TEACHING HISTORY AND THE NATURE OF SCIENCE IN SCIENCE TEACHER EDUCATION PROGRAMS

Mehmet Fatih Taşar[*†]

ABSTRACT

This paper presents different views of practitioners, teachers, and learners of science about the nature of science and aims to draw attention to why and how history and the nature of science (HP&S) should be taught as part of science teaching. Three different approaches to teaching HP&S were identified in the literature: including the nature of science as part of science teaching, learning by reflecting upon critical incidents in science classrooms, and teaching the nature of science more explicitly as a separate course. Also in this paper some features of an elective course entitled "The History and the Nature of Science" offered at the junior level at The Gazi Faculty of Education is introduced to the reader.

Key Words: History and Nature of Science, Science Teacher Education

FEN ÖĞRETMENİ ADAYLARINA BİLİMİN TARİHİ VE DOĞASININ ÖĞRETİLMESİ

ÖZET

Bu makalede bilim insanlarının, öğretmenlerinin ve öğrencilerinin bilimin doğası hakkındaki farklı görüşleri derlenmiştir. Bilimin tarihi ve doğasının neden ve nasıl öğretilmesi gerektiği hususu üzerine dikkat çekilmektedir. Bu konuda literatürde bulunan üç yaklaşım tespit edilmiştir: Bilimin doğasının, fen bilimleri eğitiminin bir parçası olarak işlenmesi; sınıfta dikkat çekici özel olaylar üzerinde derinlemesine düşünme ortamının yaratılması; ve bilimin doğasının daha açık bir şekilde ayrı bir ders olarak öğretilmesi. Ayrıca Gazi Eğitim Fakültesinde üçüncü yılda okutulmakta olan "Bilimin Tarihi ve Doğası" adlı seçmeli ders hakkında da bilgi verilmektedir.

Anahtar Kelimeler: Bilimin Tarihi ve Doğası, Fen Öğretmeni Yetiştirme

INTRODUCTION

Teaching is a very complex and dynamic process in the sense that teachers derive knowledge from different sources. It is complex because in addition to a sound content knowledge expert teaching skills are required and it is dynamic because simply possessing them does not guarantee becoming or being an outstanding teacher. The culture of the society in which we live and the cultures of the smaller social groups with which we associate ourselves shape and direct our thinking and practices. Human life is an amalgamation of many components and being a member of a society is undeniably important in making sense of things we learn. We build upon the knowledge and traditions of practices accumulated through ages. Even the language we use is in constant state of change and all kinds of new communication media are being introduced to modern people. In this age to be literate and become educated, in broader

---

[*] Gazi Üniversitesi, Gazi Eğitim Fakültesi, İlköğretim Bölümü, Fen Bilgisi Öğretmenliği Anabilim Dalı, 06500, Teknikokullar, Ankara.
[†] email: mftasar@gazi.edu.tr

sense, means much more than being able to read and write or acquire basic survival skills. It requires being able to learn continuously without getting tired of learning in all jobs. Benjamin (1939) expresses this idea in a poetic form:

"He knew how to do things his community needed to have done, and he had the energy and will to go ahead and do them. By virtue of these characteristics he was an educated man."

Osborne (1998), on the other hand, characterizes the modern society as a "risk society" and comments on the changed nature of interaction between science and society as follows:

"… living in a state of advanced modernity, the social production of wealth is now systematically accompanied by the social production of risks. It is this thesis, …, that is essential to understanding the resituated nature of the relationship between science, society and the individual. Such a repositioning has occurred, … , from the perception of the growing threats and risks posed to civilization by science. Essentially society has changed. … the contemporary society is a 'risk society' where science is not only a source of solutions but also their cause. Today, the effects of science, its claims and its benefits are regarded with mistrust."

In such a conception of the interaction between science and society surely there are plenty of why and how questions regarding science education. Driver & Osborne (1998) summarize the ideas and questions:

"… it is generally accepted that an appropriate curriculum would need to consider three aspects of science: first, the core concepts, theories and models put forward by science to explain the world; second, the processes by which scientists gain new knowledge and third, how science as a social enterprise operates and how it relates to societal problems and concerns. The critical issue is one of a balance –for what should be the appropriate balance between these components? how might it differ for children of different ages? and how would these components be embedded in curricular activities?"

One important theme in science education today is teaching the nature of science as part of science education. Griffiths & Barman (1995) emphasize that "the usefulness of an education in science is restricted when the nature of science itself is not understood." The 'nature of science' includes understanding what science is and what role it plays; who scientists are and what role(s) they play; the nature of scientific evidence, observations, facts, rules, laws, and the scientific method; and how science is done. In recent years a vast amount of literature has emerged on science teachers' beliefs and thinking about the nature of the subject matter (i.e. science), learners, and classroom practices (see Bell, Abd-el Khalick, Lederman, McComas, & Matthews, 2001; Abd-el Khalick, Lederman, 2000). Studies show that (e.g. Hashweh, 1996; Hewson, Kerby & Cook, 1995) practicing teachers do differ in their views. Informing the individuals in the community of science teachers about such diverse opinions within the community is a stimulator of change and a significant contributor for defining roles and practices of science teachers. It is always argued on what science teachers should know and how they should practice (e.g. Coble & Koballa, Jr. 1996); and what should be the goal of science education (e.g. Wavering, 1980). I argue that, beliefs about the nature of science strongly correlate with how one sees and understands science. In this respect, the above mentioned literature has a great potential for guiding both preservice and practicing teachers.

The first section below discusses the definitions and perceptions of science from multiple perspectives: practicing scientists, teachers, preservice teachers, and science learners. This will inform the reader about different views prevailing in these different groups of people concerned with science. Then, the questions of ‘what understandings about the nature of science do secondary science teachers need to possess?’ and ‘why do they need to develop these understandings?’ will be addressed. In the last section the paper concludes with suggestions from the literature on helping science teachers develop these understandings?

VIEWS ABOUT SCIENCE

Defining Science

Weisskopf (1989), a distinguished physicist, sees science as a part of our culture and as means of establishing a relationship between ourselves and the nature (p.30). He comments on teaching science and defines science as:

“Science does not provide answers to definite questions. It is not flat knowledge, formulae, names.... Science is curiosity, discovering things and asking why. Why is it so? Indeed, science is opposite of knowledge. Science asks the why and how questions and therefore *is the process of questioning not the acquisition of information.* We must always begin by asking questions not giving answers. We must create interest in things, phenomena, and processes.” [Italics added].

Furthermore, it is argued that viewing science as deterministic and absolute does not fit the nature of science. Since no one can get to the whole before making any claims about any natural phenomenon, science is inherently inductive (Horner & Rubba, 1978). It is not fixed or final (Young, 1992). For Popper (1959, p. 40-41), a scientific (empirical) system is the one that can be tested by experience. Therefore, if a system, in its logical form, covers all possibilities so that it holds true (verifiability) at all times, it can not be considered scientific. Instead, a system remains scientific as long as it can be tested and refuted (falsifiability). This is the criterion for distinguishing a scientific system from others.

Scientists' understanding of science

Research findings (Durkee, & Cossman, 1976) of a comprehensive study among a randomly selected group of philosophers (n=23) and science faculty (n=318) suggests that they don't absolutely agree on the objectivity of scientific representations of reality, but rather that science is an evolving process. As a result of these two perspectives they interpret "science as the process and product of a dynamic man-world interaction." Additionally, they feel about verification or falsification of a theory and data that having more data do not necessarily lead to a proof of theory in either sense. They characterize the main goal of science as "the search for patterns and coherence in nature via theoretical structures." On the nature of scientific laws they see a high correlation between experience and generalization as the former leads to the latter. But on the other hand, they don't interpret laws as given (existing entities) by nature. They also reject the notion that "models photographically represent reality."

Science Teachers' understanding of science

Brickhouse (1990) conducted a research on three secondary physics teachers by purposive sampling on the basis of their diverse perspectives. She found a strong correlation between these science teachers' beliefs about the nature of science and their classroom practices (i.e. how they thought children should learn science). Teachers in this study differ in their views of the nature of scientific theories, scientific process, and scientific progress.

For the nature of scientific theories two of the teachers disagree on whether the theories are tools for solving problems or mere representations of truths. On the beliefs about scientific process two findings emerge:

- seeing scientific processes as absolute recipes which need to be followed to uncover the truth and to see once more that it really works (this also might be interpreted as the purpose of science being a collection of predetermined procedures to be used by new generations since science is, by definition, exact),
- viewing theories as the foundation of observation in that they precede and lead to observation which, in turn, is validated by observation.

When it comes to scientific progress again two views emerge:

- science is built upon previous works of scientists in the sense that new understandings are driven and theories are improved by relying on these previous achievements,
- for progression older understandings (of observations) need to be reevaluated in the new contexts in order to gain deeper insights.

These last two views on progress can be expressed in short as climbing a ladder straight up without missing any steps in between; and moving up on a helix to tie together the previous understandings to newer ones respectively. These divergent views are also translated to classroom practices of the teachers (their attitudes, choice of examples, and even the way science should be learned by students).

Rampal (1992) conducted a research in India on school teachers’ views about characteristics of scientists with a sample of 199 teachers attending an curriculum enhancement program and concluded that issues related to over-idealized image of scientists and unquestioned authority of science need to be addressed by presenting “interesting “holistic” historical accounts of scientists' work from diverse fields, including occasional failures, errors, and frauds, need to be introduced in textbooks.”

Pomeroy (1993) surveyed 71 research scientists' and 109 secondary science and elementary teachers' views about the nature of science by mailing a 50 item Likert-type questionnaire. In this comparative study the scientists reflected a significantly more traditional views than teachers which is interpreted as holding positivistic views about science. Pomeroy comments that these respondents may have been trained in a ‘normal science' tradition as set forth by Kuhn.

Preservice Science Teachers' understanding of science

Wavering (1990) studied prospective secondary science teachers' understandings of the nature of science and its interaction with religious beliefs and the effect of instruction on changing the knowledge level on the nature of science in the context of the theory of evolution. He found that prospective teachers have limited knowledge of the nature of science irrespective of the number of hours of biology taken, that the more they are religiously oriented the less they understood the development of scientific knowledge, and that a methods course instruction introduced uncertainty in their minds in terms of understanding the nature of science.

On another study Mellado (1997) investigated four preservice teachers' conceptions of nature of science. He found that there was a lack of previous reflection on the nature of science and “… this lack of reflection led them to fall into clichés and contradictions in their ideas.”

Science learners' understanding of science

Ryan, & Aikenhead (1992) conducted a research based on their own *Views on Science-Technology-Society* instrument to explore grade 11 and 12 students' (n>2000) views about science. Little more than half of the students preferred content (28%) and process (24%) aspects when defining science and a third largest group (10%) viewed science as an instrument of social purpose.

Preferences on the nature of the content and process were not differentiated in this report. On the nature of scientific theories one major group (34%) prefers the view that they are indeed discovered (as opposed to the view that they are invented by human beings). This approach can be interpreted as science being in one to one correspondence with reality. On the other hand, interestingly enough, 40% of the students see that theories either can be invented or discovered.

Another item in this instrument was designed to probe the student's understandings of scientific models. 36% of the students believed that scientific models are *not* copies of reality, whereas 19% believed so (naive realist view). In this second group no one believed that "scientific models are copies of reality because scientists say they are true, so they must be true." The largest group

(37%) is the ones who don't have clear epistemological viewpoint. They believe that "scientific models come close to being copies of reality." This might be consistent with the view that science is going through an improvement through ages and that one day in the future models will inevitably represent reality. It would indicate that more than one half of the students are adopting the naive realist view.

HISTORY AND THE NATURE OF SCIENCE IN SCIENCE EDUCATION REFORM EFFORTS

National Science Education Standards

History and the nature of science (H&NS) has been set as one of the science content standards in 'National Science Education Standards' (NSES) published by National Research Council (NRC) (1996, p.108). The required student understandings about the H&NS are given in Table 1.

Table 1. Required student understandings according to grade levels.

Levels K-4	Levels 5-8	Levels 9-12
Science as a human endeavor	Science as a human endeavor	Science as a human endeavor
	Nature of science	Nature of scientific knowledge
	History of science	Historical perspectives

The nature of science and scientific knowledge are explained as follows:

"On the nature of science, NSES promotes the ideas that scientific ideas are not fixed but rather subject to change. For this reason scientists may not agree on their interpretations and evaluation is done through scientific inquiry" (NRC, p. 171).

"There are other ways of knowing and bodies of knowledge but science is different from them in that it uses empirical standards, logical arguments, and skepticism and that scientific explanations are the results of these criteria. Scientific ideas may not always be complete but this leaves more room for science" (NRC, p. 201).

Project 2061

In USA, as an effort to determine basic learning goals in achieving scientific literacy for the children American Association for the Advancement of Science (AAAS) published "Benchmarks for Science Literacy" in 1993. It defines goals of learning about science for all grades K-12. Among others the nature of science and historical perspectives are also given special emphasis. On the nature of science, for 9-12 graders the view that 'science itself is an ongoing process and therefore subject to change; objectivity is an important feature of science and scientific method is a mechanism to ensure that in the long-run; science is a human endeavor developed throughout history and has a certain value system' is promoted.

TEACHING SCIENCE AND THE NATURE OF SCIENCE

In his recent paper Machamer (1998) gives an overview of issues related to the nature of science. He defines science, epistemologically, as a method of inquiry about the things and structures in the world, and describes the concerns of the philosophy of science:

i. *Epistemological*: Philosophy of science asks what the nature and essential characteristics of scientific knowledge, how this knowledge is obtained, how it is codified and presented, how it is subjected to scrutiny, and how it is warranted and validated.
ii. *Metaphysically*: Philosophy of science examines the kinds and natures of things in the world, in so far as science deals with them.
iii. *Ethically*: Philosophy of science directs questions towards the value system that scientists have and asks how these values affect the practices and conclusions of science.

According to him, for educational purposes the epistemological point of view bears the highest significance. He asserts that "science, as it is taught and practiced in an educational setting, should be concerned with questions about the nature and adequacy of knowledge." Further, he identifies epistemological key concepts to be addressed: *aims and goals of science; limits of science; nature of scientific discovery; nature of scientific explanation; theory, law, model and hypothesis, paradigms and research traditions in science; evidence, test, confirmation, falsification, and prediction; experiments as types of empirical tests;* and finally *social, cultural, political and ethical implications of science.*

For Machamer (1998) conveying these understandings are possible by reflecting on them while doing science in science classrooms:

"… asking students to reflect upon their activities when engaging in science, or studying science, is a way to enable them to understand themselves and their motivations more clearly. Having them ask many of the questions that philosophers of science ask, actively engages them in the process of inquiry and challenges them to increase understanding of what they are doing … Philosophical questions must be raised in context and with regard to a specific content for its critical concerns to be efficacious."

DEVELOPING UNDERSTANDINGS OF THE NATURE OF SCIENCE IN TEACHER EDUCATION PROGRAMS

Teaching abstract concepts in science

As an example let's consider the concept of the atom. How would one teach such a concept? Atomic theory is taught, traditionally, by using several models of the atom, which were actually developed by physicists through the years. Teaching such a concept requires more than knowing these models (i. E. the content knowledge). A teacher should be able to foster the idea in students that science is all about theories which have been tested sufficiently enough number of times (Young, 1992) but yet "there is no guarantee that any scientific law is absolutely, certainly true" (Horner & Rubba, 1978). The role and use of models in science needs to be emphasized in science classrooms to ensure that models are not to be seen as reality but rather something able to reflect certain aspect(s) of it in some way for us to be able draw understandings about the nature. Teachers need to be cautious about the textbook expositions (Horner & Rubba, 1978) and public displays since meanings they convey may exceed the intention or perhaps actually misinterpret the original ideas.

To this end it should be added that natural scientists and philosophers in the study reported by Durkee, & Cossman (1976) have different views on whether objects like the atom do actually exist:

"A plurality of the scientists believe that 'atoms', and presumably some other theoretical entities, exist in the sense that the concept operates successfully in science. They also affirm that theories are essentially useful calculating devices, practical tools and useful techniques for organizing research. The philosophers, on the other hand, assert that 'objects' approximately corresponding to the concept 'atoms' exist, and that the 'instrumentalist' view of theories is incomplete and inadequate."

NSES also defines scientific models in accordance with the scientists view (p.117).

Consider, on the other hand, how an experiment is done traditionally in high schools (AAAS, 1993). Teachers give the question and apparatus for investigation, dictates how and what data to collect and how to organize. Findings are not repeated, discussed or interpreted in the class, and the students already know that they have to find (or at least come close to) some already known answer. This leaves no ownership to the student in doing science. This way of doing science, neither, gives excitement to children in anyway nor it is the way scientists do science. Drawing attention to such cases in teacher education programs will enrich their understandings and hence teaching of science.

Recently there had been attempts to foster understandings of the nature of science both in science classrooms and in separate specific courses. Nott & Wellington (1995) described an authentic way of dealing with the nature of science issues. They have used critical classroom incidents with in-service and preservice teachers. A critical incident is defined as "an event which confronts teachers and makes them decide on a course of action which involves some kind of explanation of the scientific enterprise." These are closely related to classroom practices, promote reflection and discussion, explore teachers' implicit understandings and help to make them explicit. They promote and probe teachers' knowledge-in-action and their practical wisdom rather than 'academic knowledge'.

It is appropriate to give one such critical incident here:

"Year 7 children are doing experiments with circuit boards. *With two lamps in series, many find that one is lit brightly whilst the other appears to be unlit.*

List the kinds of things you could say and do at this point."

Nott (1994) asserts that "novice teachers teach in the same way they themselves were taught." Therefore, it is plausible to include concepts of the nature of science in the context of science teaching. In a teacher training course, he taught 'Brownian motion' by using the original experimental data of Jean Perrin to check the value of Avogadro's number. Students were asked to be highly critical and reflective on this task (published data on different resources didn't match each other).

He found the indications of the following outcomes:

1. Some students identified science learned (as a result of this activity) as the relationship between macroscopic and microscopic.
2. Others defined science learned in terms of content, e.g. equations and facts.
3. History of science and scientific method was also considered the science learned.

Others (e.g. Matthews, 1990 and Eichinger, Abell, Dagher, 1997) argue that the nature of science should be taught more explicitly, perhaps, as a separate course at the teacher education institutions. Matthews argues that "Science in the schools cannot be taught without implicitly assuming a particular philosophy of science. Therefore, both philosophy and history of science are necessary components of undergraduate science education courses.

IMPLICATIONS FOR TEACHER EDUCATION PROGRAMS

In the context of professional development and educational reform efforts Borko and Putnam (1995) adopt the view that "... to help teachers change their practice, we must help them to expand, enrich and elaborate their knowledge systems. At the same time, however teachers' existing knowledge and beliefs act as lenses or filters through which they view calls for change." Thus, if we wish science teachers to change their instruction in a particular way we need to provide them the necessary means. Informing them about the current views of both teachers (how different, indeed, teachers are having opinions about science and science teaching) and students (letting them see what educational goals are sought and what outcomes are attained) should be the first step when beginning any reform effort. This article informs the science education community about the need of having appropriate ways of placing the nature of science in science teaching, and also emphasizes the fact that current science teacher education programs need to be revised to provide a sound basis.

The literature cited in this article and elsewhere indicates that learning scientific processes, solving problems, engaging in scientific activities, etc. do not, by themselves, lead to a coherent understanding of the nature of science in high school students and preservice teachers. Having more experience on both scientific enterprise and teaching develops certain belief systems in teachers about what science is and how it should be taught. It was found that teachers' beliefs about the nature of science affect their teaching, organizing classroom activities, and deciding what should be the outcomes of science teaching (Brickhouse, 1990). I believe that developing a coherent idea of science in students in accordance with NSES and Project 2061 is a very important aspect of learning science. But to do so requires more rigorous emphasis on the nature of science in both preservice teacher education and teacher development programs.

Becoming aware of the issues stated in this article (i.e. the nature of science and including it as an essential component of achieving science literacy) is important for practicing teachers in several ways. First, in accordance with the notion that "teachers are life long learners", personal development in this respect is part of that learning. They should continue learning about science from different perspectives, become aware of major curriculum reform efforts such as NSES and Project 2061; reflect on these and seek ways of adopting them in their classrooms. Second, teachers themselves are also practicing science in their classrooms and laboratories and setting a role model for students. Perhaps, for most students the first scientist they encounter and contact is their teacher. Third, being aware of different views about the nature of science may give teachers the opportunity to reflect on their own practices and thinking, which may in turn foster a constructivist view of science education.

A recent international study by The International Association for the Evaluation of Educational Achievement (IEA) (2000) about the effectiveness and status of science education in various countries included 'scientific inquiry and the nature of science' among the six science content areas. Turkey also participated this last study and among the 38 countries participated took 33rd place. On all six content areas the Turkish national average was significantly lower than the international average. On the basis of this study Bağcı-Kılıç (2003) supports the newly designed elective course entitled 'Scientific Inquiry' (Bilimsel Araştırma) in the high school curriculum but stresses the need that scientific inquiry and other science courses should support each other. She also emphasizes the need for teachers capable of understanding such issues and covering them appropriately in classrooms.

As an attempt to teach the history and the nature of science I designed courses for both graduate and undergraduate students majoring in science education at The Gazi Faculty of Education. The graduate course became an instant hit among the students from various programs such as teaching science, physics, chemistry, biology, and mathematics. In these courses the primary method of delivery is the Socratic dialogue. However, students are encouraged to do research projects focusing on different aspects of the history and the nature of science. It is seen that topics of a student's own choice stimulate more interest in the subject and therefore become an effective instructional tool.

In these courses the books that are available in Turkish are used (although some reading in English is also assigned in the graduate course). I believe it is appropriate here to introduce the reader some of such books in order to facilitate usage of them in courses elsewhere. Several history of science texts by different authors are available in Turkish: Ronan, 2003; Tekeli, Kahya, Dosay, Demir, Topdemir, Unat, ve Aydın, 2001; Mason, 2001; Göker, 1998; Yıldırım, 1998; Westfall, 1998. These books cover the history of science from antiquity to date and when appropriate parts are selected and used properly they can become very useful tools in such courses. Additionally, Snow's famous book "The Two Cultures" (İki Kültür) can be used as an introductory book to the topic (Snow, 2001). The books by Türkdoğan (2000), Demir (2000), and Yıldırım (2000) are excellent introductory texts for both graduate and undergraduate students on the subject of the philosophy of science and cover valuable material related to the nature of science which can arise thought provoking discussions. More advanced texts such as the monumental works of Kuhn (2000), Popper (1998), Feyerabend (1999), and Lakatos and Musgrave (1992) are more appropriate for advanced courses.

REFERENCES

Abd-el Khalick, F. & Lederman, N. G. (2000). "*Improving science teachers' conceptions of nature of science: a critical review of the literature"*. **International Journal of Science Education, 22** (7), 665-701.

American Association for the Advancement of Science (AAAS) (1993), "*Benchmarks for Science Literacy*". New York: Oxford University Press.

Aikenhead, G.S. & Ryan, A. G. (1992). "*The development of a new instrument: "Views on science-technology-society*". **Science Education, 76** (5), 477-491.

Bağcı-Kılıç, G. (2003). *"Üçüncü Uluslararası Matematik ve Fen Araştırması (TIMSS): Fen Öğretimi, Bilimsel Araştırma ve Bilimin Doğası."* İlköğretim-Online 2 (1), 42-51. http://www.ilkogretim-online.org.tr.

Bell, R., Abd-el Khalick, F., Lederman, N. G., McComas, W. F., & Matthews, M. R. (2001). "*The nature of science and science education: A bibliography*". **Science & Education, 10** (1-2), 187-204.

Benjamin, H. (1939). ***"The saber-tooth curriculum".*** New York: McGraw-Hill.

Borko, H. & Putnam, R. (1995). "*Expanding teacher's knowledge base: A cognitive psychological perspective on professional development"*. In Guskey, T. & Huberman, M. (Eds.) **Professional development in education: New paradigms and practices** (pp. 35-65). New York: Teachers College Press.

Brickhouse, N.W. (1990). "*Teachers' beliefs about the nature of science and their relationship to classroom practice*". **Journal of Teacher Education, 41** (3) 53-62.

Coble, R.C., & Koballa, Jr., T.R. (1996). **"Science Education"**. In J. Sikula, T.H. Buttery, E. Guyton (Eds.), **Handbook of research on teacher education** (pp.459-484). New York: Macmillan.

Demir, Ö. (2000). ***"Bilim felsefesi"*** (2. Basım). Ankara: Vadi.

Driver, R. & Osborne, J. (1998, April). "*Reappraising science education for scientific literacy".* Paper presented at the annual meeting of the National Association for Research in Science Teaching.

Durkee, P., & Cossman, G. (1976). "*Views on the Nature of Science Among College Science Faculty*". ED131999.

Eichinger, D. C., Abell, S. K., Dagher, Z. (1997). "*Developing a graduate level science education course on the nature of science*". **Science & Education, 6,** 417-429.

Feyerabend, P. (1999). **"Yönteme Karşı".** (Çeviren Ertuğrul Başer). İstanbul: Ayrıntı Yayınları.

Göker, L. (1998) "*Fen Bilimleri Tarihi ve Türk-İslâm Bilginlerinin Yeri*". Ankara: T.C. Milli Eğitim Bakanlığı.

Griffiths, A. K. & Barman, C. R. (1995). *"High school students' views about the nature of science: Results from three countries"*. **School Science & Mathematics, 95 (5)**, 248-256.

Hashweh, M. Z. (1996). *"Effects of science teachers' epistemological beliefs in teaching"*. **Journal of Research in Science Teaching, 33** (1), 47-63.

Hewson, P. W., Kerby, H. W., & Cook, P. A. (1995). *"Determining the conceptions of teaching science held by experienced high school science teachers"*. **Journal of Research in Science Teaching, 32** (5), 503-520.

Horner, J. K. & Rubba, P. A. (1978). "*The myth of absolute truth*". **The Science Teacher, 45** (1), 29-30.

International Association for the Evaluation of Educational Achievement (IEA) (2000). TIMSS 1999 International Science Report – Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade. Chestnut Hill, MA: The International Study Center.

Kuhn, T. S. (2000). **"Bilimsel devrimlerin yapısı"** (5. Basım). İstanbul: Alan (Çeviren: Nilüfer Kuyaş).

Lakatos, I., & Musgrave, A. (Eds.). (1992). "*Bilginin gelişimi ve bilginin gelişimiyle ilgili teorilerin eleştirisi*". (Çeviren: Hüsamettin Arslan). İstanbul: Paradigma.

Machamer, P. (1998). "*Philosophy of science: An overview for educators*". **Science & Education, 7**, 1-11.

Mason, S. F. (2001). **"Bilimler Tarihi".** (Çeviren Prof. Dr. Umur Daybelge) Ankara: T. C. Kültür Bakanlığı.

Matthews, M. R. (1990). "*History, philosophy and science teaching: What can be done in an undergraduate course?*" **Studies in Philosophy and Education, 10**, 93-97.

Mellado, V. (1997). "*Preservice teachers' classroom practice and their conceptions of the nature of science*". **Science & Education, 6**, 331-354.

National Research Council (NRC), (1996). "*National science education standards*". Washington D.C.: National Academy Press.

Nott, M. & Wellington J. (1995). "*Critical incidents in the science classroom and the nature of science*". **School Science Review, 76**, 41-46.

Nott, M. (1994). "*Teaching physics and the nature of science together: a case study*". **Physics Education, 29** (3), 170-176.

Osborne, J. (1998, April). "*Beyond belief and towards circumspection*". Paper presented at the annual meeting of the National Association for Research in Science Teaching.

Pomeroy, D. (1993). "*Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers*". **Science Education, 77** (3), 261-278.

Popper, K. (1959). **"The logic of scientific discovery**". New York: Routledge.

Popper, K. R. (1998). **"Bilimsel araştırmanın mantığı".** (Çevirenler: İlknur Aka, İbrahim Turan) İstanbul: YKY.

Rampal, A. (1992). "*Images of Science and Scientists: A Study of School Teachers' Views. I. Characteristics of Scientists*". **Science Education, 76** (4), 415-436.

Ronan, C. A. (2003). *Bilim Tarihi: Dünya Kültürlerinde Bilimin Tarihi ve Gelişimi*. (Çevirenler: Prof. Dr. Ekmeleddin İhsanoğlu ve Prof. Dr. Feza Günergun). Ankara: TÜBİTAK.

Ryan, A. G., & Aikenhead, G.S. (1992). "*Students' preconceptions about the epistemology of science*". **Science Education, 76** (6), 559-580.

Snow, C. P. (2001). **"İki kültür"** (2. Basım). Ankara: TÜBİTAK.

Tekeli, S., Kahya, E., Dosay, M., Demir, R., Topdemir, H. G., Unat, Y. ve Aydın, A. K. (2001). **"Bilim Tarihine Giriş".** Ankara: Nobel Yayınları.

Türkdoğan, O. (2000). **"Bilimsel Araştırma Metodolojisi***"* (3. Basım). İstanbul: TİMAŞ.

Yıldırım, C. (1998). **"Bilimin Öncüleri".** Ankara: TÜBİTAK.

Yıldırım, C. (2000). **"Bilim Felsefesi"** (7. Basım). İstanbul: Remzi Kitabevi.

Young, D. (1992). Cambridge University Press.

Wavering, M. J. (1980). "*What Are the Basics of Science Education? What Is Important to Know, How to Use Knowledge or How to Obtain Answers?*" **School Science and Mathematics, 80** (8), 633-636.

Wavering, M. J. (1990). "*What Do Prospective Science Teachers Understand about the Nature of Science?"* ED319603

Weisskopf, V.F. (1989). **"The privilege of being a physicist"**. New York: W.H. Freeman and Company.

Westfall, R. S. (1998). **"Modern Bilimin Oluşumu"**. (Çeviren: İsmail Hakkı Duru). Ankara: TÜBİTAK.