Chapter 70
History and Philosophy of Science in Science Education, in Brazil

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70.1 Introduction

This paper addresses the context of emergence, development, and current status of the use of history and philosophy of science in science education in Brazil. Its main scope is the application of this approach to teaching physics, chemistry, and biology at the secondary school level.

The first Brazilian researches and projects along this line appeared in the decade of 1970, although before that time it is possible to find scattered claims of the relevance of history and/or philosophy of science in science teaching. From the decade of 1980 onwards, the importance of this approach became widely accepted, and the subject became a common theme of educational dissertations and theses, appearing with a considerable frequency in papers presented at conferences on science education and published in educational journals. Since 1998, the use of history and

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M.R. Matthews (ed.), *International Handbook of Research in History, Philosophy and Science Teaching*, DOI 10.1007/978-94-007-7654-8_70,

philosophy of science was included among the government recommendations for secondary school science teaching in Brazil. Nowadays, this is an important line of research in graduate programs on science and mathematics education. However, the actual use of this approach in secondary education is still a desideratum.

Before entering in the main subject, this paper will present a short overview of the development of philosophy of science, history of science, and science education in Brazil, especially from 1960 onwards.

70.2 Philosophy of Science

The main development of philosophy of science in Brazil, in the twentieth century, began after the creation of the University of São Paulo (USP) in 1934. From its very inception, this university established a practice of bringing to Brazil foreign researchers to help starting new disciplines and research lines. In the case of philosophy, the main foreign professors were French: Jean Maugüe, from 1935 to 1943; Giles Gaston Granger, from 1947 to 1953; Martial Guéroult, from 1948 to 1950; Claude Lefort, from 1955 to 1959; and Gérard Lebrun, from 1960 to 1966 and from 1973 to 1980 (Hopos 2000). There were other strong influences, too. For instance, in 1942, Willard Van Orman Quine spent a few months in Brazil. However, the main influence was French, and Guéroult's approach to history of philosophy dominated the University of São Paulo for decades (Lefebvre 1990).

During his short stay at the University of São Paulo, Quine learned Portuguese and wrote in this language his book *O Sentido da Nova Lógica* (*The Meaning of the New Logic*), published in Brazil in 1944 (Quine 1944; Stein 2004, p. 376).[1] However, Granger was the main reference for philosophy of science at USP, for a long time. His first book was published in Brazil, in Portuguese, in 1955: *Lógica e Filosofia das Ciências* (*Logic and Philosophy of Science*) (Granger 1955).

Notwithstanding those precedents, philosophy of science would only begin to bloom in Brazil in the 1970s (Salmerón 1991). At the University of São Paulo, the main Brazilian professors who began to develop this line of research were Oswaldo Porchat Pereira da Silva and João Paulo Monteiro. Monteiro, a specialist in Hume (Monteiro 1967), was a strong influence in the development of philosophy of science at USP, attracting new philosophers to this field and creating in 1979 the journal *Ciência e Filosofia* (*Science and Philosophy*).

Oswaldo Porchat, who had studied with Victor Goldschmidt in France, wrote a Ph.D. thesis on Aristotle, but obtained a broad acquaintance with philosophy of

[1] Quine stayed in 1942 at the *Escola Livre de Sociologia e Política* (*Free School of Sociology and Politics*), which at the time was an "autonomous complementary institution" of the University of São Paulo. At that time, one of the few Brazilian scholars who could interact with him on equal grounds was the philosopher of logic Vicente Ferreira da Silva, who published an important book on logic in Brazil, *Elementos de Lógica Matemática* (*Elements of Mathematical Logic*) (Silva 1940), and later became a Heideggerian.

science (Silva 1967). Although his first connection was with French history of philosophy, he also had a postdoctoral stage at the University of California, Berkeley (1969–1970). In 1975 Porchat left the University of São Paulo to found the Philosophy Department at the State University of Campinas (Unicamp) and the Center for Logic and Philosophy of Science (CLE) at the same university. This center was a main influence in the development of philosophy of science, in Brazil, organizing meetings and publishing two journals: *Manuscrito* (*Manuscript*), since 1977, and *Cadernos de História e Filosofia da Ciência* (*History and Philosophy of Science Notepads*) since 1980. The Philosophy Department at Unicamp started the first Brazilian graduate program on logic and philosophy of science.

Leônidas Hegenberg, after graduating in mathematics, physics, and philosophy in Brazil, spent two years working with Alfred Tarski at the University of California (1960–1962). Returning to Brazil, he completed his Ph.D. in philosophy at the University of São Paulo, in 1968 (Hegenberg 1968). During most of his professional life, he taught mathematics, logic, and philosophy of science at the Technological Institute of Aeronautics (ITA). For that reason, he never supervised any M.Sc. or Ph.D. student. However, he published many papers and books and was highly influential in Brazil. Besides that, he kept up to date with the development of philosophy of science abroad and translated about 60 books to Portuguese, including works by Karl Popper, Paul Feyerabend, Max Weber, Wesley Salmon, Mario Bunge, Derek J. de Solla Price, Charles S. Peirce, and others.

In Rio de Janeiro, a strong tradition in philosophy of science began with the arrival of the Brazilian researchers Raul Ferreira Landim Filho and Oswaldo Chateaubriand Filho, in the 1970s. Chateaubriand obtained his Ph.D. in 1971, at the University of California, Berkeley, on ontology and semantics (Chateaubriand Filho 1971). After teaching at Cornell University from 1972 to 1977, he returned to Brazil, where he finally settled at the Catholic University of Rio de Janeiro (PUC-RJ). Landim, who obtained his Ph.D. at Louvain (Landim Filho 1974), also arrived to Rio at about the same time and was influential in the development of philosophy of science at the Federal University of Rio de Janeiro (UFRJ). Another important philosopher of science, Alberto Oscar Cupani, born in Argentina, obtained his Ph.D. at Córdoba in 1974, moving to Brazil in 1977 (Cupani 1974). He first worked at the Federal University of Santa Maria (UFSM) and then settled at the Federal University of Santa Catarina (UFSC).

Around 1980 the area of philosophy of science was well established in Brazil and had attained an international standard of research. There are currently 12 graduate programs in philosophy of science, several journals, and regular meetings over the country.

70.3 History of Science

History of science, in Brazil, developed later than philosophy of science. Up to 1970 there were few universities with regular courses on history of science (in general) or history of specific scientific disciplines. Those who taught history of science had no

specific training in this discipline; they were commonly senior scientists who had a broad cultural background, such as Mario Schemberg and Francisco Magalhães Gomes (physics), Antonio Brito da Cunha (biology), Leopoldo Nachbin (mathematics), and Simão Mathias (chemistry).[2] Up to the 1970s, works on history of science written by Brazilian authors were, in general, descriptive and laudatory accounts of Brazilian researchers and institutions. One of the best productions of this period was a book organized by Fernando de Azevedo, *As ciências no Brasil* (*Sciences in Brazil*), published in 1956.[3]

Research on the history of Brazilian science gradually improved. In 1971 the graduate program of the History Department of the University of São Paulo (USP) established the first research line on history of science. The main focus was the study of Brazilian science, although the group has also produced research and supervised dissertations and theses on the conceptual history of international science. In 1979–1981 they published the three-volume work *História das Ciências no Brasil* (*History of Sciences in Brazil*), organized by Mário Guimarães Ferri and Shozo Motoyama (Ferri and Motoyama 1979–1981).

One stimulus to the study of history of Brazilian science was the expectation that it could help to develop scientific policies. In Rio de Janeiro, the sociologist Simon Schwartzman, who had obtained his Ph.D. in political science at the University of California, Berkeley (Schwartzman 1973), developed an ambitious project to study the Brazilian scientific community. He conducted a large series of interviews with leading Brazilian scientists and in 1979 published the analysis of this work in an influential book: *Formação da Comunidade Científica no Brasil* (*The Development of the Scientific Community in Brazil*) (Schwartzman 2007).

In 1982 the *Sociedad Latinoamericana de Historia de las Ciencias y la Tecnología* (SLHCT) (*Latin American Society of History of Science and Technology*) was founded in México, with the participation of Brazilian historians of science. In the next year, the group of the University of São Paulo created the *Sociedade Brasileira de História da Ciência* (SBHC) (*Brazilian Society of History of Science*) (Motoyama 1988; Bassalo 1992). This association soon began to organize biennial meetings (beginning in 1986) and in 1985 started the publication of the first Brazilian journal devoted to the history of science.

The largest research institution in history of science, in Brazil, is devoted to the study of Brazilian medicine and related subjects: *Casa de Oswaldo Cruz*, in Rio de Janeiro (founded in 1986). Another important institution is the *Museu de Astronomia e Ciências Afins*, MAST (*Museum of Astronomy and Related Sciences*), founded in the same year.

Historical researches on Brazilian science had no impact in science teaching, because the curriculum of the scientific disciplines does not include any topic related to the development of national science.

The Brazilian researches on the history of international science followed another line of development that is more difficult to track down. Diverging from the

[2] See, for instance, Mathias (1975), Gomes (1978), Nachbin (1996), and Schemberg (1984).

[3] See, for instance, Beltran (1984), Goldfarb (1994), and Vergara (2004).

situation that occurred in philosophy of science, the main stimulus was not the contact with foreign researchers. However, there have been some influential foreign scholars, such as Michel Paty, who spent several periods at the University of São Paulo and also supervised Brazilian students in France.

Around 1980, several scattered scholars who taught history of mathematics, physics, chemistry, and biology began to devote a larger effort to the study of history of science. At this time, there were no graduate courses in Brazil where one could obtain the adequate training for research in the history of international science. Although they had no specific training in this field, they began to produce better research by employing primary sources and to stimulate younger scientists to dedicate themselves to this field. Among other researchers of this generation, we can cite Ubiratan D'Ambrosio and Guilherme de La Penha (mathematics), Aécio Pereira Chagas and Carlos Alberto Lombardi Filgueiras (chemistry), and Roberto de Andrade Martins and Penha Maria Cardozo Dias (physics).[4] Two philosophers who began to devote themselves to the history of science in this period should also be mentioned: Pablo Mariconda and Carlos Arthur Ribeiro do Nascimento (Mariconda 2003; Nascimento 1995).

In 1985, a series of annual meetings on history of science was started at the State University of Campinas, and in 1990 a first attempt was made to establish a graduate program on history of science at the same university. However, internal problems suspended this development. Although dissertations and theses on history of science had been produced at several Brazilian institutions, since the decade of 1980, the first specific graduate course on history of science was created at the Catholic University of São Paulo (PUC-SP) in 1997, the second at the Federal University of Bahia (UFBA) in 2000 (with strong emphasis in science teaching), and the third one at the Federal University of Rio de Janeiro (UFRJ) in 2002. There is also a graduate program on the history of medicine, at Casa de Oswaldo Cruz, Rio de Janeiro, founded in 2001.

From the late 1980s onwards, the number of researchers in conceptual history of science who had received specific training gradually increased in Brazil. Among them, we may cite Olival Freire Jr. and Antonio Augusto Passos Videira (physics); Anna Carolina Regner, Lilian Al-Chueyr Pereira Martins, Gustavo Caponi, and Nelio Bizzo (biology); Ana Maria Alfonso-Goldfarb (chemistry); and Sérgio Nobre (mathematics).[5] Most of them received part of their training abroad. In the decade of 1990, research in history of conceptual science attained an international level, in Brazil.[6]

The strong development of the history of mathematics led to the creation of the *Sociedade Brasileira de História da Matemática* (SBHMat) (*Brazilian Society for the History of Mathematics*) in 1999. This society has its own journal and regular

[4] See, for instance, Chagas (2001), D'Ambrosio (1996, 2008), Dias (1994, 1999), Filgueiras (1994, 2002), La Penha (1982), La Penha et al. (1986), and Martins (1996, 1997).

[5] See, for instance, Alfonso-Goldfarb (1999), Bizzo (1991, 2004, 2009), Caponi (2010, 2011), Freire Jr. (1995, 2002), Martins (2005, 2007), Nobre (2001), Regner (1995, 2003), and Videira (1994).

[6] For more recent developments, see Krause and Videira (2011).

biennial meetings. In 2000 the *Associação de Filosofia e História da Ciência do Cone Sul* (AFHIC) (*South Cone Association for Philosophy and History of Science*) was created, bringing together scholars from Brazil, Argentina, Chile, and Uruguay. This society gave a new impetus to interchanges between historians and philosophers and stimulated the formation of thematic groups. The idea of creating AFHIC was initially discussed at the *First Meeting of Philosophy and History of Science of the South Cone*, which took place in 1998 at the Federal University of Rio Grande do Sul (UFRGS), Brazil, under the aegis of the Research Group on Philosophy and History of Science (GIFHC), from that university.

The development of research in history and philosophy of biology started with the first *Meeting of Philosophy and History of Biology* that occurred in 2003, in São Paulo, followed by a series of annual conferences. During the fourth meeting, in 2006, the *Associação Brasileira de Filosofia e História da Biologia* (ABFHiB) (*Brazilian Association for Philosophy and History of Biology*) was founded and in the same year began the publication of the journal *Filosofia e História da Biologia*. It is possible to notice a conspicuous interest on the use of history and philosophy of science in biology teaching in the meetings and publications of this society.

Although history of physics is a very strong research area in Brazil, no specific society for its study has been created, neither for the history of chemistry.

The largest part of the researches in history and philosophy of science developed in Brazil had no impact in science education. High-level researches in those fields, written in specialized jargon, published in professional journals or in foreign languages, are seldom read by Brazilian science educators. Besides that, philosophers and historians of science hardly ever write textbooks or popular works in this country.

70.4 Science Education in Brazil

This section will present an overview of the development of science education in Brazil, in the second half of the twentieth century. Although science education can be understood as including all levels from elementary school to graduate studies, the focus here will be the Brazilian equivalent to high school or secondary education, that is, the 3 last years of basic education, preceding higher education. We may confine our analysis to this level, since most researches on the use of history and philosophy of science in science teaching, in Brazil, deal with secondary education.

Before describing the historic qualitative changes in science education in Brazil, it is relevant to remark that in this country only a very small part of the population was able to attain secondary education in the first half of the twentieth century and that this proportion has been increasing up to the present. Around 1995, the Brazilian gross secondary school enrolment ratio reached about 50 %, being much worse than that of other South American countries, such as Argentina (76 %), Chile (73 %), and Uruguay (81 %) (Rigotto and Souza 2005). This unpleasant situation was one of the reasons for the educational reform announced by the Brazilian government in 1996,

which proposed several policies for improving the enrolment ratio of students between 15 and 17 years old at secondary schools. The huge quantitative increase of the secondary school enrolment was achieved with a significant deterioration of material conditions and teaching and learning quality. Improving the overall quality of education is the current challenge for educational authorities in the country. Nevertheless, let us go back and review the development of science teaching in that country.

Until the Second World War, the main educational influence in Brazil was European (especially French). Textbooks were translated, laboratory equipment used in demonstrations was imported, and educational methods were copied. Secondary education was not compulsory and there were few public schools offering this level. In general, only people who intended pursuing higher education would enroll in high school. Access to the universities requires both the completion of secondary education and approval in competitive entrance examinations.

Shortly after the end of the war, several changes occurred. The American influence expanded very fast; there was a stronger concern with the scientific development of the country; and there arose the first attempts to develop national teaching projects. The prevalent view was that scientific development was a necessity for industrial and economical development of the country; and the government of President Getúlio Vargas was deeply concerned with those issues.

Two important institutions were created in 1951: the *National Research Council* (CNPq), to stimulate and support scientific researches, and the *Campaign for the Improvement of Personnel for Higher Education* (CAPES), belonging to the *Ministry of Education and Culture* (MEC), with the aim of improving the level of university professors by the creation of graduate courses and international exchange.[7]

In the early 1950s, under the leadership of Isaías Raw, the recently founded *Brazilian Institute of Education, Science and Culture* (IBECC) produced the first laboratory kits developed in this country. This was a nice innovation in education in Brazil, because it introduced low-cost equipment that could be used by students (not for class demonstrations, as the former imported equipments) and had a strong positive influence in science teaching. In the late 1960s, the industrial dimensions of the production of laboratory equipment led to the creation of the *Fundação Brasileira para o Desenvolvimento de Ensino de Ciências* (FUNBEC) (*Brazilian Foundation for the Development of Science Teaching*) to cope with the large-scale production of teaching materials (Villani et al. 2009; Nardi 2005).

In 1965, six centers of science for teaching training and development of educational materials were created in Brazil: in Pernambuco (CESINE), Rio Grande do Sul (CECIRS), Minas Gerais (CECIMIG), Rio de Janeiro (CECIGUA), São Paulo (CESISP), and Bahia (CECIBA). The leaders of those centers were trained at IBECC, in 1966 (Nardi 2005). Most of these initiatives, however, were not maintained to the present day.

[7] The names of these institutions were later changed to *National Council for Scientific and Technological Development* and *Coordination of Improvement of Personnel of Higher Education*, respectively, although their acronyms were maintained.

Nowadays many critics point out that the empiricist view behind those projects was naïve and inadequate – and that is a correct appraisal (Villani et al. 2009; Nardi 2005). However, positive features cannot be denied. Brazilian science educators had been deeply influenced by John Dewey's work, especially his book *How We Think* (1910). This book was first translated into Portuguese in 1933 and republished in 1953 and 1959. Following Dewey's ideas, science educators were striving to provide a more active involvement of students with science, attempting to develop their reasoning capacity and critical attitude (Freire Jr. 2002).

Notice that, parallel to any innovatory trends, there was a conservative undercurrent in Brazilian education. Essentially, in the 1960s as now, science and mathematics teaching in secondary schools was grounded upon books written with a very simple aim: to train the students to obtain a good performance at the universities' entrance examinations.[8]

In 1961, an educational reform increased the weight of scientific disciplines in both elementary and secondary education. In 1964 a military *coup d'état* and the beginning of a long dictatorship in Brazil (1964–1985) led to deep changes in the educational system, but the previous impetus to improve science education was maintained. The educational influence of the United States increased, and an agreement established in 1965 between the Brazilian *Ministry of Education and Culture* (MEC) and the *United States Agency for International Development* (USAID) led to introduction of many North American educational materials in Brazil (Nardi 2005).

It is well known that in the late 1950s, due to the Cold War between the United States and the Soviet Union, five outstanding American educational projects were developed to improve the teaching of mathematics, physics, chemistry, and biology at high school level: *Physical Science Study Committee* (PSSC), *Biological Science Curriculum Study* (BSCS), *Chemical Bond Approach* (CBA), *Chemical Education Material Study* (CHEMS), and *School Mathematics Study Group* (SMSG). Those projects were introduced in Brazil in the decade of 1960 and they had a strong impact. The textbooks were translated and the experimental kits were reproduced, with small adaptations, by *Instituto Brasileiro de Educação, Ciência e Cultura* (IBECC) (*Brazilian Institute for Education, Science and Culture*). In the United States, about 200,000 students used the PSSC and CHEMS materials, 600,000 used the BSCS texts, and 1,350,000 students used SMSG books. In Brazil, about 400,000 copies of PSSC volumes were published and a similar number of copies of BSCS (Barra and Lorenz 1986, *apud* Nardi 2005). Other foreign products, such as the Nuffield Foundation project, were also translated and used in Brazil (Krasilchik 1992; Villani et al. 2012).

[8] Universities are free to create any kind of entrance examination. The most traditional one is called "vestibular" and assesses the student's knowledge on the subjects studied in the secondary school. Except the last decade exams conducted by University of Campinas (UNICAMP), "vestibular" in general has a strong inertia regarding the style and content. In recent years, the performance at *Exame Nacional do Ensino Médio* (ENEM) (*High School National Exam*), designed to assess scientific contents and other competencies as reading and comprehension, has also been used as entrance examinations by over 300 institutions. This is a nonmandatory exam, attended by 5.8 million students in 2012.

In the American projects, the use of the "scientific method" was emphasized, with a strong empiricist bias. Those approaches were typical in science education during the 1960s and were still influential in the 1970s, in Brazil.

The reception of the American projects among secondary school teachers was not altogether positive. They had difficulties in dealing with the new methods and contents (Villani et al. 2009). In January 1970 the *Sociedade Brasileira de Física* (SBF) (*Brazilian Physics Society*) sponsored the *First National Symposium on Physics Teaching*. The PSSC project was much criticized, and the participants of the event reached the conclusion that it was necessary to develop Brazilian projects to elaborate new textbooks and laboratory materials. The first initiatives were already on the move, at the University of São Paulo (USP) under the leadership of Ernest Hamburger and at the Federal University of Rio Grande do Sul (UFRGS), by initiative of Marco Antonio Moreira (Oliveira and Dias 1970). Educators such as Pierre Henri Lucie, who was one of the main supporters of the introduction of PSSC in Brazil, were already looking for alternatives. In 1969 Lucie started the publication of an original line of physics textbooks for secondary schools, with a deeper conceptual discussion, using cartoons: *Física com Martins e eu* (*Physics with Martins and I*) (Lucie 1969).

70.5 Brazilian Research and Projects in Science Education

There were new educational reforms in Brazil in 1968 (higher education) and 1971 (elementary school and secondary education). In 1972 the *Ministry of Education and Culture* (MEC) started the *Project of Expansion and Improvement of Education* (PREMEN) to promote an enhancement of education with the development of teaching materials for science and mathematics in the country and adapted to the national context, also providing adequate teaching training for the use of those materials. In the early 1970s, stimulated by government guidelines and financial resources, the formation of research groups and the development of science teaching projects started up in Brazil (Barra and Lorenz 1986).

At that time, three physics teaching projects were under way: *Physics Teaching Project* (PEF) at the University of São Paulo (coordinated by Ernst W. Hamburger and Giorgio Moscati), *Self-Instructive Physics* (FAI) by the *Group of Studies in Physics Teaching Technology* (Fuad Daher Saad, Kazuo Watanabe, Paulo Yamamura, and others), and *Brazilian Project for Physics Teaching* (PBEF) at FUNBEC (organized by Rodolpho Caniato, Antonio Teixeira Jr., José Goldenberg). The three projects were student centered, without expositive classes. The first project had a stronger experimental emphasis which generated a difficulty for its application at secondary schools that could not acquire laboratory equipment. In the two other projects, experiments were secondary activities to illustrate knowledge that had already been learned using self-instructive techniques. The FAI project included passages describing the history of physics, written by Shozo Motoyama. Its books sold 490,000 copies, between 1973 and 1976 (Flores et al. 2009).

In the early 1970s, educational projects on chemistry and biology were also developed in Brazil: *The National Project for the Teaching of Chemistry* (1972), developed by the *Northeast Coordination of Science Teaching* (CECINE), and the Project of Biology Applied to Secondary School (1976), an initiative of the *São Paulo State Center for Science Teaching* (CESISP) (Barra and Lorenz 1986, *apud* Nardi 2005). The most relevant educational initiative in mathematics was developed under the guidance of Ubiratan D'Ambrosio at the State University of Campinas (Unicamp): *New Materials for the Teaching of Mathematics*, for the fundamental school level.

In 1972 the *Brazilian Foundation for Science Teaching* (FUNBEC) and the publisher *Abril Cultural* launched a new project called *Os Cientistas* (*The Scientists*): a series of 50 experimental kits for the study of chemistry, biology, and physics, which were sold in newsstands. Each edition contained an experimental kit, instructions for performing the experiments, and the biography of a famous scientist related to the experiment (Newton, Pasteur, Lavoisier, etc.). This initiative was planned by two professors of University of São Paulo, Isaías Raw and Myriam Krasilchik, and was coordinated by the latter. The project was highly successful and sold three million units (a mean of 60,000 copies of each edition). It was later translated into Spanish, English, and Turkish and sold in other countries (Krasilchik 1990). Although the project included material related to the history of science (the biographies), this was circumstantial: the authors of the biographies and of the experimental kits had no interaction,[9] and the emphasis of the project was an empiricist approach to science.

The development of the area of science and mathematics education along the last decades in Brazil can be noticed in the beginning of regular conferences, founding of societies, creation of journals devoted to school teachers and researchers, and establishment of graduate courses.

The first regular series of congresses devoted to physics education, called *Simpósio Nacional de Ensino de Física* (SNEF) (*National Symposium on Physics Teaching*), started in 1970, one decade before the creation of general congresses devoted to science education in general or to the teaching of the other scientific disciplines such as *Encontro Nacional de Ensino de Química*, ENEQ (*National Meeting on Chemistry Teaching*) (1982); *Encontro Perspectivas do Ensino de Biologia*, EPEB (*Meeting on Perspectives of Biology Teaching*) (1984), discontinued; *Encontro de Pesquisadores de Ensino de Física*, EPEF (*Meeting of Researchers of Physics Teaching*) (1986); *Encontro Nacional de Educação Matemática*, ENEM (*National Meeting on Mathematics Teaching*) (1987); *Encontro Nacional de Pesquisa em Ensino de Ciências*, ENPEC (*National Meeting on Research in Science Teaching*) (1997); *Colóquio de História e Tecnologia no Ensino de Matemática*, HTEM (*Conference of Technology and History of Mathematics Teaching*) (2002); and *Encontro Nacional de Ensino de Biologia*, ENEBIO (*National Meeting of*

[9] Roberto de Andrade Martins, one of the authors of this paper, can safely state that the two sides of the project were widely independent, because of his personal involvement with the project: he was the author of some of the biographies of *Os Cientistas*.

Biology Teaching) (2005). Most of these are biennial meetings. There are also many regional and local relevant conferences. Besides that, for a long time other general scientific and educational conferences have also included sessions on science and mathematics teaching.

Since 1976, when *Boletim Gepem* devoted to mathematics education was created, many other Brazilian journals on general and specific areas of science education appeared along the years, for instance, *Revista de Ensino de Física, Caderno Catarinense de Ensino de Física, Química Nova na Escola, Investigações em Ensino de Ciências, Ciência & Educação, Revista Brasileira de Pesquisa em Educação em Ciências, Revista de Ensino de Biologia,* and *Alexandria: Revista de Educação em Ciência e Tecnologia,* among many others.

Several scientific societies began to sponsor educational activities, and later on, specific associations were created. The *Sociedade Brasileira de Física* (SBF) (*Brazilian Physical Society*) established a Commission for Physics Teaching in 1970. In 1988 the *Sociedade Brasileira de Educação Matemática* (SBEM) (*Brazilian Society of Mathematical Education*) was founded. In 1997 the *Associação Brasileira de Pesquisa em Educação em Ciências* (ABRAPEC) (*Brazilian Association for Research in Science Education*) and the *Associação Brasileira de Ensino de Biologia* (SBEnBio) (*Brazilian Association of Biology Teaching*) were founded. There are no specific societies related to the teaching of chemistry and physics. In both cases, there are teaching divisions belonging to the corresponding national scientific societies.

Although there were educational initiatives in the several disciplines, physics took the leadership in the establishment of a definite enterprise for the improvement of science teaching. In 1967 the graduate program in physics of the Federal University of Rio Grande do Sul (UFRGS) established the area of physics teaching. The first specific graduate course in science teaching was created in Brazil in 1973, at the University of São Paulo (USP), as a joint initiative of the Physics Institute and the Faculty of Education; about 20 years later, the areas of chemistry and biology were also introduced. There was also an attempt to establish the area of physics teaching in the graduate program created at the Catholic University of Rio de Janeiro (PUC-RJ) in 1967, but it did not succeed. In 1975, the first graduate course in mathematical education started at the Catholic University of São Paulo (PUC-SP) and the second one in 1984, at the Rio Claro campus of the São Paulo State University (UNESP). The latter was the first one to offer a Doctor degree, in 1993. Other graduate courses in science education started at the Federal Rural University of Pernambuco (1995), Federal University of Rio de Janeiro (1995), and at the Bauru campus of UNESP (1997) (Moreira 2004). From 1972 to 1995, 572 theses and dissertations had been finished on science and mathematics education, including those that have been produced at other graduate programs. There was a very fast increase of graduate programs on science and mathematics education from 2000 to 2010, reaching a total of 78 programs in the area at the end of 2010 (CAPES 2010).

In 1999 the first Brazilian graduate program devoted to history and philosophy of science and science education was founded in Bahia State: the *Graduate Program*

in Teaching, Philosophy and History of Sciences (EFHC). It is an interinstitutional program between Federal University of Bahia and State University of Feira de Santana, with master and doctorate courses (Freire Jr. and Tenório 2001).

70.6 History and Philosophy of Science in Science Education

According to Susana de Souza Barros, it is possible to find several uses of history and philosophy of science in different periods, in Brazil. In the decade of 1970, history of physics was regarded as an important component of the teaching training. The transposition of this historical knowledge to physics teaching at the secondary school level was not discussed, however. During the 1980s, the study of concept formation and conceptual change led to the combined use of psychological, epistemological, historical, and sociological approaches. There were researches using classroom experimentation, and the new line of attack was regarded as useful for the training of physics teachers. Nevertheless, it was not directly applied to introduce educational changes at the secondary school level. During the next decade (1990), there was a strong emphasis on the relation of science teaching and the education for citizenship, using the science, technology, and society approach (STS). The idea that science educators should teach not only science but also about science (i.e., the inclusion of a metascientific level) launched a new use for history and philosophy of science in physics teaching (Martins 1990). Towards the end of the last century, the Ministry of Education established new educational guidelines recommending the use of history and philosophy of science at the secondary school level (Barros 2002).

70.6.1 The Beginning: Physics

It was already remarked that physics was the first area where science education research began, in Brazil. Let us see how the use of history and philosophy of science in physics teaching started and was understood in this discipline, in the early period. This occurred at the University of São Paulo (USP), and therefore our focus, here, will be that institution.[10]

History of physics was taught from the very beginning of the establishment of its undergraduate physics course, at USP. One of the most influential early professors who taught this discipline was Mário Schenberg (1914–1990), a Brazilian physicist with strong political interests. He was a member of the Brazilian Communist Party before this political organization was banned from the Brazilian politics, and he was

[10] The other early group, at the Federal University of Rio Grande do Sul (UFRGS), did not develop this line of research at first, and its leader complained in 1970 that there was no one available at that institution to teach history of physics (Oliveira and Dias 1970, p. 106).

twice elected deputy of the State of São Paulo (1946 and 1962). He was arrested twice for his political involvement. He was highly influential, and his interest for Marxism and history of science was shared by many other physicists.

Several books on history of science with a Marxist outlook were well known in Brazil, around 1970 (Azevedo and Costa Neto 2010). Friedrich Engels' *Dialectics of Nature* had been translated into Portuguese in 1946, with John Burdon Sanderson Haldane's introduction, and it was republished in 1962 and 1964. It was a very popular book among physicists, at USP, in the 1960s and 1970s. John Desmond Bernal's works were also very influential. Bernal's *Science in History* (1954) was translated in México, in 1959, and in Portugal, in 1965. Both translations, as well as the original English version, were familiar to many Brazilian physicists. Boris Hessen's "The Socio-economic Roots of Newton's Principia" was also well known and highly praised. The Marxist play writer Bertolt Brecht's version of Galileo's life was very popular in Brazil, and parallels were drawn between his struggle with the Catholic Church and the scientists' resistance to the Brazilian military government of that period. The play was enacted in São Paulo, in 1968, with the priests using olive dresses – olive being the color used by soldiers, in Brazil. At that time, the study of the relations between science, history, politics, society, etc. was regarded as a means to denounce the alleged neutrality of science, leading the students to have a more critical view of the scientific endeavor, and also critical of the Brazilian political situation of the time. Students were regarded as citizens that should be educated to deal, among other things, with the political and economic forces surrounding them.

This was a very influential trend, in the early development of the use of history (and sociology) of science in science education in Brazil (Villani et al. 2010). Even now, long after Marxism had become outmoded, its inspiration is still present as an undercurrent in the *science, technology, and society* (STS) approach, in Brazil, although the recent generation is not aware of its early history.

Besides this politically motivated interest in the history of science, there was another view about its educational value. In 1970 the *Harvard Project Physics* was being introduced in Brazil, and its strong use of history of science was described by Giorgio Moscati, who emphasized the motivational aspect of the historical and humanistic approach (Oliveira and Dias 1970). There was a widespread belief that mere contact with history of science could enhance the motivation of students and also to improve their learning of scientific concepts.

This was also, seemingly, the opinion of Pierre Lucie, who taught physics at the Catholic University of Rio de Janeiro. As mentioned above, Lucie had been a strong supporter of the PSSC project in Brazil. However, in 1970 he was devoting himself to other educational projects. In that year he delivered a course on the history of mechanics during the first *National Symposium on Physics Teaching* that occurred in São Paulo. He published a book on this subject in 1978, called *Gênese do Método Científico* (*Genesis of Scientific Method*). This work was not an adaptation of history of physics for science teaching; it was just a plain work on history of science, written by an outstanding educator (Lucie 1978). Several papers published in the early volumes of *Revista de Ensino de Física* (*Journal of Physics*

Teaching), such as those authored by José Maria Filardo Bassalo, were also devoted to the presentation of historical information, without any special application to physics teaching.

Although there was a widespread interest in the history of science at the USP group from its very beginning, its effective influence only began to produce noticeable results in the late 1970s. Let us notice some instances of works produced by the group. In 1978 Amélia Império Hamburger produced a study of physics textbooks, including "the concept of physics and science" among the several features that should be analyzed. In the same year, she wrote a historic and philosophical analysis of mechanics and electricity to help circumventing conceptual learning difficulties. In 1979, João Zanetic wrote a work on the role of history of physics in education. Ernest Hamburger and Joaquim Nestor de Morais presented a historical analysis of the concept of electrostatic potential, comparing it with its textbook presentation. Amélia Hamburger proposed a project using historical examples for teaching physical concepts. In 1980 Alberto Villani started a research on the history of the theory of special relativity. In 1981 Amélia Hamburger began the development of a series of didactic booklets, and one of them contained texts on "science, technology, and society." Zanetic and José D. T. Vasconcellos proposed the introduction of the Popper-Kuhn debate in physics teaching (Gama and Hamburger 1987).

From 1979 onwards, the USP group invited several foreign visitors who delivered courses on history and philosophy of physics: Marcelo Cini (in 1979 and 1980), William Shea, in 1979, and Michel Paty, in 1982, (Gama and Hamburger 1987; Robilotta et al. 1981).

In 1981 Alberto Villani published the first paper, in Brazil, that referred to the so-called spontaneous concepts, mentioning the recently published works (1979) of Laurence Viennot and John William Warren on this subject. Viennot was invited to Brazil and delivered a course on this subject at USP, in 1981. In the following years, this became a very strong line of research of the USP group, involving several researchers such as Villani, Jesuina Lopes de Almeida Pacca, Anna Maria Pessoa de Carvalho, and Yassuko Hosoune, together with graduate students. Three M.Sc. dissertations on this subject were finished between 1982 and 1985 (Gama and Hamburger 1987).

Independently of the USP group, Arden Zylbersztajn, who was a professor at the Federal University of Rio Grande do Norte (UFRN) and had strong interest in history and philosophy of science, started in 1979 his doctoral studies in the University of Surrey, under the guidance of John Gilbert, and began the study of physical "spontaneous concepts," publishing his first paper on this subject (with Michael Watts) in 1981 (Gilbert and Zylbersztajn 1985; Watts and Zylbersztajn 1981). After his return to Brazil, in 1984, Zylbersztajn continued to develop this research line at UFRN and, after 1987, at the Federal University of Santa Catarina (UFSC).

The comparison between the students' concepts and the historical evolution of science became one of the main uses of history of science in physics education, in Brazil, for a significant period. This trend was soon linked to the work of Piaget and Garcia (1982) on the parallels between psychogenesis and history of science.[11]

[11] There were some critics of this kind of parallelism, for instance, Franco and Colinvaux 1992.

The study of the students' previous concepts and of the strategies to produce conceptual change became more and more sophisticated during the decades of 1980 and 1990, with the development of analogies between science education and the ideas of Feyerabend, Laudan, Bachelard, and other philosophers of science.

In the 1990s, educational experiments developed by Anna Maria Pessoa de Carvalho and Ruth Schmitz de Castro introduced historical texts in secondary school classrooms, to explore the similarity between the student's concepts and the ideas presented in those texts (Castro and Carvalho 1995). Many students were stimulated by noticing the similarity between their own concepts and those of important scientists. The discussion of historical texts also helped in producing a conceptual change in the students. The texts and the description of their use were later incorporated in teachers training courses, showing a specific useful application of history of science in science teaching.

There were other different trends. Towards the end of the 1970s, another group of the University of São Paulo, including Luis Carlos Menezes, João Zanetic, and the graduate students Demétrio Delizoikov Neto and José André P. Angotti, endeavored to apply the educational ideas of Paulo Freire (Freire 1970) to science teaching, linking some of his ideas to Thomas Kuhn's views. Delizoikov, Angotti, and other educators put to practice this proposal during a stay in Guinea-Bissau, one of the countries where Freire had worked during his exile from Brazil, after the 1964 military *coup d'état* (Delizoikov Neto et al. 1980). The dissertations of Delizoikov and Angotti, supervised by Menezes, were completed in 1982 (Delizoikov Neto 1982; Angotti 1982). Although Kuhn's ideas had been a starting motivation, the stronger emphasis of those works is neither historical nor philosophical.

Menezes also supervised Alexandre José Gonçalves de Medeiros, who finished in 1984 his M.Sc. dissertation on the sociocultural and economic influences that acted upon the development of physics up to the end of the seventeenth century. As pointed out above, this line of social history of science had been strongly influenced by Marxist authors.

Although several researchers of USP involved with history and philosophy of science participated in projects that produced educational materials for secondary schools, those projects did not include the use of history and philosophy of science.

Since that time, the uses of history, philosophy, and sociology of science in teaching are a thematic area in graduate programs and conferences on physics and science teaching. There are several research groups devoted to this topic exploring different approaches and methodologies. Along the last years, several books and papers were published on this topic, attesting that history and philosophy of physics is embedded within physics education in Brazil since its very beginning. One strong trend is that several authors hold that the study of historical episodes of science can help students to form a more accurate view of the nature of science and to learn about scientific concepts.[12]

[12] Assis (2008), Batista (2004), Braga et al. (2012), Carvalho and Vannucchi (2000), Forato et al. (2012), Greca and Freire Jr. (2003), Martins and Silva (2001), Pagliarin and Silva (2007), Rosa and Martins (2009), Moura (2012), Silva (2006), Silveira et al. (2010), Silveira and Peduzzi (2006), and Teixeira et al. (2012), Silva and Moura (2012).

70.6.2 Chemistry

The development of a research line in chemistry teaching, in Brazil, had its beginning at the University of São Paulo (USP). When this university was created, in 1934, a German chemist called Heinrich Rheinboldt (1881–1955) was invited to begin the chemistry department. Rheinboldt had a strong interest in the education of teachers and also in history of chemistry, having published in 1917 a study about Johann Baptist van Helmont. He was very influential in stimulating the study of history of chemistry and chemical education (Schneltzler 2002). Under his inspiration, Simão Mathias devoted himself to the history of chemistry, especially after retiring from the Chemistry Institute, in 1972, when he became a professor at the History Department and was responsible for the discipline of history of chemistry.

In the decade of 1960, Ernesto Giesbrecht, of USP, became involved with the translation and adaptation of the North American projects of chemistry (CBA, CHEMS). In the next decade, a group began to form at the Chemistry Institute of USP, under the leadership of Luiz Roberto de Moraes Pitombo and Maria Eunice Ribeiro Marcondes, devoted to the formation of chemistry teachers. José Atílio Vanin also began the development of activities of popularization of chemistry, with the help of students. Those activities finally led to the creation of the Group of Research in Chemical Education (GEPEQ), which is very active. In the decades of 1980–1990, the approach of the group was contributing to chemistry teaching at the secondary school level, with an emphasis in experimentation, relations between chemistry and everyday life, and the use of cognitivist proposals (Ausubel, Piaget).

Although there were some early activities related to chemistry education, such as those described above, the expansion of the area is strongly linked to the creation of the *Sociedade Brasileira de Química* (SBQ) (*Brazilian Chemical Society*) in 1978. During the first meeting of this society, there was a session devoted to the discussion of chemistry teaching, and interest in this line increased in the following years. The journal of this society *Química Nova* (*New Chemistry*) started the publication of papers on chemistry teaching in 1980.

At the same time, at the south edge of the country (State of Rio Grande do Sul), a series of regional annual meeting started in 1980: the *Encontro de Debates sobre Ensino de Química* (EDEQ) (*Meeting of Debates on Chemistry Teaching*), organized by Attico Chassot. In 1988 the *Brazilian Chemical Society* founded its Teaching Division and in 1982 began the series of biennial conferences called *Encontro Nacional de Ensino de Química* (ENEQ) (*National Meetings on Chemical Teaching*). In 1995 the *Brazilian Chemical Society* founded a new journal: *Química Nova na Escola* (*New Chemistry at School*), the main target of this publication being secondary school chemistry teachers.

One of the strongest lines of research in the 1990s was the study of previous concepts of students and the way of dealing with those ideas. The earlier idea that those spontaneous concepts should be transformed or replaced by the standard scientific concepts was given up by Eduardo Fleury Mortimer, who developed a new approach of conceptual profiles, inspired by Gaston Bachelard (Mortimer 1995, 2000).

The new attitude allows the students to keep their previous concepts, being aware of the difference between the scientific and popular cultures.

During the decade of 1990 the analysis of the epistemological beliefs of chemistry teachers led to the conclusion that they adopted a naïve empiricism and transmitted this attitude to their students. It became evident that the training of chemistry teachers should include not only the knowledge of chemistry but also its historical and epistemological features, as well as the social, economic and political context of the development of this science (STS approach).

Contributions from history and philosophy of science are not very common in research on chemistry teaching. Among several different approaches that can be found, we can point out an emphasis in the analysis of epistemological views presented in textbooks and by students and teachers and proposals of strategies to provide a more adequate view on the nature of science using historical studies of chemistry. The science, technology, and society approach is also deemed important, and historical examples (such as the development of dyes) are suggested to introduce this issue. Some of the works also claim the improvement of learning of chemical concepts using a historical approach.

Many works that cannot be classified as "research in chemistry education" should also be mentioned. From the 1990s onwards, several Brazilian chemists have published popular books on history of chemistry (Vanin 1994; Chassot 1994) and many papers on specific subjects. More recently, Juergen Heinrich Maar is producing a three-volume work on the history of chemistry (two parts have been published: Maar 2008, 2011). The production of papers on specific episodes of the history of chemistry has also provided the Brazilian teachers with some nice works that can be put into use in their educational practice.[13]

70.6.3 Biology

As noticed above, the BSCS project was introduced in Brazil in the 1960s. Besides many innovations, the project included a historical study of biological concepts. However, this did not lead to any stimulus for the development of studies of history of biology applied to science education in Brazil, at that time.

Brazilian educational projects related to biology teaching were produced from the decade of 1960 onwards. They attempted to produce textbooks with new content, together with laboratory materials. Until the next decade, the main concern was the production of teaching materials and the teaching training, and there was no concern with educational research in biology. Around 1990 the area begins to produce researches on spontaneous concepts of students and teachers and on the use of history and philosophy of science.

[13] Among the articles devoted to the use of history of chemistry on education see, among others, Bagatin et al. (2005), Baldinato and Porto (2008), Chassot (2001), Farias (2001), Flôr (2009), Oki (2000), Paixão and Cachapuz (2003), Porto (2004), Tolentino and Rocha Filho (2000), and Vidal et al. (2007).

In the cases of physics and chemistry, the respective scientific institutes of the University of São Paulo (USP) played a relevant role in the development of the area of science education. The national physical and chemical societies also gave strong support to this area. In the case of biology, the situation was widely different. Research in biology education was strongly developed at the Faculty of Education of USP, especially under the leadership of Myriam Krasilchik – not at the Institute of Biology.[14] Besides that, since a *Brazilian Society of Biology* never existed, there was no association that could support the area. Indeed, there are several biological societies in Brazil, related to genetics, zoology, etc. but none that could assume the improvement of biology teaching as its concern.

In 1984 the Faculty of Education of USP began a series of conferences, called *Encontro Perspectivas do Ensino de Biologia* (*Meeting on Perspectives of Biology Teaching*). Although they did not have a national character, those events attracted researchers from other institutions, starting a process of organization of the area. The creation of the *Sociedade Brasileira para o Ensino de Biologia* (SBEnBio) (*Brazilian Society for the Teaching of Biology*) in 1997 led to a decentralization of the events, with regional conferences on biology teaching promoted at other states. The first *National Meeting for the Teaching of Biology*, organized by SBEnBio, occurred only in 2005. The journal of this society, *Revista de Ensino de Biologia* (*Journal of Biology Teaching*), started in 2007. In 2008, the *Brazilian Association for Philosophy and History of Science* (ABFHiB) created a Commission for Biology Teaching and produced a series of case studies for application in secondary schools.[15]

Up to 1996 the number of theses and dissertations on biology teaching was very small. In the last years of the twentieth century, there was a strong increase, parallel to the creation of the *Brazilian Society for the Teaching of Biology*, but not as an effect of this society (Teixeira et al. 2009). Around 1990 the area begins to produce researches on spontaneous concepts of students and teachers and on the use of history and philosophy of science.[16] The first works on the STS approach in biology education appeared a few years later.

Works using this approach usually stress the importance of introducing history of science in biology teaching to present science as a human construct, subject to mistakes, influenced by external factors, producing provisory knowledge. They denounce the inductive view of science, the idea that biology was produced by a few bright minds, and the view that science is the attainment of absolute truth. Those researches also emphasize the need to introduce history and philosophy of science in the teaching training. The STS approach is also recommended, adding the environment dimension. Besides discussion and recommendations, there are several

[14] It is worth mentioning that the situation has changed along the last 5 years. Due to the Teacher Education Program of USP, the Institute of Biosciences hired professors on biology teaching and history of biology, and new similar positions for science teaching were created in other science institutes (Universidade de São Paulo 2004).

[15] Andrade and Caldeira (2009), Batisteti et al. (2009), Bizzo and El-Hani (2009), Carmo et al. (2009a), Brandão and Ferreira (2009), Martins (2009a), (2009b), and Prestes et al. (2009).

[16] Among others: Bastos (1998), Cicillini (1992), Martins (1998), Slongo (1996).

works that include the production, application, and analysis of teaching activities using history and philosophy of biology.[17]

70.7 National Educational Guidelines

The relevance of history and philosophy of science in science teaching was officially recognized, in Brazil, at the end of the twentieth century. In 1996, the Brazilian Ministry of Education (MEC) began an educational reform. The first official step was the promulgation of the *Leis de Diretrizes e Bases* (*Law of Brazilian Education Guidelines and Bases*), followed by a *Resolution* of the National Education Council that established the *National Curricular Guidelines for Secondary Education*, in 1998 (Brasil 1996, 1998). This *resolution* describes, in its tenth article, some of the abilities and competencies that the students should acquire in their study of mathematics and natural sciences, including:

> (a) To understand the sciences as human constructs, recognizing that they develop by accumulation, continuity or paradigm rupture, correlating the scientific development to the transformation of society; […] (i) To understand the relation between the development of the natural sciences and the technological development and to associate the different technologies to the problems that they intended to solve; (j) To understand the impact of the technologies associated to the natural sciences in the student's personal life, in the production processes, in the development of knowledge and in social life (Brasil 1998, p. 4–5).

The first of those items is directly related to the nature of science issues, associated to history and philosophy of science, and the other ones, to history of science and technology and science-technology-society issues. That document did not suggest any other roles for history and philosophy of science.

A group of educators, invited by the Ministry of Education, produced in 1997–1998 a document explaining how the general guidelines should be applied by teachers: *Parâmetros Curriculares Nacionais para o Ensino Médio* (PCNEM) (*National Curriculum Parameters for Secondary Education*) (Brasil 1997). This was followed by a more detailed complement, published in 2002: *PCN + Ensino Médio: Orientações Educacionais Complementares aos Parâmetros Curriculares Nacionais* (*Educational Complementary Guidelines to the National Curriculum Parameters*) (Brasil 2002). The sections of those two official documents concerning mathematics, physics, chemistry, and biology point out, at several places, the relevance of history and philosophy of science to science education.

The elaboration of the two documents on natural sciences and mathematics was coordinated by Luís Carlos de Menezes. For each discipline, the group provided

[17] Among others, see Almeida and Falcão (2005), Batista and Araman (2009), Baptista and El-Hani (2009), Bastos and Krasilchik (2004), Caldeira and Araújo (2010), Carmo et al. (2009b), Carneiro and Gastal (2005), El-Hani and Sepulveda (2010), El-Hani et al. (2004), Goulart (2005), Justina (2001), Leite (2004), Meglhioratti (2004), Pereira and Amador (2007), Rosa and Silva (2010), Santos (2006), Santos et al. (2012), Scheid et al. (2005), and Slongo and Delizoikov (2003).

specific instances of the use of history and philosophy of science, especially related to the issues of the nature of science and science, technology, and society. The previous official documents understood the contextualization of science education in the sense of the cognitive approaches to education. The group interpreted the contextualization in a much broader sense: "In general terms, contextualization in science education includes competencies related to the insertion of science and its technologies in a historic, social and cultural process and the recognition and discussion of practical and ethical features of science in the contemporaneous world […]" (Brasil 2002, p. 31). The *Educational Complementary Guidelines* (PCN+) provide a large number of specific instances that can be used by teachers in addressing those issues.

Besides those features related to history and philosophy of science, there were many other new proposals that cannot be described here. If the guidelines could be put into practice, they would greatly improve science teaching, in Brazil. Unfortunately, more than 10 years after the educational reform and the publication of the above-described documents, one cannot recognize any definite transformation in science education. Secondary school science teachers could hardly understand all the changes that have been recommended. One can attribute this failure to a lack of effective public policies to improve the school system as a whole. One central aspect that is rarely addressed is the fact that teachers had no adequate training for coping with the new proposals that could help them to attain the new aims.

70.8 Conclusion

Nowadays, the relevance of history and philosophy of science in science education is widely recognized in Brazil. Although the effective classroom practice has not yet incorporated its use, the official educational guidelines are stimulating its development. A large number of books and papers, theses and dissertations, have been produced on this theme. This approach is an important trend in graduate programs and in educational conferences.

Two specific meetings on this subject were held in Brazil, in 2010: the *8th International Conference for the History of Science in Science Education* (ICHSSE) and the *1st Latin American Conference of the International History, Philosophy and Science Teaching Group* (IHPST-LA), with the participation of about 150 researchers (Silva and Prestes 2012). Some specific books on the subject, providing information and suggestion of classroom activities, were published in recent years. There is also an increasing international and regional collaboration.

The Brazilian contributions in this area are not well known worldwide, because most works are published in Portuguese. Although it is relevant to participate in global conferences and projects and to publish in other languages that can reach a wider public abroad, it is very important to produce works in Portuguese for local use. The vast majority of secondary school teachers cannot understand books and papers in English, and even those who can do it prefer reading works published in our national language.

There are several types of publications in this area. The academic ones (those presented at conferences or published in scholarly journals and books) describe the

several approaches and defend (or criticize) their use; they review researches published abroad and in Brazil; they analyze textbooks; they present surveys of the concepts of students and teachers concerning the nature of science and other subjects related to history and philosophy of science; they provide information about history and philosophy of science that can be used in science teaching; they describe specific developments of syllabi, texts, and other educational materials applying history and philosophy of science in education; they report classroom experiments using history and philosophy of science; and they present proposals of new initiatives in the field, such as teaching learning sequences based in application of history and philosophy of science in science education (Peduzzi et al. 2012). Nowadays, the focus of history and philosophy of science in science education is the discussion of the nature of science and science, technology, society and environment issues. The uses of history of science to improve the learning of scientific ideas, to increase the motivation of students, its intrinsic cultural value, and other uses that were proposed in the 1970s and 1980s, are nowadays seldom mentioned.

The vast majority of authors of the abovementioned academic works are either university professors or graduate students. Most of this production will never reach in-service science teachers, but might be used for preservice teaching training at the university, or in specific courses for in-service teachers.

On the other hand there are publications targeted at in-service teachers (and also students), such as the journals that have already been described (*Revista do Professor de Matemática*, *Química Nova na Escola, Física na Escola*) and books. Those journals have a wide penetration, but their function is mainly informative. It is doubtful that they have contributed to effective changes in science teaching, because they only contain short papers. There are many books on history and philosophy of science published in Portuguese. However, teachers interested in this subject usually read popular, out-of-date books that reproduce the old views on the nature of science.

There is a shortage of educational materials using history and philosophy of science in the secondary school classroom. As described above, as a rule science textbooks include mistaken information about history and philosophy of science. There have been attempts to produce supplementary texts on history of science for use by students, but their effective utilization has been very limited.

Much remains to be done in consolidating the effective use of the history and philosophy of science in Brazilian science education. Nevertheless, it is possible to say that there is a solid ground, in research and graduate courses; there is clear official interest in the use of history and philosophy of science in education; there is a growing awareness and interest in this subject by teachers; there is a pressure by the Ministry of Education upon publishing houses in order to improve the quality of history views on nature of science in textbooks; in a nutshell, there are nice conditions to take off and fly. Of course, government support is essential and is sometimes unavailable; but many initiatives that depend only on researchers can start a snowball effect and produce important results.

It is necessary to consider the complexity of the education system in order to create a successful implementation of history and philosophy of science at schools. There is a gap between research and practice to connect curricular innovation with teaching

practice; it is not restricted only to history and philosophy of science (see, among others, Pekarek et al. 1996; Pena and Ribeiro Filho 2008; Höttecke and Silva 2011). Thus, working collaboratively with in-service teachers is essential. In order to foster the use of history and philosophy of science in science education, it is important to take the teachers' perspective into account; otherwise curricular innovations will be hard to implement.

The introduction of disciplines in teachers training courses that combine scientific content and historical and philosophical issues with didactical aspects is highly desirable. It can allow future teachers to develop some of the needed skills to implement this approach in practice and to develop an awareness of the real worth of the use of history and philosophy of science in their teaching (Höttecke and Silva 2011).

It is also important to establish stronger cooperation between scholars in this field: one swallow does not make a summer. Collaboration may occur at several different levels. The creation of a national society for history and philosophy of science in science education, together with a specific journal and periodic meetings, might enhance the visibility of the area and provide a better forum for debate of researches and for the planning of national strategies. This does not mean that researchers working in this area should keep apart from other societies, of course. The creation of national databases for dissertation, theses, electronic versions of books, conference proceedings, and papers would be a nice instrument both for the improvement of research and for the dissemination of works. A teamwork including many groups and institutions could propose and lead ambitious projects – both research projects and educational ones. In a lower scale, a researcher producing new educational materials should ask the help of other researchers, from different institutions, to test and comment on his/her work; a researcher doing a survey of concepts on the nature of science at one institution should ask the cooperation of colleagues from other institutions to do a similar survey at other places, to compare their results. Researchers should think great: could my current work improve if I asked other people to collaborate?

Another front to be developed is a combination of research and application. We mean *real* application, such as posting on the Internet educational materials, together with suggestions for their use and additional materials (such as a video uploaded to *YouTube*). Of course, quality should always be a concern – both in research and application. A careful transposition can produce high-quality popularization and educational materials. The combination of those last two attitudes – trying to cooperate and to be useful in a broader sense – could greatly improve the situation in the area.

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