

A COMPARATIVE ANALYSIS OF EARTH SCIENCE EDUCATION IN ELEMENTARY SCHOOLS IN TURKEY AND IN THE USA

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Abstract

Research in education gives initiatives to countries evaluate and modify their curriculum. Large-scale international assessments such as TIMSS usually inspire these curriculum reforms by that countries compare the results of large-scale assessments with other countries' scores. Domestic practices also need to be considered for the educational reforms because domestic practices can picture education systems very clearly that international studies might not be able to detect. To make better curriculum decisions both the domestic practices and the large-scale international assessments need to be evaluated together. As a result, local implementations of specific content might be very informative to improve the curriculum of other countries. The purpose of the current study is to compare earth science education in Turkey and in the USA in elementary school levels and identify the characteristics of the instructional practices in order to make suggestions to improve earth science education.

Key words: *comparative analysis of educational systems, earth science, elementary science, science education, TIMSS, Turkey, USA*

Introduction

Educational research is usually conducted domestically (Swain, Monk, & Johnson, 1999). Consequently, the findings and results interpreted in domestic content without any comparison to other nations. This process brings the disadvantage that when curriculum decisions are made in local context, other nation's practices are ignored. Therefore, domestic studies need to be checked against the results of international studies and other nation's practices in the same context. Studies which compare the international studies and domestic applications provide the background for interpreting domestic research from an international perspective and increase the reliability of both types of studies.

Large-scale international studies, such as Trends in International Math and Science Studies (TIMSS), usually compare countries based on scores and list them individually with little or no discussion (Su & Su, 1994). Su and Su criticize large-scale international studies because "no specific examples were provided to compare particular systems and few recommendations were made regarding what each nation can learn from the other" (p.2). These studies also rely mostly on quantitative research methods (Swain at al., 86), which do not provide in-depth evidence. These studies only report the countries' total scores and sub-scores in a specific subject, such as math, science,

or reading. Since the comparisons are made only on a per-subject basis, no deeper analysis can be provided at the level of each teaching unit or syllabus module. Detailed content-specific studies are important because countries need to conduct evaluations within a specific context in order to assess the efficiency of their instructional practices.

The current study describes earth science education in two countries and points out their characteristics in order to identify effective earth science teaching strategies and propose alternative approaches to increase earth science education in elementary school levels. The study was emerged from the results of TIMSS 2007 and both countries' science education practices. Specifically, this study compares elementary school earth science education practices in Turkey and in the USA from TIMSS 2007 standpoint.

This study focuses on 8th grade earth science education. Typically elementary education extended from kindergarten to 8th grade in the US public schools. American science education standards are categorized under grades K-4, 5-8, and 9-12 (National Research Council [NRC], 1996). In other words, 8th grade is the last year of elementary school in the US public school system. Mandatory education lasts 8 years in Turkey, after which students are placed into a system that includes schools other than the traditional high school, such as vocational schools, art schools, and science and social science schools. Due to their specialized curricula, some of these high schools place little or no emphasis on earth science topics. Similarly, in the US, high school students are not required to take earth science classes. Therefore, this study is limited to earth science curricula in grade 8th in both countries. Another reason to focus on 8th grade is that TIMSS assesses 4th and 8th grade science and mathematics. Thus, it would be a good overlap between both nation's science education practices and their performance in TIMSS. Since Turkey did not participate at 4th grade level to TIMSS, the current study focused only 8th grade earth science education.

TIMSS

Trends in Mathematics and Science Study (TIMSS) is conducted in every 4-year cycle since 1995 and the last one was completed in 2007 for the 4th and 8th graders. It has been considered one of the most comprehensive and large-scale assessments in which 59 countries participated around the world. The idea of the TIMSS is summarized as "TIMSS measures trends in mathematics and science achievement at the fourth and eighth grades, as well as monitoring curricular implementation and identifying the most promising instructional practices from around the world." (Martin et al. 2008, p.14). Participating countries not only compare their education system with other participating countries but also tries to modify their curriculums based on this comparison (Reddy, 2005; Britton & Scheider, 2007). In addition, participating countries place more emphasis on math and science education, and math and science become more valuable subjects as a result of this study (Ersoy, 2006; Britton & Scheider, 2007). Turkey participated in TIMSS two times in its history, the first one was in 1999 and the second one was in 2007 with 8th grade level. Whereas, the US participated in all of the TIMSS study both 4th and 8th grade level.

Why we should teach earth science?

Every citizen who needs to make choices and express thoughts about everyday events has to be scientifically literate (NRC, 1996), especially regarding environmental issues and technology. Scientific literacy not only means knowing scientific subject material; it also requires an ability to think critically and apply scientific skills to everyday life (NRC, 1996). A solid understanding of earth science helps develop awareness of many of the issues confronting society, such as climate change, natural hazards, space science, and natural resources. Knowledge of earth science, therefore, becomes critical to understanding the world in which we live in order to make informed decisions. Earth science is a major part of scientific literacy in contemporary societies.

Most children and adults have some experience with earth science topics, such as the reasons behind day and night, moon phases, seasons, tides, and the nature of terrain in general. Children usually bring their own ideas about easily observed events to the science classroom, and many people hold onto these initial ideas well into adulthood (Driver, 1989). Students usually continue to

hold alternative conceptions even when they are presented with scientific explanations (Osborn & Freyburg, 1985). Students' conceptual understandings of earth science have been studied broadly in domestic context, especially regarding the shape of the Earth and Earth's gravity (Baxter, 1989; Mali & Howe, 1979; Nussbaum, 1979; Sneider & Pulos, 1983), the reasons for day and night (Atwood & Atwood, 1995; Vosniadou & Brewer, 1994), the science of seasons (Atwood & Atwood, 1996), and logical explanations of moon phases (Trundle, Atwood, & Christopher, 2002), rock cycles (Ford, 2005), and geological time scales (Dodice & Orion, 2003; Trend, 1998). These studies gave insight to science educators about prevalent alternative conceptions and proposed meaningful instructional interventions to promote scientific literacy. However, these studies usually were all conducted domestically. Therefore, cross-national studies comparing curriculum applications are needed to build a bridge between the large-scale international assessments and the domestic contexts.

Methodology of Research

This study compares Turkish and US earth science instruction at the elementary school level from different perspectives. Comparisons were made between USA and Turkish students because the US educational system is well known by Turkish educators – a large number of Turkish scholars have pursued Ph.D.s at American universities. In the last 2 decades, about 750 Turkish students were sent abroad to take Ph.D.s in education as a part of Turkey's education reform movement (Kavak, Aydın, & Altun, 2007, p.45). Most of them went to the USA and the number doing so increases every year. The author is one of the many students who completed such a Ph.D. program in the USA. In addition, the scientific researches in the field of Science Education and five-year experience in teaching Science in Turkish elementary schools give me a good chance to compare the systems of science Education in both countries.

In this study, I explore and compare earth science education in Turkey and in the USA in the context of school system, instruction time, teacher qualifications, textbooks, use of educational technologies, students' attitudes toward science, curriculum, constructivism emphases, pedagogical content knowledge, and content. I contextualize these differences with data from the TIMSS 2007.

TIMSS Results for Earth Science Education

The TIMSS study showed that countries vary in achievement levels in science and mathematics. According to TIMSS 2007 data, US 8th graders performed better than their Turkish counterparts in science subjects generally. Turkey's science achievement score was 454 and the US science achievement score was 520 (Martin et al. 2008). In comparison to the international science achievement score, which were 500, Turkey's overall performance was not promising in international scales. The cumulative TIMSS science score includes earth science as a sub scale along with biology, physics, and chemistry. Therefore, it is appropriate to compare earth science sub-scores from the US and Turkish students (Table 1). It was reported that Turkish students performed not well in the earth science sub-category with a national mean of 466 and an international mean of 500. The US students' performance was still better than that of Turkish students and international average with a national mean of 525 and an international mean of 500.

Table 1. Average achievement scores in the science content (adapted from Martin et al. 2008, p. 117).

Country	Biology	Chemistry	Physics	Earth Science
Turkey	462	435	445	466
The USA	530	510	503	525
TIMSS scale average	500	500	500	500

School Systems

In the USA children go to kindergarten at the age of five followed by the 8-year elementary school in the form of K-4 plus 5-8 grades (Mullis et al., 2008). Grades K-4 is usually taught by classroom teachers and grades 5-8 are taught by subject teachers. High school comprises the 9th to the 12th grades. Science education standards start at kindergarten and science subjects are taught by classroom teachers until the 4th grade. Thereafter, a specialized science teacher will teach earth science topics.

Children in Turkey optionally started preschool Education at the age of five. Elementary school starts at the age of six and takes eight years to complete. The elementary school curriculum is organized in a 5+3 year structure. During the first five years, classroom teachers teach reading, writing, math, art, and behavior classes. These years are called primary school in Turkey. During the final three years of elementary school, classes are taught by specialized teachers in science, math, literature, history, art and so on. After completing elementary school, students move up either to traditional high schools or to vocational high schools. The choice is based on the students' examination results that are administered nationally each year for grades 6-8. Science education standards start at 4th grade and continue until 8th grade in Turkey. In Turkey, science education standards are practiced between grades four and eight. During these grades, science courses are usually taught by primary teachers in grades four and five and by science teachers in grades 6-8.

Turkey has undergone a major educational reform movement during the past decade. In 1997, the mandatory education period for children was extended from 5 to 8 years. Along with that reform, the whole education system was revised, including science education. The changes impacted science education standards, teacher education programs, and in-service professional development. A large number of scholars were sent to western countries to take masters and Ph.D. degrees in education to serve in Turkish college of educations after completing their graduate studies.

Instruction time

Science instruction time comprises the eight percent of weekly instruction time in Turkey. Conversely, 13 % of the instruction time is devoted to science in the USA (Martin et al., 2008). Another big difference between Turkey's and USA's instructional times lies on the yearly hours of implemented instruction time for science. Turkish 8th graders spend 72 hours yearly for science while their peers in the USA spend 139 hours (Martin et al, 2008). Almost as twice as Turkish instruction time is spent by US 8th grade students for science.

The number of science topics intended to be taught up to and including 8th grade does not show much difference between Turkey and the USA. Total 14 earth science topics identified by TIMSS are all taught to Turkish schools while 13 of the 14 are taught by the US schools. Turkey has instructed only one more topics than the US at the 8th grade. However, it was reported that there was a huge yearly instructional time difference between both country- 72 hours for Turkey and 139 hours for the USA. The difference between the numbers of topics taught between both countries does not reflect the difference between the total yearly instruction times between both countries. Therefore, it can be concluded that unit time spend on an earth science topic may not equal for Turkey and the USA.

In addition to the limited instruction time in Turkish science classes, class sizes constitute another problem for efficient and effective teaching of planned science materials. Based on TIMSS 2007 results classes are very crowded in Turkish public schools in comparison to those in the US public schools. Only % 18 of Turkish students is studying in a science class with the size of 24 or less students. However, % 43 of the US students is in a science class with the size of 24 or less students (Table 2).

Table 2. Class size for science instruction (%) (adapted from Martin et al. 2008, p. 290-291).

Countries	1-24 students	25-40 students	41 or more students
Turkey	18	62	20
The USA	43	46	11
International average	31	58	11

Teacher Qualifications

Teacher education programs are established by the Turkish higher education council and accordingly there is only one type of science teacher education program that is endorsed by the majority of Colleges of Education in Turkey. By contrast, different licensure and teacher education programs exist at both graduate and undergraduate levels (Mulis et al., 2008) in US universities.

The teacher preparedness is percentage score describing teacher proficiency for a course. The teacher preparedness score for Turkey and the USA were given by TIMSS. Comparison of the earth science scores for two countries showed that the US teachers' preparedness score in teaching all five TIMSS earth science topics (Table 3) is at or above % 75 which is higher than Turkish science teachers' percentage scores and international average percentage score. Turkish science teachers' preparedness scores are higher than international average only in three topics. However, two topics of which Turkish science teachers' scores are lesser than the international average are "Earth's Structure and Physical Features" and "Earth's Processes, Cycles, and History". These two topics are directly related to geological science which indicates that Turkish science teachers were not prepared well for geological science related topics.

Table 3. Percentage of Students Whose Teachers Report Feeling Very Well Prepared to Teach the TIMSS Earth Science topics (5 topics) (adapted from Martin et al. 2008, p. 282) (%).

Countries	Earth's Structure and Physical Features	Earth's Processes, Cycles, and History	Environmental Concerns	Use and Conservation of Earth's Natural Resources	Earth in the Solar System and the Universe
Turkey	38	48	76	73	64
United states	83	80	75	78	75
International average	57	55	70	68	59

Teachers' subject-matter knowledge plays an important role in the implementation of standards (Grossman & Stodolosky, 1995). There is no earth science major or licensure program in Turkish teacher training programs. Therefore, in Turkey the educators who are expected to teach earth science topics rarely have any formal training in this field. The educational reform movement placed some emphasis on earth science education but no significant progress has been done in teacher training programs. There is only one mandatory earth science class in the science teacher training programs (YÖKb) and there is no such a class in primary teacher training programs (YÖKa). On the contrary, US teacher education programs offer earth science majors and licensure programs. Moreover, teachers who are expected to teach earth science need to be certified to teach such classes.

Team teaching is an instructional method demanding each topic is taught by different instruc-

tors. Two or more teachers can team teach, allowing each educator to teach the topics in which they have the most experience. Team teaching is a common practice in US schools, provided that there is sufficient number of teachers available. By contrast, the Turkish school system does not allow team teaching. Accordingly, some teachers tend to teach the content they are most familiar with. This familiarity may be steamed from not their teaching experience but related to their experiences in college. Therefore, in the US schools, it is more likely that earth science may be taught by teachers who are trained and experienced with earth science than in Turkish schools.

Teachers in the US have their own science classrooms equipped with science materials and computers. Students can come to these classrooms for both theoretical and practical work. The classroom organization gives the teacher the opportunity to prepare the classroom in advance, and keep the students working for the subsequent weeks. In Turkey, on the other hand, science teachers do not have their own classrooms. Students usually have to sit in the same classroom for the whole day, while teachers for different course visit the classroom. Usually there is a laboratory that may be shared by multiple teachers and students at prearranged times. The US classroom structure provides American students more time—and better quality time—in labs in comparison to Turkish students.

Schools with a science laboratory show a similar pattern in both countries. Referred to Table4, % 84 of Turkish students has a chance of using a science laboratory while %80 percent of the US students have a science laboratory available. However, there is a huge gap in achievement levels of students, who has science laboratories, between two countries. Both countries have the same number of labs but the US students performed better than Turkish students at earth science which indicate that labs may not be used effectively in Turkey. One of the biggest reasons not to use science laboratories is that the university entrance exam or other similar exams in Turkey do not ask for any knowledge or experience related to the lab activities. Both teachers and students are under a social obligation to score higher in these standardized tests which emphasize the theoretical knowledge instead of lab skills.

Table 4. Schools with Science Laboratory (adapted from Martin et al. 2008, p.373).

Countries	Have Science Laboratory in the School		Do Not Have Science Laboratory in the School	
	Percent of Students	Average Achievement	Percent of Students	Average Achievement
Turkey	84	460	16	425
The US	80	522	20	513
International average	76	470	24	446

Textbooks

Textbooks are very important components of science instruction for both teachers and students. Textbooks are used by most teachers as a curriculum guide, and this is especially true for new teachers (Lynch, 1997). That trend also applies to Turkish science teachers. Turkey uses a national curriculum for all subjects and grades. The national curriculum required that, textbooks in Turkish schools are standardized by the ministry of education and published by the government publishing office or its contractors. Although Turkish students use standardized sets of textbooks, the majority of students will attend university entrance exam preparation centers to prepare for the university entrance exam or for specialized high school exams. Students who enroll in these courses experience various types of explanations or examples from a book that are not published under the government's standardized program. The textbooks used in preparation centers focused on exams and question techniques and include the lists of multiple choice questions with little or no explanatory text.

On the other hand, the US does not have a national curriculum. Curriculum decisions are made at the state and local levels. Therefore, the US schools do not use standardized textbooks and curriculum materials. Some states provide a list of textbooks from which districts or schools may choose. Due to marketing concerns, textbooks in the US cover more content than a class may actually cover in a given year (Mullis et al., 2008). It is the teachers' responsibility to decide which textbook units to teach or omit.

The national curriculum in Turkey does not give teachers the flexibility to focus on local phenomena related to earth science education. Conversely, the US curriculum, which is not a national curriculum, allows teachers to adjust the material to local needs. As Martin et al. (2008) summarize, "centralized decision making can add coherence and uniformity in curriculum coverage, but may constrain a school or teacher's flexibility in tailoring instruction to the needs of students" (p.160). Therefore, Turkish teachers and students are disadvantaged because they do not have access to a diverse set of textbooks.

The percentage of the teachers who use a textbook as primary basis for instruction in Turkey is almost equal to the international score and higher than those of the US (Table 5). That could be an indication of low level of access to instructional materials additional to textbooks or lack of content knowledge. However, Table 6 shows a low level of textbook read by students. That indicates that teachers use textbook as a primary basis for a lesson in Turkey, but they do not require students to read it.

Table 5. Percentage of Students Taught by Teachers Reporting Textbook Use (adapted from Martin et al. 2008, p.319) (%).

Countries	Use Textbook to Teach Science		Do Not Use Textbook to Teach Science
	As Primary Basis for Lessons	As Supplementary Resource	
Turkey	52	45	3
United states	38	58	5
International average	53	40	7

Table 6. Percentage of students whose teachers reported students reading their science textbooks and other resource materials (adapted from Martin et al. 2008, p.313) (%).

Countries	Every or almost every lesson	About half the lesson	Some lessons or never
TR	35	23	42
USA	16	23	61
International average	23	22	55

Use of Educational Technologies

The most representative format for the earth science topics are in three dimensional. Therefore, understanding earth science topics requires certain geospatial abilities. For instance, understanding tides requires a thorough understanding of gravity and of the moon-sun-Earth system in three dimensional space (Hartel, 2000). Understanding geological time also requires spatial skills (Kali, Y.& Orion, N., 1996). Educational technology might be promising to provide three dimensional representations of earth science topics so that explanations are not limited to print media (Hartel, 2000).

Turkish science teachers reported that 41 % of the Turkish students have computer available in the class for science instruction, whereas, 74 % of the US students have computers available in the class for science instruction (Martin et al., 2008). The TIMSS 2008 (Martin et al., 2008) study shows that there is a huge gap in the availability of computer technology at the students' houses between Turkey and the US (Table 7). Technology is widely used in the US science classes because it is more readily available. Turkish schools are not equipped with appropriate technology for earth science teaching and moreover, some teachers are not ready to use the technology what it is already available in the classroom. Teachers need to be technologically literate before they can use such systems as instructional tools. Moreover, crowded classrooms and a heavy curriculum load prevent teachers from using computer-aided or computer-assisted approaches to assist the earth science instruction.

Table 7. Computer and internet connection in the home (adapted from Martin et al. 2008, p. 157) (%).

Countries	Have computer	Do not have computer	Have internet connection	Do not have internet connection
Turkey	43	57	20	80
The USA	94	6	87	13
International average	70	30	50	50

In earth science topics, numbers associated with geology events are very large, such as the age of a rock layer that might be over a million years old, or the distance of a star in terms of multiple light years. It is critical to use a calculator in order to understand the content without getting lost in the algebra. Calculators are not allowed in Turkish schools at the elementary level because of the belief that students need to first learn how to perform calculations by hand (Uçar, 2005). By contrast, calculators are widely used in American schools. More advanced calculator systems, such as clickers and TI-Navigator systems have begun to enter US science classes (Abrahamson, 2006). In addition, smart boards, overhead projectors, and LCD projectors are more readily available to US teachers than to Turkish science teachers. In the US, some textbooks are provided with a supplemental CD-ROM available. Textbooks often devote entire sections to technology applications.

Students' attitude toward science

Student attitudes toward science are assessed by TIMSS 2007. Comparison of both countries attitude scores and average achievement levels (Table 8) reveal that % 77 of Turkish students have positive attitude toward science with an average achievement score of 461. On the other hand, % 54 percent of the US students have high level of positive attitude toward science with an average achievement score of 533. That is interesting because it is expected that higher positive attitude results in higher achievement (Simpson & Oliver, 1990; Osborne & Collins, 2000), however, in this case students with higher positive attitude do not performed well.

Table 8. Students with higher positive attitudes toward science (adapted from Martin et al. 2008, p.174).

Countries	Percent of students	Average achievement
Turkey	77	461
The USA	54	533
International average	65	476

Curriculum

In Turkey, earth science is taught between the grades 4-8. The general format is based on a spiraling curriculum that introduces the topic in one year and then builds on it in subsequent years by adding new material and increasing the level of difficulty (Jiang & Eggleton, 1995). The disadvantage of the spiraling curriculum is that if students do not master the material at the first time they experienced, they cannot build on it successfully in the following years. Rather than using a spiraling curriculum, the US prefers a traditional curriculum that employs a linear approach so that students can progress toward pre-determined goals.

There are some similarities in both countries' curriculums. Science is usually taught as a single, general subject in both countries. Both Turkey and the US schools teach science as a single general subject which integrates life science, physical science, and earth science (Martin et al., 2008). A possible problem with the integrated curriculum approach is that if the teachers are specialized in a field such as physics or chemistry, they have hard to time to teach life science or earth science, or teachers intend to organize and teach the courses around the subject in which they feel experienced and comfortable.

There is a huge difference in the percentages of time devoted to earth science education between the two nations (Table, 11). In the US curriculum, the time allocated for the earth science (32 %) four times more than the time allocated in the Turkish (7 %) curriculum. On the other hand, Turkish curriculum allocates too much time on biology in comparison to the US curriculum.

Table 11. Percentage of time in science class devoted to TIMSS content domains during the school years (adapted from Martin et al. 2008, p.211).

Countries	Biology	Chemistry	Physics	Earth science	Other
Turkey	42	25	22	7	5
The USA	15	23	26	32	4
International average	28	24	27	16	6

Based on the results presented in Table 12, "Process in the rock cycle and the formation of rocks, Weather data/maps and changes in weather patterns, and Geological process occurring over millions of years" were the topics which are reported as the least taught topics, %45, %38, and %50 respectively, in Turkey. Common characteristic of these three topics is that they all belong to geology, specifically. The lack of geology classes in Turkish teacher training programs possibly resulted in this way.

Table 12. Percent of students taught the intended TIMSS earth science topics (adapted from Martin et al. 2008, p.252-256).

Intended TIMSS earth science topics	Turkey	The USA	International average
Earth's structure and physical characteristics	63	91	64
Water on Earth	63	84	61
Earth's atmosphere	74	84	62
Earth's water cycle	84	87	69
Process in the rock cycle and the formation of rocks	45	87	61
Weather data/maps, and changes in weather patterns	38	87	48
Geological process occurring over millions of years	50	88	57

Intended TIMSS earth science topics	Turkey	The USA	International average
Formation of fossils and fossil fuels	61	80	60
Environmental concerns	83	78	63
Earth's resources	77	78	57
Relationships of land management to human use	54	63	39
Supply and demand of fresh water resources	60	66	47
Explanation of phenomena on earth in relation to the solar system	89	83	61
Physical features of earth compared with other planets	81	84	55

Emphasis on Constructivism

The constructivist approach was introduced to Turkish teachers following the major reform movement in 1997. Previously, educational system reforms were based primarily on a teacher-centered behaviorist approach. Because of traditional practices, most of the teacher found the reform very challenging. New teachers would still follow the practices that they had observed from their own teachers, instead of applying the constructivist approaches, they learned in teacher training programs (Lambert, 1990).

Although the teachers in both countries are encouraged for the use of hands-on science, they tend to avoid time consuming activities and try to organize their classes to prepare their students for the university entrance exams in Turkey and for the SATs in the US. Theoretical knowledge, rather than practical applications or experiments, seems more valuable because it is directly assessed in these standardized tests (Su & Su, 1994). Therefore, the instruction moves from a student-centered paradigm to a teacher-centered approach and from a hands-on or inquiry-based instruction focus toward a test-oriented and lecture-based instruction.

Only the % 33 of the Turkish science teachers are 29 years old or younger (Martin, p.262). That represents the number of teacher who was trained in the new constructivist teacher training program which was launched after 1997. Therefore, most of the teachers were trained in previous teacher training programs which make them unaware the constructivist approach.

Pedagogical Content Knowledge (PCK)

To teach earth science topics effectively, teachers need to understand the related subject matter conceptually and integrate it with the discipline of pedagogy. The result of the integration between the content and pedagogy is the basis of pedagogical content knowledge (PCK). Shulman wrote that PCK includes "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (1987, p. 8). This implies that teaching a specific content requires a unique set of skills specific to that content.

Pedagogical content knowledge for teaching earth science needs to be addressed in teacher training programs - teaching this subject requires slightly different pedagogical content knowledge than teaching physics, chemistry, or biology. There are limited lab activities for earth science because the lab is our earth and our universe. All the experiments have been conducted in the past 4.6 million years. Students are expected to go out and observe their results. As Frodeman (1996) posited, "visual intelligence" (p. 417) is needed to understand earth science. Earth science requires field trips and visits to informal science environments. Since outdoor science activities require expertise in observing information, collecting data, organizing data and making inferences about the process, teachers need to be experts in pedagogy. Frodeman (1995) also said that "Geological reasoning has developed its own distinctive set of logical procedures" (p.960).

PCK is not emphasized sufficiently in Turkish science teacher education programs because of faculty preferences in such programs. Many faculty members in elementary science education departments have backgrounds in hard science in the fields of physics, chemistry, or biology. These educators tend to have conducted research in their own area of expertise, which is not science education. That trend has been changing dramatically since the major educational reforms of the late 1990s. An increasing number of science educators who obtained Ph.D. degrees in education in Turkey or abroad have begun to work in elementary science education departments. This trend is different in the US teacher training, where the faculty usually came from an education background or specialized in science education after their appointment began.

Conclusion

International assessments, such as TIMSS, contribute to the development of scientific literacy throughout the world as countries adjust their curricula and standards according to the assessments' findings. Eventually, the integration of such international studies and domestic evaluations will help to improve curricula generally and the quality of earth science education in particular. The current study investigated several factors influencing earth science achievements. Among these factors, it seems that enhancing understanding and application of pedagogical content knowledge and the integration of constructivist approach could be the most promising ones to raise the students' achievement in earth science.

More emphasis needs to be placed on pedagogical content knowledge for earth science education in teacher training and in professional development organizations. Teachers need to see the examples of PCK from the faculty who teaches earth science. As has been pointed out by Shulman (1987), the major components of PCK, including content knowledge, pedagogical knowledge, students' alternative conceptions and curricular planning, all need to be presented to prospective teachers and to trainee teachers. More earth science courses, either compulsory or elective, need to be offered in teacher training, and these courses should be taught by professors who are aware of the PCK and alternative conceptions paradigms. In addition, professional development activities focusing on earth science should be available for in-service teachers.

While constructivism has been a major approach in science teaching since 1980's, it was only explicitly addressed in Turkish science education standards with the 1997 reform movement. More emphasis on constructivism is needed in teacher education programs for pre-service teachers and in professional development for in-service teachers.

Several recommendations are made throughout this study. However, followings seem to be more urgent and important to increase achievement of earth science education in Turkey.

1. Pedagogical Content Knowledge (PCK) for earth science needs to be addressed in teacher education programs.
2. Teachers should be trained to integrate technological tools with appropriate pedagogy to teach earth science. Providing technology alone does not increase the use of technology.
3. Teachers need to be provided with the opportunity for team teaching in science classes.
4. Textbooks should not be published only by a single organization which decreases the variability of methods and contents presented in these books.
5. The ratio of earth science to total instruction time needs to be increased. Less time needs to devote to biology and more time to earth science.
6. Instruction time for science generally and earth science in particularly should be increased.
7. Initiatives should start to teach earth science, physical science, and life science subject separately instead to teach science as a single subject.

8. More geology classes should be offered in science teacher training programs.
9. Classrooms should be organized where teachers are stationary and have their own classrooms whole day and students are mobile and visit the science classroom when they are scheduled.
10. Student's attitudes are high but it was not reflected on achievement. Research studies need to be conducted to investigate this discrepancy.

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