

Middle School Students' Views of Scientific Inquiry: An International Comparative Study

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ABSTRACT: The aim of this study is to investigate middle school students' views of scientific inquiry. A total of 489 middle school students (238 from the United States, and 251 from Turkey) participated in the study. The Views of Scientific Inquiry-Elementary (VOSI-E) was used to assess participants' scientific inquiry views. The instrument covered four aspects of scientific inquiry which are "all investigations begin with a question", "there is no single scientific method", "scientists collect empirical data to answer their questions", and "data and prior knowledge are used to answer questions". A series of chi-square test of independence tests were employed to examine differences in views of scientific inquiry as an effect of the country. The results revealed that there is a significant difference in students' views of scientific inquiry between the countries. The USA sample demonstrated more contemporary views on the aspects of "all investigations begin with a question", "scientists collect empirical data to answer their questions", and "data and prior knowledge are used to answer questions" while Turkish sample demonstrated more contemporary views on the aspect of "there is no single scientific method". The differences between middle school students' views of scientific inquiry and implications are discussed.

KEY WORDS: Comparative study, middle school students, scientific inquiry, Turkey, USA

INTRODUCTION

In recent years, the issue of scientific literacy has been at the center of debate among the science education community and it is indicated to be the main aim of science reform in many countries. Science educators have emphasized the importance of nature of science and scientific inquiry as these subjects are fundamental and essential components of scientific literacy (e.g. Lederman; Lederman & Antink, 2013; Roberts, 2007). Scientific inquiry is a major curriculum standard in many countries (e.g. American Association for the Advancement of Science, 1990, 1993; Council of Ministers of Education of Canada, 1997; Ministry of Education

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of the People's Republic of China, 2001 as cited in Liang et al., 2009; National Research Council [NRC], 1996; Turkish Ministry of National Education [MONE], 2005). According to the NRC,

"Scientific inquiry refers to the diverse ways in which scientists study the natural world and proposes explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and views of scientific ideas, as well as views of how scientists study the natural world" (NRC, 1996, p. 23).

Based on the statement above, it is important to help students to understand "what/why scientist work as they do and how knowledge is accepted within the scientific community" (Schwartz, Lederman, & Lederman, 2008, p.2), in other words, it is important to engage students in the activities to think and act like scientists (Yeh, Jen, & Hsu, 2012). Scientific inquiry involves, but is not limited to, scientific knowledge and science process skills. Scientific inquiry encompasses science methodology and merges it with scientific knowledge, scientific reasoning and critical thinking (Lederman, 2006). In spite of the fact that there is a close connection between scientific inquiry and nature of science, scientific inquiry focuses on processes of inquiry whereas nature of science focuses on the product of inquiry (Schwartz et al. 2008).

Turkey's educational institutions put scientific literacy at the center of the science education. Indeed, the institutional vision for the curriculum in Turkey is: "all students, regardless of individual and cultural differences, should develop scientific and technological literacy" (MONE, 2005, p. 5). Consequently, the importance of the scientific inquiry and the nature of science are promoted in the ongoing design of the curriculum.

According to results found by the Organization for Economic Cooperation and Development (OECD) by means of the Program for International Student Assessment (PISA), both the United States, a developed country and Turkey, a developing country, are below the OECD average score (OECD, 2013). In addition, science curricula in the US and Turkey both feature a spiral model design and are student-centered. However, the educational bureaucracy and administration is decentralized in USA while that of Turkey is highly centralized. Teachers of middle schools use multiple textbooks, explain science ideas to whole class, prefer whole group discussion, and have students work in small groups, and employ hands-on and laboratory activities on a weekly basis in U.S. (Banilower et al., 2013). On the other hand, teachers use a textbook which is selected by MoNE, prefer lecturing and whole class discussion in Turkey (Turkmen, & Pedersen, 2005). Even Turkish teachers who are eager to include hands-on activities and small group works to their instruction have

limited opportunities to implement this due to lack of equipment and science materials in their classrooms (Yilmaz, & Turkmen, 2007).

There is considerable research on the nature of science in both Turkey (e.g. Cavas, Ozdem, Cavas, Cakiroglu, & Ertepinar, 2013; Dogan & Abd-El-Khalick, 2008; Dogan, Arslan, & Cakiroglu, 2006; Irez, 2006; Kilic, Sungur, Cakiroglu, & Tekkaya, 2005; Koksal, 2010; Kucuk, 2008) and the US (e.g. Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000a; Akerson, Morrison & McDuffie, 2006; Khishfe, 2008; Lederman, 1992; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Marra & Palmer, 2005). Considering the belief that doing inquiry develops views of scientific inquiry, studies focused on the doing of inquiry rather than that on views of scientific inquiry (Lederman et al., 2013). Indeed, studies on students' views of scientific inquiry are scarce. For instance, a limited number of studies concentrated on how to improve learners' views of scientific inquiry. These studies revealed that explicit instruction (Gess-Newsome, 2002; Lederman et.al, 2003; Schwartz, 2007), working with scientists (Bahbah et al., 2013), and engaging in authentic scientific research (Aydeniz, Baksa & Skinner, 2011) are effective in developing learners' views of scientific inquiry. Therefore, due to the lack of related studies, identifying and examining students' views of scientific inquiry is warranted. Considering the similarities and the differences of educational systems in the US and Turkey, examining middle school students' views of scientific inquiry in these two distinct contexts was the aim of the present study. The questions guiding this study are as follows:

1. Is there a difference between middle school students' views of scientific inquiry in the United States and Turkey?
2. Is there a difference in students' views of scientific inquiry with regard to different aspects of scientific inquiry?

METHODOLOGY

Participants

Two convenience samples were involved in the study. A total of 489 middle school students from the region of the Midwest in the United States, and the region of the southwest in Turkey participated in the study. The American sample consisted of 238 middle school students (103 female, 135 male). The Turkish sample included 251 (120 female, 131 male) middle school students. Table 1 displays the distribution of the participants' grades. The participants in both samples attended public schools in urban areas. The US participants were from low-middle socioeconomic status homes, while those from Turkey were from middle socioeconomic status families.

Table 1 Distribution of participants' grade

	N (The USA)	N (Turkey)
6 th grade	66	87
7 th grade	77	72
8 th grade	95	92
Total	238	251

Instrument

The Views of Scientific Inquiry-Elementary (VOSI-E, Lederman & Ko, 2003) is used to assess participants' views of scientific inquiry. Four aspects emerged in the instrument which are explained as follows (Lederman & Ko, 2003):

1. All investigations begin with a question: Scientific studies and researchers integrate interviews and questionnaires with a series of questions, answering questions in those questionnaires and probing questions from interviews, and most significantly making comparison between the collected data and what is already known from the scientific field. Therefore, the scientific studies are initiated through questions, although they do not essentially confirm or disconfirm a hypothesis.
2. There is no single scientific method: There is no defined set or series of procedures that characterize all scientific studies. With the inclusion of a classic investigational design, descriptive and correlation studies are also considered to be valid techniques for developing scientific knowledge and skills. Scientific researchers employ various research techniques in different studies depending on the research questions they aim to answer.
3. Scientists collect empirical data to answer their questions: The use of experimental evidence as the foundation for explaining their findings distinguishes science from other fields such as social studies. Scientific researchers always focus on collecting accurate and evidence-based data from observations of facts and events. This helps them to draw precise and evidence-based conclusions that are consistent with the facts collected.
4. Data and prior knowledge are used to answer questions: Scientific investigators extract their explanations from evidence and facts and interrelate this the scientific knowledge and information they already have about the universe.

In order to assess Turkish participants' views of scientific inquiry, a Turkish version of the instrument was developed. The VOSI-E was translated and adapted into Turkish by Cetinkaya, Sariaydin, Kutukcu and Akcay (2010). They conducted a study with 253 (106 6th grade, 50 7th grade,

and 97 8th grade) middle school students validating the Turkish version of VOSI-E.

Because the correspondence of items to aspects are not one-to-one, the responses from participants were evaluated holistically throughout the questionnaire, based on a rubric. Each response was categorized as 3 point = informed (contemporary views on the scientific inquiry), 2 point = transitional (partially contemporary views on the scientific inquiry), 1 point = naïve (completely inconsistent with contemporary views or misconceptions on the scientific inquiry), 0 point = no response or unclear. In the rubric, the contemporary views, referring to “the questions guide the approach and the approaches vary widely within and across scientific disciplines and fields” (Lederman, Antink, & Bartos, 2014, p.290), were those accepted by scientists, science philosophers, and science educators. Scores of the aspects and total scores were computed for each student. Along with the author, a researcher, whose research interest was in the fields of the nature of science and scientific inquiry, scored the questionnaires. The inter-rater reliability was found to be 88% of the total number of questions scored. If disagreements arose, the two researchers discussed their scores until they reached a consensus on their joint categorization.

RESULTS

Descriptive Statistics

Descriptive statistics for the students' scores on the VOSI-E aspects were as displayed in Table 2. As shown in the table, the middle school students in the US sample, generally had transitional views of scientific inquiry (56.3%). More specifically, most of the students had transitional views for: “all investigations begin with a question” (66.0%), and naïve views “there is no single scientific method” (43.8%) while they held informed views for: “scientists collect empirical data to answer their questions” (50.4%), and “data and prior knowledge was used to answer questions” (49.6%).

On the other hand, in the Turkish sample, most students held naïve views of scientific inquiry (75.3%) as well as: “all investigations begin with a question” (88.0%), and “scientists collect empirical data to answer their questions” (64.1%). They had transitional views for: “there is no single scientific method” (49.8%), and “data and prior knowledge was used to answer questions” (33.9%).

Table 2 Descriptive statistics

Aspects	USA (N=238) (%)				Turkey (N=251) (%)			
	0	1	2	3	0	1	2	3
All investigations begin with a question	6.3	13.8	66.0	13.9	0.4	88.0	1.6	10.0
There is no single scientific method	0.4	43.8	39.0	16.8	18.3	4.0	49.8	27.9
Scientists collect empirical data to answer their questions	14.3	16.8	18.5	50.4	0	64.1	0.4	35.5
Data and prior knowledge are used to answer questions	8.4	6.3	35.7	49.6	25.8	33.1	33.9	7.2
Total	8.8	9.7	56.3	25.2	2.4	75.3	2.0	20.3

Table 3 demonstrated examples of participants' responses to the questions in terms of their categories for the related aspects.

Inferential Statistics

A series of chi-square test of independence were conducted to answer the research questions. The results revealed that Turkish and American students differed significantly on their views of scientific inquiry, $\chi^2 (3, N = 489) = 263.57$, $p \leq .001$, Cramer's $\Phi = .73$ representing a large effect. The results also revealed that there was a statistically significant difference in students' views of scientific inquiry with respect to all aspects, by country.

- (1) Investigations begin with a question: According to the results, there is a significantly difference in responses between American and Turkish students' views measured as $\chi^2 (3, N = 489) = 357.58$, $p \leq .001$, Cramer's $\Phi = .86$ representing a large effect. Most American middle school students had transitional views while most Turkish students' had naïve views on guiding investigations with scientific questions.
- There is no single scientific method: A significant difference was found in proportions accepting multiple methods of scientific investigations between American and Turkish students' views, $\chi^2 (3, N = 489) = 70.06$, $p \leq .001$, Cramer's $\Phi = .38$ representing a medium effect. Most American middle school students had naïve views while most Turkish students had transitional views on this aspect.

Table 3 Examples of the responses

<i>Naïve</i>	<i>Transitional</i>	<i>Informed</i>
All investigations begin with a question		
They use their brains to do their research.	They set up a hypothesis and test it.	First of all they find a question. They try to find different ways to solve it. Then, they choose the best of these solutions.
There is no single scientific method		
It is scientific because scientist did an experiment.	It is scientific because scientist made observation and inference. It is not an experiment.	It is scientific because scientist made observations and related beaks to food. It is not an experiment because scientist didn't do testing.
Data and prior knowledge are used to answer questions		
They ask their scientists friends.	They use historical and biological information.	Scientists come to conclusions based on the fossils.
Scientists collect empirical data to answer their questions		
They come up with the same reasons because they influence each other.	Since they know different 'stuff', they do not come up with the same reasons at the beginning. But at the end they all agree among themselves.	They do not come up with the same reasons. They all have different knowledge, ideas and theories. They do their job in different ways and get different results.

- (2) Scientists collect empirical data to answer their questions: The results revealed a significant difference in responses between American and Turkish students' views, $\chi^2 (3, N = 489) = 168.18, p \leq .001$, Cramer's $\Phi = .59$ representing a large effect. Most American middle school students had informed views while most Turkish students had naïve views on this aspect.

Data and prior knowledge are used to answer questions: A significant difference was found in responses aspect between American and Turkish

students' views, $\chi^2 (3, N = 489) = 146.13$, $p \leq .001$, Cramer's $\Phi = .55$ representing a large effect. Most American middle school students had informed views while most Turkish students had naïve views on this aspect.

DISCUSSION

In this comparative study, American and Turkish middle school students' views of scientific inquiry were examined. The Views of Scientific Inquiry-Elementary (VOSI-E) was used as the research instrument. The comparisons were conducted between the total proportions, as well as aspect proportions, to explore variations. A difference was identified between the countries. American students' views were notably more contemporary than Turkish students. This result was expected since the curriculum focused on scientific inquiry for a longer period of time in the US than in Turkey. Although the curriculum was well-prepared and had been filling the gap in the Turkish science education system, there have been some obscurities in application processes (Dindar & Yangin, 2007; Sert, 2008). Even teachers seemed to have difficulties in understanding views of scientific inquiry. Because teachers could not possibly teach a subject they did not understand (Carlsen, 1987; Steinberg, Haymore, & Marks, 1985), it was critical to educate them for teaching scientific inquiry.

Fortunately, the current science teacher education program in Turkey includes a specific course on nature of science and scientific inquiry. Eventually, it is hypothesized that Turkish students hold more contemporary views about scientific inquiry. Nevertheless, seminars and professional development programs may be organized on these subjects for pre-service and in-service teachers to raise views of scientific inquiry both for themselves and their students. Additionally, since participating in inquiry activities do not necessarily develop views of inquiry (Trumbull, Bonney, & Grudens-Schuck, 2005), explicit reflection through reading, mentoring and other means is also suggested (Abd-El-Khalick & Lederman, 2000b).

Analyses of the aspects reveal further differences. American students' views are more contemporary than Turkish students' views on the aspect "all investigations begin with a question." This result indicates that according to Turkish students, investigations do not start with a question; instead they begin by testing a hypothesis. The hierarchical development of hypotheses, theories, and laws is actually a common misconception in Turkey. For instance, studies reveal that teachers believe this hierarchical relationship (e.g. Ayvaci & Er, 2010; Leblebicioglu, Metin & Yardimci, 2012).

Regarding the aspect "there is no single scientific method," Turkish students' views are more contemporary than their American counterparts. Although the Turkish education system stresses and promotes use of the

laboratory in science courses (Ayvaci & Kucuk, 2005; MONE, 1997), many Turkish science teachers prefer demonstration rather than letting students do their own hands-on experiments due to lack of equipment and time (Demir, Boyuk, & Koc, 2011; Gecer & Ozel, 2012; Yildiz, Akpinar, Aydogdu, & Ergin, 2006). As such, they may be better able to develop their observation skills. However, this may lead them to think descriptive studies alongside experiments are also scientific.

On the other hand, due to the curricula in American middle schools, American participants in this study engaged with hands-on science activities and scientific experimentation most of the time. Unfortunately, hands-on activities tend to be called experiments even if they do not involve aspects such as controlling and testing variables (McComas, 1998). Taking these facts into account, American students may view experimentation as the only proper scientific method.

On the aspects “scientists collect empirical data to answer their questions” and “data and prior knowledge are used to answer questions,” American students’ views are more contemporary than Turkish students. Although the latest reform on science education promotes nature of science and scientific inquiry in Turkey, people, regardless of whether being teachers, pre-service teachers or students, tend to believe that science is objective (Ozdem, Demirdogen, Yesiloglu, & Kurt, 2010; Dogan & Ozcan, 2010; Ozgelen & Yilmaz-Tuzun, 2011). For instance in one study, teachers state that science does not depend on individuals and is affected by their beliefs or opinions (Ozdem et al., 2010). Thus, it can be said that scientists’ prior knowledge, experiences, and methodologies towards the interpretation of the same data are ignored. Consequently, in the current study, the majority of Turkish middle school students believe that scientists come up with the same reasons for why dinosaurs died.

Limitations of the study

Unlike the American curriculum, the Turkish curriculum does not include a study about dinosaurs at all. Turkish middle school students’ knowledge about the ancient reptiles is very limited; most of the students left this question blank. This issue limits the scope of the questionnaire. Since the students are not familiar with dinosaurs, this question may not enable accurate assessment of their view of these aspects.

Another limitation is related to sample size in the current study. The samples are relatively small and do not represent average students within each country. In addition, although the participants were middle school students in both countries, due to the differences between cultures, their science backgrounds and experiences may be dissimilar.

Future studies

Overall, in order to get in-depth views and provide better explanations, a qualitative approach may be employed in future studies in this area of inquiry. Such an approach can help determine deeper students' views of scientific inquiry, and the differences among their views. Moreover, how culture, curriculum, and the use of science terminology affect students' views of scientific inquiry may be investigated to understand the differences between students' views of scientific inquiry in these two countries.

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