including these new perspectives in 1997 for teacher's colleges; 4 years later, in 2001, the first group of elementary school teachers graduated with this training. However, there has been no evaluation as to whether the training truly is enabling them to teach natural sciences with an evolutionary focus or, even more importantly, if the students manage to develop an evolutionary mindset.

69.3.3 Chemistry and Its Social Benefits

In junior high school there were three courses in which chemistry was involved: in the first year 'introduction to physics and chemistry', in the second 'chemistry I' and in the third 'chemistry II'. A thorough revision of the curriculum changes and the teachers' training effort needed for this reform is detailed in Chamizo, Sánchez and Hernández (2006). The major theme in chemistry I is the identification of the particulate nature of matter until its concretion in Bohr's atomic theory. The third course is centred on energy and environmental topics (Chamizo 1992).

The most important change in the chemistry curriculum of the 1993 Reform surely was the focus on the STS dimension. The main purpose of the two last chemistry courses is quoted as being one where 'pupils preserve the main elements of basic culture, to enrich their vision of Mexico and the world and assess social benefits that represent the contribution of this science, as well as the risk of its inappropriate utilization' (SEP 1993, p. 95).

The six units in which the courses chemistry I and II were divided had the following names:

Unit 1. You and chemistry
Unit 2. Matter: its manifestations. Mixtures: its separation. Compounds and chemical elements
Unit 3. The discontinuous nature of matter
Unit 4. Water, dissolutions and chemical reactions
Unit 5. Burning fuel. Oxidations
Unit 6. Electrochemistry

The necessity to include environmental education topics is emphasized often. The following can be mentioned as examples: acid rain, ozone and low atmosphere contamination; management of industrial residues; sulphur and nitrogen oxides produced by internal combustion machines; chlorofluoroalkanes; and the ozone hole in the stratosphere. And the STS focus insists in integrating the same critical stance on everyday chemical products such as acids like vinegar, lemon juice, gastric juice; bases like antacids or drain cleaner; colloids like gelatin, mousse, mayonnaise or egg white; hydrocarbons like gasoline, candle, gas cooker, asphalt; and gases solubility like soda and fish tanks.

The introduction of historical facts and biographies of scientists is welcome, because 'science is not a mystery, but a product of human activity…It is not about fulfilling an encyclopaedic commitment, but about giving science a vitality focus' (Chamizo and Garritz 1993, pp. 136–7).[14] A relevant point of this reform is that an ambitious updated programme accompanied it for teachers, which included readings from various issues of history and philosophy of chemistry and physics (Chamizo et al. 2006). An interesting impact of the 1993 Reform in chemistry was documented by applying a 'chemistrymeter' to a set of students just finishing its secondary studies (Tirado et al. 2001).

[14] A couple of more references on the philosophical bases of this reform can be found in Chamizo (1994, 2001).

69.3.4 School Physics and Philosophy of Science

Like chemistry, physics had its curricular presence in three junior high school years: introduction to physics and chemistry, physics I and physics II, taught in the first, second and third grades, respectively. Some aspects of modern philosophy of science are clearly presented among general aims of the subject, such as:

1. The students should think about the nature of scientific knowledge and how it is generated, developed and applied (SEP 1993, p. 77).
2. Formulations of an alleged scientific method, unique and invariable and formed of successive phases should be avoided in teaching. That version of the method is hardly adequate for the students and does not correspond to the real steps which scientists follow in carrying out their work. It is more valuable that students have a vision according to which scientific knowledge production from systematic and rigorous procedures and from intellectual flexibility derive in a capacity to plan adequate questions and search for unconventional explanations (SEP 1993, p. 78).
3. Physics should be presented as a product of human activity and not as an accidental result of work of a few exceptional persons. To this aim, it is convenient to propose examples of scientific developments motivated by challenges and problems which appear in social life and to stress concrete cases in which scientific advances are results of the accumulative work of many people, although they may have worked independently and in different places (SEP 1993, p. 78).

The inclusion of physics' history is rightly suggested as a way to exemplify the nature of science: 'It is convenient to study and discuss biographies of important persons in physics history, not as an encyclopedic recount, but stressing the forms of reasoning, inquiry, experimentation and error correction which leaded to some relevant discoveries and inventions' (SEP 1993, p. 78).

Although the importance of philosophy and history of science is clearly stressed among the general aims of the physics' curriculum, it is not explicitly materialized and specified at the content level. Only three obligatory topics have this historical and philosophical perspective:

Physical view of the world
Analysis of the Galileo Galilei's experiments and their relevance in scientific work
The ideas of Copernicus, Galileo, Kepler, Newton and Einstein

Without clear curricular indications about philosophical and historical themes, further developments of the intended curriculum were left to the textbook authors. Common models of curricular processes in science education fall into three levels (Robitaille et al. 1993; Valverde et al. 2002):

1. Intended curriculum (aims and goals)
2. Potentially implemented curriculum (textbooks and other organized resource materials) and factually implemented curriculum (teachers' classroom strategies, practice and activities)
3. Attained curriculum (students' knowledge, ideas, constructs and schemes)

At the level of the potentially implemented curriculum and in the absence of further guidelines, historical themes can have very distinct and arbitrary presentations. This was the case in 15 authorized physics' textbooks, written according to the 1993 curriculum reform, where three famous experiments by Galileo had diverse presentations. Regarding the Pisa Tower experiment, five authors did not mention it, five authors described it in a relatively acceptable way and five authors treated it completely wrong. Namely, these last authors present it as an experiment in which times and positions of a body in free fall were measured exactly. Obviously, the authors ignored that such measurements were technologically impossible in Galileo's time. Precisely due to this impossibility, Galileo designed and carried out his groundbreaking inclined plane experiment!

Eleven authors did not mention the thought experiment, one author treated it properly by using Galileo's account of it and three authors presented it as a real experiment.

The inclined plane experiment also had diverse presentations in physics' textbooks. Five authors omitted to mention it; only two authors gave it a satisfactory treatment, while eight authors presented that historically important experiment either wrongly or incompletely.

As all authorized textbooks passed an expert evaluation by the Mexican Ministry of Public Education, the authors are not the only ones to blame. It means that real content and meaning of historical episodes should be disseminated among textbook authors and reviewers (maybe via workshops organized by educational authorities), especially when such episodes form part of the intended national curriculum's objective in order to give students a reliable information about how science works. Furthermore, for an adequate curricular impact in Mexican classrooms, a pedagogical analysis and implementation strategies of such historical episodes should be included in professional programmes for in-service and prospective teachers.

69.3.5 The 2006 Reform

During the presidency of Vicente Fox Quesada (2000–2006), the Junior High School Reform (Reforma de la Escuela Secundaria, RES) was undertaken by the federal government in the National Programme of Education (Programa Nacional de Educación) 2001–2006. It established that the 'Mexican State must offer democratic, national, intercultural, secular and mandatory education that favours the development of the individual and his community, as well as a sense of belonging to a multicultural and multilingual nation, and the awareness of international solidarity of the educated' (SEP 2006).

In 2000, Mexico dedicated 100 dollars to each one of its elementary students. This amount that can be compared with the 600 dollars spent in the USA, the 130 USD used for Argentineans and the 220 USD spent by Chileans (Chamizo et al. 2006).

The designing group of this reform spent a lot of sessions deciding the order in which the three natural sciences should be presented. The decision was centred in a

Table 69.1 2006 Reform. Secondary science contents

Sciences I (emphasis in biology)
Unit I. Biodiversity: result of evolution
Unit II. Nutrition as the base for health and life
Unit III: Respiration and its relation with the environment and health
Unit IV. Reproduction and the continuity of life
Unit V. Health, environment and quality of life
Sciences II (emphasis in physics)
Unit I. The description of movement and force
Unit II. Laws of motion
Unit III: A model to describe the structure of matter
Unit IV. Internal structure of matter manifestations
Unit V. Knowledge, science and technology
Sciences III (emphasis in chemistry)
Unit I. The characteristics of materials
Unit II. Properties of materials and their chemical classification
Unit III: Materials transformation: chemical reaction
Unit IV. Formation of new materials
Unit V. Chemistry and technology

Project 2061 document (AAAS 2001) that recommended biology first, physics second and chemistry third. The natural sciences programmes were called sciences I, II and III, in accordance with the three grades in junior high school. In the first grade the students take sciences I (biology), in the second sciences II (physics) and in the third sciences III (chemistry). The scientific contents of the 3 years of education are represented by the titles of its units in Table 69.1.

At the end of each unit or at the end of the course, projects are developed by each student or groups of students as a good way to develop competencies because 'it favors integration and application of knowledge, skills and attitudes, giving the study a social and personal meaning' (SEP 2006).

Often, the projects select aspects related with the everyday life of students and their interests. Projects must favour attitudes as curiosity, creativity, innovation, informed scepticism and tolerance towards different ways of seeing the world. Each project requires the consideration of historical aspects as well as experimental work, and at the end students have to share their results. This objective was based on Stone and Tripp (1981), SATIS (1986) and Chamizo and Garritz (1993).

Some studies made a diagnosis of the scientific curriculum in basic education in Mexico prior to the 2006 Reform. For example, among the problems detected in the teaching of science, Flores and Barahona (2003) found a split between elementary and junior high schools; problems associated with the conception, development and decoupling of science and technology; the inadequate incorporation of the history of science in some subjects; little exploration of values and, finally, that science had not been inserted into the frame of culture.

It is necessary to emphasize that the teaching of science and technology was not marginalized, but played an important role in the focus of the curricula and new textbooks. This reform, despite requiring improvement in the future regarding the teaching of science and technology, promises to be a necessary step for the consolidation of a national science and technology programme and establishes graduation profiles related to science. Some of the most sensible decisions are mentioned below:

> The history of science employs a line of argument and reasoning to analyse situations, identify problems, formulate questions, pass judgment and propose diverse solutions. The teaching of science selects, analyses, evaluates and shares information from diverse sources and takes advantage of technological resources within reach to deepen and widen the learning of science in a permanent manner. It employs knowledge acquired with the purpose of interpreting and explaining social, economic, cultural and natural processes, as well as to make decisions and act, individually or collectively, to promote health and care for the environment as ways to improve the quality of life. (SEP 2006)

Also, the RES mentions the need to take advantage of information and communication technologies in general education, and particularly in scientific education, for this is a powerful tool in the socialization of knowledge and holds important pedagogical and didactic possibilities. The RES starts with a broader vision of technological education, understood as a social, cultural and historical process, which allows students to develop knowledge to solve problematic situations in an organized, responsible and informed manner, as well as to meet needs of a diverse nature. Technological education must contribute to the training of students as competent and critical users of the new technologies, in order to face the challenges of today's society.

It was established in this reform that scientific training is a goal for boosting cognitive development, strengthening individual and social values in teenagers as well as learning to reflect, exercising curiosity and using informed critique and scepticism, which will allow them to decide and, when necessary, act. A fundamental epistemological focus of the teaching of science relates to the understanding of science and technology as historical and socially constituted activities performed by men and women from different cultures.

The way in which different cultures in Mexico explain and construct knowledge about nature constitutes a practice that arrives nowadays through knowhow, folk knowledge and techniques in which different logics for building knowledge are mixed. From there, it is important to know, recognize and value such perspectives (SEP 2006). The history of science, according to this point of view, gained particular importance in the modification of the study programmes.

The RES expects that when students finish junior high school:

1. They have broadened their conception of science, of its processes and interactions with other areas of knowledge, as well as its social and environmental impact, and value in a critical manner their contributions for the betterment of the quality of life of people and the development of society.

2. They have advanced in the understanding of explanations and arguments of science about nature and use them to better understand the natural phenomena of their surroundings, as well as to place themselves within the scientific and technological development context of their time. This implies that students build, enrich or modify their first explanations and concepts, as well as develop abilities and aptitudes that provide them with elements to configure an interdisciplinary and integrated vision of scientific knowledge.
3. They can identify the characteristics and analyse the processes that separate living beings, relating them to their personal, family and social experience, to know more about themselves, their potential, their place among living beings and their responsibility in the way they interact with their surroundings, so they can participate in promoting health and the sustainable conservation of the environment.
4. They progressively develop knowledge that favours the understanding of concepts, processes, principles and the explanatory logic of science and its application to diverse common phenomena. They should go deeper into basic scientific ideas and concepts and establish relationships among them so they can build coherent explanations based on logical reasoning, symbolic language and graphic representations.
5. They have boosted their capacity to handle information, communication and social coexistence. This implies learning to value diverse ways of thinking, discern between founded arguments and false ideas and make responsible and informed decisions, at the same time as strengthening self-confidence and respect for themselves and for others (SEP 2006).

69.3.6 Biology: The Essence of Evolution

In the case of biology, evolution and genetics appear as central pillars in its teaching. For this reason the teaching of biology in junior high school starts with integrative theories such as evolution by natural selection, referring to biology as a scientific discipline from a historical perspective. Many references to Darwin's construction of the theory are taught in order to focus the attention of students on the historical and epistemological aspects of this discipline. Following the elementary school curriculum, the teaching of evolution is reinforced in junior high school. Regarding genetics, Mendel's laws are taught using his famous experiments with peas to show the manifold aspects of the experimental method in biology.

According to the RES in junior high school, as in elementary school, the scientific learning method must be encouraged, not as the scrupulous monitoring of a series of steps to be followed mechanically (observation, hypothesis, experimentation), but as a flexible and applicable method for the construction of knowledge over a whole course, not only in biology but also in other subjects such as physics, chemistry and geography.

In the 1993 Reform, the changes to the content of the educational programmes represented progress considering the epistemological and pedagogical references, but social aspects remained much diluted. For this reason the intercultural perspective was included in the RES, based on the idea that the diversity of forms in which human beings build knowledge about nature is of a cultural, social and historical order. In our country, cultural diversity has been the source of multiple ideas, explanations and interpretations, which have enriched, complemented and sometimes strained the development of scientific and technological knowledge. It is very important to recognize the diversity of ways to interpret the world and how, in some cases, these have aided scientific developments (like herbalism), or native technological development, which is beneficial to communities' relationship with the environment (SEP 2006).

69.3.7 School Physics and Philosophy of Science

In general terms, the 2006 curriculum framework is much better articulated than the 1993 version to move school physics activities closer to authentic science practices (Chinn and Malhortam 2002). Namely, it is planned that students gain basic scientific culture, in resonance with actual constructivist views on school science learning, through various (and even ambitious) learning tasks:

(a) Select and relate, in a causal and functional way, adequate variables to explain phenomena.
(b) Establish relationships between fundamental concepts which make it possible to construct coherent interpretative schemes in which logical reasoning, symbolic language and graphical representations are involved.
(c) Pose questions, elaborate hypothesis and inferences and construct explanations of some ordinary physical phenomena.
(d) Carry out experiments, get information from diverse sources, use different means to make measurements, analyse data and look for alternative solutions.
(e) Communicate, listen to and discuss ideas, arguments, inferences and conclusions related to physical concepts and their applications in scientific, technological and social contexts (SEP 2006, pp. 65–66).

Explicit curricular spaces and times for such activities are dedicated to develop projects which students are supposed to carry out at the end of each of five blocks.

As in the 1993 curriculum, philosophical aspects of science are not among explicit general aims. Nonetheless, the historical development of physics, the nature of scientific knowledge construction, the integration of science and relationships between science, technology and society are supposed to be taken into account, together with different students' comprehension levels, conceptual problems and previous ideas, as criterions for selection, organization and continuity of the course content (SEP 2006, p. 66)

Such intention is clearly visible in the general structure of the physics course parts, summarized in the Table 69.2.

At the content level, historical and philosophical aspects of physics have a more visible presence than in the 1993 curriculum. Besides the Galileo's

Table 69.2 Relationships between physics domains, representational means and thematic blocks

Physics domain	Elements for representations of physical phenomena	Thematic blocks
Study of motion	Descriptive schemes	Block I. Description of the changes in nature
Analysis of forces and changes	Relationships and sense of mechanism	Block II. The forces. Explanations of the changes
Particulate model	Images and abstract models	Block III. Interactions of matter. A model for description of unseen
Atomic constitution	Images and abstract models	Block IV. Manifestations of internal structure of matter
Universe, interaction of physics, technology and society	Integrated interpretations and relationships with environment	Block V. Knowledge, society and technology

contribution to science (SEP 2006, p. 76), students are supposed to know not only about motion laws but also about the role Newton had in the development of scientific thinking (SEP 2006, p. 86). In addition, the historical development of kinetic model and the atomic model of matter (SEP 2006, p. 102) are mandatory contents.

However, the main difference regarding the 1993 curriculum is the central place given to scientific models. Students are supposed to learn about the general role of models in the construction and verification of scientific knowledge. This intention is explicitly stated in the subthemes (what is the use of models, the models and the ideas they represent, the role of models in science) and curricular goals (the role of models in explanations of physical phenomena, as well as their advantages and limitations).

Nevertheless, the features of scientific models presented might be misleading for the expected learning results. It is said that students should 'recognize that a model is an imaginary and arbitrary representation of objects and processes which include rules of its function and is not the reality itself' (SEP 2006, p. 94). Strictly speaking, although theoretical models in physics are abstract representations and not copies of reality, they are not arbitrary because their predictions must be in concordance with observations.

Regarding textbook presentations of Galileo's work, the situation is similar as it was with the 1993 curriculum. Majority of authors treat the inclined experiment either inadequately or wrongly (Miguel Garzón and Slisko 2010).

69.3.8 Chemistry Presented as Projects and Models

Following the proposal expressed in the course of physics regarding the use of models, an important emphasis on the features of models in scientific explanation is made in chemistry (Gilbert and Boulter 1998, Chamizo 1988). Teachers generally ignore the issue, as exposed in educational research whose products have been books (Chamizo and García 2010) and articles on training experiences (Justi et al. 2011) and the reconceptualization of the subject (Chamizo 2011).

Nevertheless, this reform took into serious account Jensen's proposition of three Chemical Revolutions (1998) and explicitly mentioned them even in the programme (SEP 2006). The types of projects mentioned in the curriculum are scientific, technological and of citizenship. At the end of the units, the following projects must have been developed:

Unit I. The characteristics of materials
Projects related with separation methods to purify substances from mixtures. Or the work developed in a salt installation and its impact to the environment. Discussion, evidence research, information and communications technology (ICT) use, measurement, information analysis, interpretation of results and argumentation are to be fostered.

Unit II. Properties of materials and their chemical classification
The suggested projects point to the identification of elements of the human body, its health and environmental implications.

Unit III: Materials' transformation: chemical reactions
Projects related with soap production, energy release and absorption by human body are suggested.

Unit IV. Formation of new materials
In the framework of sustainability, the projects suggested have to do with avoiding corrosion or with fuel efficiency.

Unit V. Chemistry and technology
These technologic projects are developed to integrate the four previous units. The following topics are suggested: synthesis of an elastic material, Mexican contributions to the chemistry of fertilizers and pesticides, cosmetic products, Mesoamerican construction materials, chemistry and art and the importance and impact of petroleum products.

69.3.9 The Recent Years

During the Presidency of Felipe Calderón Hinojosa (2006–2012), the Mexican authorities launched a new reform in 2009 that has not yet concluded. It began in 2009 with curriculum changes to the first and sixth grades, in 2010 the changes affected the second and fifth grades, and finally in 2011 they included all the grades of elementary school. In July 2011, the SEP announced a new junior high school reform that intended to link all basic education levels (preschool, elementary and junior high school) and the production of new textbooks accordingly. Much of the progress made in previous reforms regarding the introduction of history and philosophy of science in science education was lost, particularly in the production of the most recent science textbooks.[15]

This new reform, called the Integral Reform for Basic Education (Reforma Integral de la Educación Básica, RIEB), intended to give continuity to the curricula and study programmes of all basic education. The organization of the subjects remained the same, although big changes were introduced in the natural sciences curricula (SEP 2011).

The national standards for science are the acquisition of scientific literacy, the use of scientific and technological literacy, development of skills associated with science and attitudes towards science. It does not mention the use of the history and philosophy of science in the teaching of sciences, and in the case of sciences I (biology), many topics about evolution are missing, but most importantly biology is not taught from an evolutionary perspective. The references to Darwin are very few, the Voyage of the Beagle is not mentioned, and fossils are seen as evidence of living beings in the past (not as relatives of present organisms). Although the topic of biodiversity is seen as the result of evolution, little is said about the processes that make up biological diversity and the evolutionary history of organisms. The teaching of biology in this reform is descriptive in comparison with the two previous ones.

69.4 Conclusion

We have tried to illustrate how science and technology are essential and at the same time constitutive parts of the modern society known as the knowledge society. Their importance demands, on one hand, reflection on the impact and scope of knowledge and, on the other, the modification of the educational agenda to make scientific and technological knowledge available to everyone. This strategy goes beyond the introduction of natural sciences as mandatory subjects; it implies a different focus on the selection, organization and sequencing of contents and the way to work with them.

It is decisive to collaborate in the change of the public perception of science and technology. In knowledge societies it is necessary that citizens have a positive attitude towards science and technology. This means that they have scientific and technological literacy that allows them from an early age to understand the potentials, benefits and risks of technoscientific products. This way, citizens, as well as local, municipal or federal officials, can make informed decisions before the problems technological changes produce in society take effect.

In this sense, the educational reforms in Mexico, the 1993 Reform and the RES, manifest the significance that the history and philosophy of science have had in the conception of teaching of science. Particularly, evolution and STS in Mexican education constituted an important advancement. It is worth saying that the

[15] These two reforms (2009 and 2011) are so recent that it is impossible for us to make an evaluation that provides a comparison with regard to the reforms referred to in this document.

introduction of the history and philosophy of science into the formal science curriculum in Mexico took the country some steps forward and some backward. For instance, the 1993 natural sciences programme for elementary education was more progressive regarding the history and philosophy of science than the 2006 programme for junior high education, and contrary to these advances, the 2009–2011 Reform lacked the teaching of science from a historical perspective and the evolutionary one regarding biology. This is to say that in the latest reform 2009–2011, the history and philosophy of science in relation with the teaching of biology is absent. We must wait for results to modify glitches and consolidate progress.

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Ana Barahona is full-time Professor at School of Sciences of the National Autonomous University of Mexico, UNAM. She followed undergraduate studies on biology and graduate studies on history and philosophy of biology at the UNAM. She made postdoctoral studies at the University of California, Irvine. In Mexico, as one of the pioneers in the historical and philosophical studies of science since 1980, she founded the area of Social Studies of Science and Technology at the School of Sciences of the UNAM. Some of her interests focus on the history and philosophy of evolution and genetics (especially in Mexico), and in the relationship between epistemology and science teaching, and science education. She has published more than 80 specialized articles and book chapters, several research books and textbooks on biology and history and philosophy of science for elementary and middle school (among which the Mexican free textbook of natural sciences edited by the Education Ministry have been published to date more than one hundred million copies) and also for college education. She has been President (2009–2011) of the International Society for the History, Philosophy and Social Studies of Biology and Associated Editor of the journal *History and Philosophy of the Life Sciences*; currently she is a member of the editorial board of *Biological Theory* and a member of the editorial committee of *Almagest, History of Scientific Ideas* and *Science & Education*. She has been technical advisor of the National Institute for the Assessment of Education in Mexico for the period 2002–2010. Currently she is a Council Member of the Division of History of Science and Technology of the International Union of History and Philosophy of Science and has been recently acknowledged as a Corresponding Member of the International Academy for the History of Science.

José Antonio Chamizo is full-time Professor at the School of Chemistry of the National Autonomous University of Mexico, UNAM. Since 1977 he has taught over 100 courses from high school to Ph.D. and published over one hundred refereed articles in chemistry, education, history, philosophy and popularization of science. His BS and MS degrees were in chemistry from the National University of Mexico and his Ph.D. from the School of Molecular Sciences at the University of Sussex. He is author or coauthor of over 30 chapters in books and of more than 50 textbooks and popularization of science books among which the Mexican free textbook of natural sciences, coordinated by him and edited by the Education Ministry which have been published to date more than one hundred million copies.

Andoni Garritz is full-time Professor at the School of Chemistry of the National Autonomous University of Mexico, UNAM, where he teaches and researches 'Didactics of Chemistry', 'Structure of Matter' and 'Science and Society'. He studied chemical engineering at UNAM and got his Ph.D. with a stay in the Quantum Chemistry Group at Uppsala University, Sweden, where he received the Hylleraas' Award. He has been giving lectures for 40 years at different levels, from high school to postgraduate. He is a consultant of UNESCO, coordinating seven chemistry experimental education projects in Latin America. His most relevant books are *Chemistry in Mexico: Yesterday, Today and Tomorrow* (UNAM, 1991); *From Tequixquitl to DNA* (Fondo de Cultura Económica, 1989); *Atomic Structure: A Chemical Approach*; and *You and Chemistry* and *University Chemistry* (Pearson Education 1986, 2001, 2005). He is the founder Director of the Journal *Educación Química* that now has 23 years of circulation, and it is indexed by Scopus.

Josip Slisko (B.Sc. in physics, M.Sc. in philosophy of physics, Ph.D. in philosophical sciences) teaches courses on physics and mathematics education at Facultad de Ciencias Físico Matemáticas of the Benemérita Universidad Autónoma de Puebla. His research interests include student explanatory and predictive models of physical phenomena, student strategies for solving untraditional physics and mathematics problems, presentation of knowledge in textbooks and design of learning sequences which promote cognitive development of students. Josip Slisko is author or coauthor of 80 journal articles and 12 physics textbooks. Since 1994 he joins the Sistema Nacional de Investigadores (National System of Researchers), a programme of Mexican Government through which scientific production of one is evaluated and a stipend is paid to recognized scientists. He is a member of American Association of Physics Teachers and serves in editorial boards of various educational journals (*Latin American Journal of Physics Education*, *European Journal of Physics Education*, *Metodicki ogledi* and *Eureka*). Since 1993, every last week in May, he is the president of the committee which organizes an international workshop called new trends in physics teaching.