An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline

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Abstract

Althoug understandings of scientific inquiry (as opposed to conducting inquiry) are included in science education reform documents around the world, little is known about what students have learned about inquiry during their elementary school years. This is partially due to the lack of any assessment instrument to measure understandings about scientific inquiry. However, a valid and reliable assessment has recently been developed and published, Views About Scientific Inquiry (VASI; Lederman et al. [2014], Journal of Research in Science Teaching, 51, 65–83). The purpose of this large- scale international project was to collect the first baseline data on what beginning middle school students have learned about scientific inquiry during their elementary school years. Eighteen countries/regions spanning six continents including 2,634 students participated in the study. The participating countries/regions were: Australia, Brazil, Chile, Egypt, England, Finland, France, Germany, Israel, Mainland China, New Zealand, Nigeria, South Africa, Spain, Sweden, Taiwan, Turkey, and the United States. In many countries, science is not formally taught until middle school, which is the rationale for choosing seventh grade students for this investigation. This baseline data will simultaneously provide information on what, if anything, students learn about inquiry in elementary school, as well as their beginning knowledge as they enter secondary school. It is important to note that collecting data from all of the approximately 200 countries globally was not humanly possible, and it was also not possible to collect data from every region of each country. The results over-whelmingly show that students around the world at the beginning of grade seven have very little understandings about scientific inquiry. Some countries do show reasonable understandings in certain aspects but the overall picture of understandings of scientific inquiry is not what is hoped for after completing 6 years of elementary education in any country.

Keywords: international, literacy, scientific inquiry

1. INTRODUCTION

Scientific inquiry (SI) has been a perennial focus of science education for the past century and it generally refers to the combination of general science process skills with traditional science content, creativity, and critical thinking to develop scientific knowledge (Lederman, 2010). Perhaps the most influential advocacy for the importance of understandings about scientific inquiry can be found in the conceptual paper by Showalter (1974) in which he outlines the critical components of scientific literacy (Welch, 1979). Few would argue that scientific literacy is not the primary goal of science education. Consistent with Showalter's work, recent reform documents have emphasized that students should develop the abilities necessary to do inquiry and/or science practices as well as have an under- standing about inquiry (e.g. *Benchmarks for Science Literacy*, American Association for the Advancement of Science, 1993; *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, National Research Council [NRC], 2011). The National Science Education Standards (NRC, 2000) were explicit in their differentiation between the abilities to do inquiry and knowledge about SI. This distinction also continues to be evident in the Next Generation Science Standards (NGSS, 2013). Although, the NGSS refers to science practices as opposed to the inquiry. The NGSS considers "practices" as extending well beyond simply being involved in science processes. In either case, "inquiry" or "practices" refers to the engagement of students in behaviors similar to those of scientists. Similar distinctions are becoming more prominent in reform documents throughout the world. Quite simply, it seems logical that students will improve their ability to do inquiry/practices if they have an understanding about what they are doing and this knowledge, combined with knowledge of science, will enable students to make more informed decisions about scientifically based personal and societal decisions. The position here is not that the doing of science is unimportant. It is important for students to be engaged in inquiry practices. Indeed, these experiences provide the best instructional platform for students to reflect back upon how scientific knowledge is developed. However, despite the continued emphasis on understandings of SI worldwide, there has never been a systematic assessment of how well this educational outcome is being accomplished.

Research indicates that neither teachers nor students typically hold informed views of SI (Lederman & Lederman, 2004; Schwartz et al., 2002). However, the research base is small primarily due to the lack of availability of valid and reliable assessments of SI. Now with the development of the *Views of Scientific Inquiry,* [VASI] (Lederman et al., 2014) the research base for SI can begin to grow. There are those that have concerns with instruments that purport to assess students' understandings about constructs such as inquiry and NOS (Hammer & Elby, 2009; Hammer, Elby, Scherr, & Redish, 2005). Their arguments primarily revolve around the idea that context impacts students' abilities to express what they understand about NOS and this has been extended to the inquiry. The results of this investigation show otherwise as the VASI clearly provides students with a variety of contexts within which to express what they understand about the inquiry. Additionally, prior research also would call into question the claims made by Hammer and colleagues (Bartels & Lederman, 2017; among others).

While knowing about SI is intuitively linked with the doing of SI, what is notable is the lack of a robust research base centered on students' understandings about the inquiry. What is evident is the preponderance of research focused on the doing of inquiry, which oftentimes is assumed to imply an understanding of inquiry. The belief that doing inquiry is a sufficient condition for developing understandings about SI, unfortunately, is a misconception. (Wong & Hodson, 2009, 2010).

The intent of this collaborative project was to report on students' understandings of SI across the globe with a valid and reliable assessment tool; we can begin to see what students of the same grade levels know about SI in various countries/regions. The purpose is not to focus on comparisons across countries (especially since instruction, curricula, and cultures vary widely across nations), but rather to develop a baseline of understandings worldwide. Readers are urged to resist the temptation to com- pare the findings from their country/regions with the findings from the other countries/regions. Although one to one comparisons between countries/regions around the world are not appropriate, it is clear that there are similarities across countries/regions that can help explain the rather consistent findings. These explanatory factors are elaborated on in the conclusions.

1.1 Why should students understand scientific inquiry and what should they know?

Students should be able to understand how scientists do their work and how scientific knowledge is developed, critiqued, and eventually accepted by the scientific community. SI is this process. The NSES content standards for Science as Inquiry for grades K-12 advocated the merit of students developing (a) the abilities necessary to do inquiry and (b) understandings about scientific inquiry (NRC, 2000).

In the US, a relatively new set of science standards define what students should be learning. Although students should be engaged in conducting scientific inquiry the "doing" of scientific inquiry is emphasized in the new standards (NGSS, 2013), within the category of "Practices." The NGSS expects teachers to have students; asking questions, planning and carrying out investigations, and constructing explanations. Thus in the United States, teachers are encouraged to engage their students in conducting scientific investigations in their classrooms. However, the explicit teaching of understandings about SI/Practices is missing from the NGSS. Although conducting an inquiry, or the

process skills of science, is important, students can often do inquiry without knowing how and why scientists go about their work. The efficacy of such implicit approaches to developing understandings of SI, and for that matter NOS, have been called into question by a growing body of research (Abd- El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, Bartels, Liu, & Jimenez, 2013; Lederman & Lederman, 2004; Schwartz et al., 2002; Schwartz, Lederman, & Crawford, 2004). Therefore, it is important to identify and explicitly teach the aspects of SI that can serve, in the end, to develop informed views of SI. And, of course, the major endpoint desired is the development of a scientifically literate citizenry. It is important to note that "explicit' does not mean lecture or teacher-centered instruction, as misunderstood by some researchers (Duschl & Grandy, 2013). Explicit/reflective instruction engages students in reflections upon what they have done in an investigation and the implications this has for how scientists do their work and the knowledge that is produced. Such understandings are critical for the development of a scientifically literate public, con- sidering that our citizenry is confronted with scientifically based issues upon which decisions must be made, yet few citizens engage in scientific investigations after they have graduated high school or college.

The initial formal teaching of SI begins in primary school. The age at which a child enters primary school is different depending on the country or region. The NGSS Lead States (2013) begins with kindergarten and, therefore, the formal teaching of SI in the US is supposed to begin in kindergarten. The formal start of science instruction also differs around the world. Studies have been con- ducted on young children's understandings of SI. These studies have found that young children have the ability to understand certain aspects of SI that are developmentally appropriate (e.g., science begins with a question, no single scientific method, and conclusions are consistent with data collected and prior knowledge) (Lederman, 2012). Students in grades Kindergarten through fifth grade have the ability to understand some aspects of SI (Sodian, Zaitchik, & Carey, 1991; Tytler & Peterson, 2003). Two studies have looked at elementary students who spoke English and other languages at home found that after instruction in their native language students had an understanding of SI for their age level regardless of language spoken (Cuevas, Lee, Hart, & Deaktor, 2005; Lederman et al., 2013). It is in fifth grade and beyond that, the introduction and teaching of the additional aspects of SI are developmentally appropriate.

1.1.1 Aspects of SI

The aspects of SI that follow are empirically shown to be appropriate in the context of K-12 class- rooms (Bartels & Lederman, 2017; Lederman, 2012; Lederman et al., 2013), but can also be appropriately applied to college level students. For a more in-depth elaboration of each of these aspects, see Lederman et al. (2014). Specifically students should develop an informed understanding of the following aspects.

1.2 Scientific investigations all begin with a question, but do not necessarily test a hypothesis

"Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world" (National Research Council [NRC], 2000, p. 20). In order for scientific investigations to occur there has to be a question asked about the natural world. Traditional experimental designs typically include a formally stated hypothesis, but this is not necessary or typical of other designs (e.g. descriptive and correlational).

1.3 There is no single set or sequence of steps followed in all investigations

Clearly, there are other ways that scientists perform investigations such as observing natural phenomena. Most often, descriptive and correlational research methodologies are employed to gather data in this field. Students need to develop not only an understanding of the variety of research methodologies employed both across and within the domains of science but that, in general, "scientist[s] use different kinds of investigations depending on the questions they are trying to answer" (NRC, 2000, p. 20).

1.4 Inquiry procedures are guided by the question asked

While scientists may design different procedures to answer the same question, these invariably need to be capable of answering the question proposed. Similar to the aforementioned aspect of SI, stu- dents need to understand the necessity of this alignment between the research question and method, in that the former drives and ultimately determines the latter. In general, students should understand that the question determines the approach, with the approaches differing both within and between scientific disciplines and fields (Lederman, Antink, & Bartos, 2012).

1.5 All scientists performing the same procedures may not get the same results

Students need to understand that "scientific data does not stand by itself, but can be variously interpreted" (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003, p. 708). As such, scientists who ask similar questions and follow similar procedures may reach different conclusions, owing in part to their theoretical commitments, what scientists consider as evidence and how they handle anomalous data also influence the results of a scientific investigation. Because of this, scientists who examine the same data may justifiably come to different conclusions.

1.6 Inquiry procedures can influence results

The procedure selected for a scientific investigation invariably influences its outcome. The operationalization of variables, the methods of data collection, and how variables will be measured and analyzed all influence the conclusions reached by the researcher.

1.7 Scientific data are not the same as scientific evidence

Data and evidence serve different purposes in a scientific investigation. Data are observations gat ered by the scientist during the course of the investigation, and they can take various forms (e.g. numbers, descriptions, photographs, audio, physical samples, etc.) Evidence, in contrast, is a product of data analysis procedures and subsequent interpretation and is directly tied to a specific question and a related claim.

1.8 Research conclusions must be consistent with the data collected

Each research conclusion must be supported by evidence. Students need to understand that the strength of a scientist's claim is a function of the preponderance of the evidence that supports it. The validity of the claims is further strengthened by the alignment of the research method with the research question. It follows as well then, that claims must be reflected in the data collected which are analyzed to provide the evidence for said claims. Scientific knowledge is empirically based, thus any explanations for the phenomena explored in investigations are anchored by the data that facili- tates scientists' development of those explanations.

1.9 Explanations are developed from a combination of collected data and what is already known

Investigations are guided by current knowledge. Conclusions, while derived from empirical data, are additionally informed by previous investigations and accepted scientific knowledge. Scientists need to recognize when conclusions differ from accepted scientific knowledge and determine how findings must be interpreted given what is already understood.

2 STATEMENT OF THE PROBLEM

Although the teaching of SI is valued around the world, there has never been a worldwide assessment of what students actually know about SI. This study sought to examine grade seven students' under- standings, at the beginning of the school year, of SI in various countries/regions worldwide. This baseline study gives us data on what, if anything, students learn about inquiry in elementary school, as well as their beginning SI knowledge as they enter secondary school. It provides the global science education community a starting point from which instructional, curricula and policy decisions can be made at the national, regional, or local levels.

3 METHOD

3.1 Sample

The sample was taken from every continent around the world, with the exception of Antarctica. The research sites (from 18 countries/regions) were; Australia (n = 108), Brazil (n = 169), Chile (n = 142), Egypt (n = 109), England (n = 103), Finland (n = 149), France (n = 109), Germany (n = 96), Israel (n = 92), Mainland China (n = 378), New Zealand (n = 87), Nigeria (n = 102), South Africa (n = 106), Spain (n = 159), Sweden (n = 126), Taiwan (n = 167), Turkey (n = 268); and the United States (n = 164). The total sample size of grade seven students was 2,634 students. One could conceptualize the sample as actually consisting of 18 samples (i.e. one per each country/ region) rather than using an overall total. Although the researchers in each country/region were urged to sample representative students (based on average academic ability, representative diversity of the region and socioeconomic background), it is clear from the size of the sample in each location as well as the resulting characteristics of the student samples, that the sample be considered separate samples of convenience rather than representative of an entire country/region. Consequently, no statistical tests or comparisons were pursued because such comparisons would be inappropriate.

The students were selected for this study by the contact people from each region/country and they determined which schools represented their regions based on the aforementioned criteria. The contact researchers selected a sample of convenience. There is no claim that the sample selected for each country/region can definitively represent that country/region. Such would not be humanly possible. However, the sample does give the first insight into the status of students' understandings of scientific inquiry worldwide.

There was a total of 18 primary contact people participating in this study, one contact person for each country/region, who almost always worked with a team of colleagues. Each site had one city with the exception of South Africa, Turkey, and the U.S., which had two sites each and Mainland China, which had three sites. In short, the contact people across the six continents were responsible for language translation/back translation to maintain VASI validity when a language other than

English was used, data collection (including paper and pencil assessments and individual interviews), completion of training in the coding/scoring of the VASI, data analysis, and the writing of location- specific aspects of the results.

3.2 Sources of data

The primary data collection instrument was the VASI. This instrument has established validity and reliability and was previously published in the *Journal of Research on Science Teaching* (Lederman et al., 2014). Briefly, the eight aspects of SI previously described were derived from THE; NGSS (NGSS, 2013), Benchmarks for Science Literacy (American Association for the Advancement of Sci- ence, 1993), National Science Education Standards (NRC, 2000); among others. All the aspects and associated VASI questions were evaluated for alignment by teachers and university science educators. In every case, an agreement of 80% or higher was achieved. Twenty percent of the students in the validation study were interviewed to assure face validity. An in-depth description of the validation of the VASI can be found in the previously cited article. Reliability of the VASI was not only previously established but also re-established in this study with the researchers of each of the coun- tries/regions. In both cases, inter-rater agreements exceeded 80%. Data on reliability FOR this study can be found in the data tables. The entire VASI questionnaire can be found in Figure 1.

VASI

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds that eat insects have long, slim beaks. He wondered if the shape of a bird's beak was related to the type of food the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

    a. Do you consider this person's investigation to be scientific? Please explain why or why not.

    b. Do you consider this person's investigation to be an experiment? Please explain why or why not.

    c. Do you think that scientific investigations can follow more than one method?

    If no, please explain why there is only one way to conduct a scientific investigation.
    If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why?

3. (a) If several scientists ask the ***same question*** and follow the ***same procedures*** to collect data, will they necessarily come to the *same conclusions*? Explain why or why not.

 (b) If several scientists ask the ***same question*** and follow ***different procedures*** to collect data, will they necessarily come to the same conclusions? Explain why or why not.

4. Please explain if "data" and "evidence" are different from one another.

5. Two teams of scientists were walking to their lab one day and they saw a car pulled over with a flat tire. They all wondered, "Are certain brands of tires more likely to get a flat?"

    Team A went back to the lab and tested various tires' performance on one type of road surface.

    Team B went back to the lab and tested one tire brand on three types of road surfaces.

    Explain why one team's procedure is better than the other one.

6. The data table below shows the relationship between plant growth in a week and

Minutes of light each day	Plant growth-height (cm per week)
0	25
5	20
10	15
15	5
20	10
25	0

the number of minutes of light received each day.

Given this data, explain which one of the following conclusions you agree with and why.

Please circle one:

a) Plants grow taller with **more** sunlight.

b) Plants grow taller with **less** sunlight.

c) The growth of plants is **unrelated** to sunlight.

Please explain your choice of a, b, or c below:

7. The fossilized bones of a dinosaur have been found by a group of scientists. Two different arrangements for the skeleton are developed as shown below.

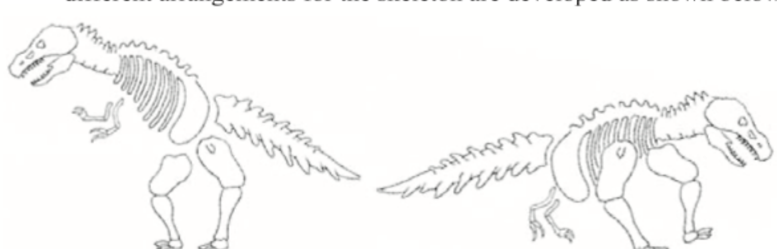

Figure 1 Figure 2

a. Describe at least two reasons why you think most of the scientists agree that the animal in *figure 1* had the best sorting and positioning of the bones?

b. Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?

3.3 The translation and back translation process

In order to have a valid VASI questionnaire in a language different from the original English version, the researchers in each country/region translated the English version into the local language. One researcher in each country was responsible for doing the translations. The translated version of the VASI was then translated back into English by another member of the local team who had proficiency in reading and writing English. The back-translated version was evaluated and compared with the original VASI questionnaire by one of the authors of the instrument in order to check if the new version maintained the same meanings as the original version. In some cases, it was necessary to con- tact the local teams to clarify some words used in the new local version of the VASI to double check if those words maintained the same meaning or were able to capture the answers in the same way as the original questionnaire. Similar changes in wording were made when members of the non-US teams felt that there was a cultural influence on how students would interpret how words were translated. For example, when working on the back translation between the Swedish version of the VASI and the English version, a discussion took place about the word “evidence.” In Swedish, this word translates into “proof” which has a different meaning in the US Even in countries where English was the official language, researchers had to use some alternative words according to the local context in order to have a valid VASI questionnaire. For instance, the VASI version for US, England, and Australia had to adjust words and phrases to reflect local vernacular to better match the meaning of the original questions. For example, in the US, we often use the phrase “flat tire.” However, in England, it would be called “punctured tire.” Similarly, the Spanish versions for Spain and Chile are different from each other. Only after the process of translation and back translation, was each team able to administer the questionnaires in each country/region. It should be clear that the process of translation and back translation is a critical issue in research and it is highly complex. The process used in this research project directly followed the well-established standards in the field (Grisay, 2003; Guillemin, Bombardier, & Beaton, 1993; Hambleton, 2002; Hambleton & Patsula, 1998; Maneersriwongul & Dixon, 2004; Organization for Economic and Cooperation and Development (OECD), 2017).

3.4 Training Sessions for Scoring the VASI

The selection and training of the contact people for this study were directed by the US researchers. This project formally began with an initial meeting at the European Science Education Research Association (ESERA) meeting. The initial timeline of the study was determined when the personne at each research site was able to specify their local constraints. Individual meetings were arranged and conducted via Skype between each site and the primary US site. Depending on the research team, there were two to three meetings. The first meeting involved learning to administer and score the VASI. After the administration of the VASI in each country/region, each site was required to send four or five completed (but unscored) VASI questionnaires from their sample. The responses were translated into English by each local team. Then, each questionnaire was independently scored by a group of four to five researchers from the US team. Once the questionnaires were scored, a second meeting with the international local team was scheduled to explain how the questionnaires were scored and how the questions targeted the aspects of SI. During this meeting, each local team discussed the quality of the answers, scoring, reliability, and inter-rater agreement. Any issues of cultural impacts on the meaning of students' responses were discussed and reconciled. This manifested itself in some situations where the US scoring team deferred to the interpretation of the international team because of the importance of a potential cultural influence on the meaning of student's responses. In a third meeting, each team scored a new set of questionnaires for themselves and then compared their scores with the US team. This meeting allowed the local teams to “calibrate” the scoring process in order to get 80% or greater inter-rater agreement. If additional meetings were needed, they were scheduled on a case by case basis. Once teams could reliably score the VASI with the US team, they then proceeded to establish reliability with their local team before scoring the entire set of questionnaires. They scored their entire sample and met with their local team to ensure 80% or greater inter-rater agreement for each aspect of the VASI. The interrater agreement established for each research site can be found in Table 1.

TABLE 1 VASI Scoring Examples

Knowledge of Inquiry	More Naïve Views	Mixed Views	More Informed Views
Scientific investigations all begin with a question but do not necessarily test a hypothesis	"I agree with no, because they don't always need to have a question."	"You need a question, but sometimes you just observe"	"Yes, because in order to know what to investigate you have to have a question asking you or telling you what to find."
There is no single set and sequence of steps followed in all scientific investigations (i.e. there is no single scientific method)	"because you have to have the scientific method: purpose, hypothesis, procedure."	"Yes, because he invested a lot of time, made observations, searched additional information and finally, made a conclusion."	"Yes the scientist could 1. Dissect frogs- observe internal organs or 2. Grow plants and change a part of photosynthesis"
Inquiry procedures are guided by the question asked	"Team B's procedure is better because they show the tires reactions to different types of roads."	"Team A uses the right procedure, because you do not know exactly which brand of tires gets broken on the road"	"Team A's procedure is better because it matches the question. My evidence is that both the question and Team A's procedure involves different types of tires. "
All scientists performing the same procedures may not get the same results	"Yes they would because they're doing the same thing step by step"	"probably yes. Sometimes, different conclusions may result from small differences in the data collected"	"If several scientists are working independently, ask the same questions and follow the same procedure to collect data they won't necessarily draw the same conclusion because things can be different indicators to different people based on their experiences, they may also collect different data and data leads to different conclusions."
Inquiry procedures can influence the results	"Yes because if you have the same question it must lead to the same answer no matter what the procedures are."	"mostly no. Sometimes, two different procedures may result in the same conclusions"	If they are doing different procedures they may get them different results."
Research conclusions must be consistent with the data collected	"Plants need water, food and sunlight to grow."	"According to the form, the longer daylight, grow higher"	"Plants grow taller with less sunlight because you can see on the data table above you see the more light the less it grow."
Scientific data are not the same as scientific evidence	"They are the same because you collect both.	"Data is 'to gather information about something' and evidence is to find proof about something. They are different."	"Data is stuff you observe from an experiment, evidence is organized data making them support the conclusion."
Explanations are developed from a combination of collected data and what is already known	"Because it is bigger."	"The hind limbs' support is important for the whole body, so the hind limbs are stronger than the fore limbs"	"I think they use the main dino structure, their prior knowledge of how the dino looked, and fixing the dino like a puzzle."

3.5 Data collection

This study took place at the start of the grade seven school year which varied in timing depending on the beginning of the school year in the various continents and hemispheres. Countries in the Northern hemisphere collected data in August/September and the Southern hemisphere countries collected data in January). Each student was given a VASI questionnaire (Figure 1) to complete in a 45–60 min time period. In Figure 1, below is the full VASI instrument. The version distributed to the students contained more than adequate space for the students to provide their responses after administration of the VASI, the responses were scored by the primary contact person (and colleagues) in each country. Each student was given a score of; No Answer, Naïve (students' responses contained all inaccurate understandings), Mixed (students' responses contained some accurate and some inaccurate understandings) or Informed (students' responses are complete and accurate) for each aspect of SI. Please refer to Table 1 for examples of responses and how they were coded. Numerical scores are not used with the VASI, student's responses are categorized with respect to how accurately their responses align with the measured aspect of SI. If a respondent provided a response consistent across the entire questionnaire that is wholly congruent with the target response for a given aspect of SI they were scored as “informed”. If, in contrast, a response was either only partially provided, and thus not totally consistent with the targeted response, or if a contradiction in the response is evident, a score of “mixed” was given. A response that is contradictory to accepted views of an aspect of SI, and provides no evidence of congruence with accepted views of the specific aspect of SI under examination, was scored as “naïve”. Refer Table 1 for examples of how VASI responses are scored. At least 20% of the students were interviewed to ensure that the scoring of the VASI was accurate in representing what the students' written response meant. This insured face validity for the questionnaire. The interviews were recorded and transcribed. The inter-rater agreement reported for the VASI was 80% or better for each site.

4 OVERALL FINDINGS

In general, this study found that grade seven students' understandings of SI are poor. However, it was apparent that, for each country or region in the study, there were some students who held more moderate understandings than others. These variations differed from place to place depending on the curriculum, instruction, and the myriad of other factors that influence what students learn. Again, the reason data from each country/region were not compared with other countries/regions is that such comparisons would be inappropriate and is certainly not in line with the intended focus of this investigation. The following paragraphs highlight the findings from each country/region. Researchers from each were asked to write a brief summary of their site-specific findings. They wrote about the most interesting findings from their country/region. They also explained the possible reasons for these partticular results. See Tables 2 and 3 for a complete set of data from each country/region for each aspect of SI.

What follows is country/region specific explanations (in alphabetical order) of findings and possi- ble factors influencing SI understandings based on local standards, curriculum, and teaching practice. The lead researcher for each country/region wrote the site-specific findings section, this resulted in some uneven language. Thus, some editing was done, but substantive were not made and every attempt was made to allow each contributor to convey their own findings from their own distinct place in the world. Additionally, reiterations of the same data found in the previous tables were omit- ted in an effort to conserve space.

TABLE 2 The worldwide average of findings for each aspect of SI

Aspect	Naïve %	Mixed %	Informed %
Starts with a question	43.9	29.9	20.7
Multiple methods	54.4	33.8	6.0
Same procedures may not yield same results	54.0	25.5	14.0
Procedures influence results	40.7	33.1	15.9
Conclusions must be consistent with data collected	39.7	20.6	33.3
Procedures are guided by the question asked	44.8	20.1	27.5
Data and evidence are not the same	48.5	32.1	10.4
Conclusions are developed from data and prior knowledge	41.3	37.9	10.9

TABLE 3 Complete set of data from each country/region for each aspect of SI

		Starts with a Question (%)			Multiple Methods (%)			Same Procedures may not Yield Same Results (%)			Procedures Influence Results (%)			Conclusions must be consistent with Data C. (%)			Procedure are Guided by the Question Asked (%)			Data and Evidence are not the Same (%)			Conclusions are Developed from Data and Prior Knowledge (%)		
Country/ Region	*n*	N	M	I	N	M	I	N	M	I	N	M	I	N	M	I	N	M	I	N	M	I	N	M	I
Australia	108	25.0	40.0	30.0	16.0	66.0	4.0	39.0	48.0	9.0	9.0	71.0	5.0	24.0	21.0	52.0	23.0	20.0	51.0	15.0	74.0	3.0	16.0	58.0	8.0
Brazil	169	83.2	11.2	0.6	74.3	10.9	0.6	82.8	9.5	0.0	81.1	6.5	0.6	68.0	17.1	0.6	74.5	6.5	1.8	75.7	4.7	0.6	66.3	8.3	0.0
Chile	142	53.5	35.2	8.5	75.4	24.6	0.0	63.4	28.2	2.8	39.4	50.7	3.5	55.6	16.9	26.1	67.6	23.2	2.8	58.5	33.8	1.4	56.3	40.8	0.7
China Beijing	166	31.3	56.0	10.8	33.1	51.8	3.0	57.8	31.3	8.4	22.3	59.0	15.7	16.9	46.4	36.7	13.9	26.5	57.2	43.4	52.4	3.6	12.0	81.9	4.8
China Shanghai	106	56.3	19.4	23.3	91.8	8.3	0.0	57.8	38.8	2.4	53.4	37.9	3.9	60.7	5.8	29.6	53.4	19.4	22.3	90.3	7.8	0.0	65.5	31.6	0.0
China Zhejiang	106	33.0	4.7	59.4	29.2	70.8	0.0	50.0	11.3	33.0	36.8	22.6	32.1	29.3	23.6	41.5	30.2	7.5	60.4	30.2	64.1	0.0	0.9	45.3	50.0
Egypt	109	30.0	55.0	14.0	50.0	47.0	1.0	51.0	23.0	23.0	47.0	30.0	18.0	50.0	13.0	34.0	57.0	29.0	10.0	55.0	37.0	5.0	16.0	73.0	7.0
England	103	39.8	35.0	20.4	56.3	26.2	10.7	58.3	19.4	11.7	22.3	46.6	5.8	35.0	26.2	24.3	38.8	8.7	36.9	35.0	25.2	22.3	24.3	48.5	1.9
Finland	149	38.3	26.8	26.2	58.2	28.4	6.5	21.5	54.4	18.1	26.8	44.3	16.1	40.9	15.4	40.3	50.3	8.1	29.5	26.2	22.1	47.0	18.5	42.5	25.2
France	109	41.0	41.0	7.0	79.0	19.0	2.0	47.0	38.0	3.0	53.0	27.0	3.0	48.0	23.0	16.0	24.0	54.0	7.0	42.0	46.0	6.0	72.0	8.0	1.0
Germany	96	41.7	28.1	26.0	20.8	64.6	13.5	62.5	20.8	15.6	39.6	31.3	25.0	28.1	19.8	52.1	34.4	16.7	47.9	45.8	26.0	9.4	8.3	47.9	39.6
Israel	92	44.2	30.4	23.2	47.8	27.5	15.9	46.4	20.7	17.8	45.7	15.6	22.5	24.3	21.7	44.2	17.0	30.4	44.9	39.5	35.5	17.6	46.0	30.1	15.2
New Zealand	87	37.9	27.6	26.4	63.2	33.3	3.4	71.3	25.3	2.3	64.4	29.9	3.4	42.5	34.5	16.1	48.3	24.1	25.3	39.1	41.4	14.9	78.2	19.5	1.1
Nigeria	102	57.8	40.2	2.0	68.6	23.5	2.0	77.5	13.7	5.9	24.5	10.8	54.9	42.2	28.4	27.5	61.8	22.6	12.8	26.5	34.3	36.3	60.8	28.4	4.9
South Africa	106	21.0	31.0	48.0	32.0	42.0	23.0	57.0	13.0	26.0	24.0	33.0	39.0	33.0	17.0	48.0	53.0	15.0	30.0	51.0	20.0	18.0	14.0	67.0	17.0
Spain	159	65.4	17.6	12.6	83.6	15.7	0.0	68.6	11.3	16.4	62.9	27.7	4.4	47.8	10.7	37.7	54.1	8.8	32.1	78.0	17.0	0.6	73.6	23.3	0.0
Sweden	126	30.2	17.5	29.4	30.2	32.5	20.6	30.2	35.7	19.8	31.0	21.4	21.4	30.2	11.1	28.6	42.9	3.2	27.8	55.6	14.3	2.4	36.5	20.6	8.7
Taiwan	167	27.5	38.9	20.4	37.1	44.3	9.0	12.0	32.3	49.7	15.0	52.1	25.1	24.5	22.8	49.7	15.6	50.3	30.5	30.5	44.9	11.4	41.9	34.7	15.0
Turkey	268	70.2	18.7	8.6	67.2	29.1	3.0	63.8	23.5	7.5	59.7	23.9	6.0	54.5	17.5	26.5	72.8	10.1	9.3	60.5	29.1	6.0	48.5	32.8	13.8
United States	164	50.6	23.2	17.7	74.4	11.6	1.2	62.8	12.2	7.3	56.7	20.1	12.8	37.8	20.1	34.1	63.4	17.7	10.4	72.0	11.6	3.7	70.7	16.5	3.0

Note. N = Naive; M = Mixed; I = Informed.

4.1 Australia

Scientific inquiry (SI) is part of the Australian national curriculum. The Australian curriculum: Science F-10 (ACARA, 2015) is structured around three interrelated strands: *Science understanding, Science as a human endeavor, and Science inquiry skills.* However, there is no expectation that SI is explicitly addressed in elementary classrooms. Elementary teachers are responsible for teaching across the entire curriculum and typically do not hold tertiary qualifications, often resulting in low confidence in teaching science (McKenzie, KOS, Walker, & Hong, 2008). For this study, a total of 108 students from two Catholic single-sex schools in Queensland, Australia completed the VASI. After accepting the invitation to participate in the study, students completed the instrument and their responses were analyzed and scored by two researchers. Finally, 21 students comprising a 20% sub- sample were interviewed, representing a range of views about SI aspects. The results show that Australian seventh grade students failed to express informed views of the majority of the aspects of SI examined in this study. Most students held naïve or mixed views of six of the eight aspects, with half of the students expressing informed views in only two aspects. Overall, Australian seventh grade students enter high school with largely uninformed views of SI. Overall, students showed adequate understandings of the need for alignment between the research question and method, and claims being supported by data. Unfortunately, a lack of understanding of the role of data interpretation and previous scientific knowledge was found in the grade seven students. A majority of the students also had an inability to describe multiple methods used by scientists. These findings are concerning as evidence suggests that inadequate views of SI may hamper students' abilities to appreciate how the scientific enterprise operates, and may lead to disengagement in science in the postcompulsory years of schooling.

4.2 Brazil

Two official documents guide teaching in Brazil: The National Curricular Parameters (BRAZIL, 1998) and the National Education Plan (BRAZIL, 2014).

Unfortunately, none of the documents pro- mote and prioritize SI in science classrooms through activities. In most Brazilian elementary class- rooms, science is taught using a teacher-centered approach with few or no practical activities. In this study, 169 students from five public and private co-educational schools were selected to participate. As a way to represent the majority of Brazilian schools, students have different socioeconomic levels. After the questionnaires were answered, they were scored by two researchers. Then a sub-sample of 20% of students were interviewed. The results show that the majority of Brazilian students' responses were classified as naïve For all aspects of SI. Overall, after analyzing the responses of Brazilian stu- dents, it can be seen that they can conceptualize some SI aspects, but cannot identify them in real sit- uations. This result reflects the lack of national curricular emphasis of SI for elementary school and the absence of experience in doing inquiry in science classrooms.

4.3 Chile

The Chilean national science curriculum for elementary school (MINEDUC, 2012) establishes learn- ing objectives related to science content, scientific skills, and attitudes. Moreover, the idea of SI appears to be considered as a research skill that refers to the actions of doing science and not to the reflection on the meaning of inquiry itself. This emphasis is strengthened in all the official documents suggested for instruction. In spite of the curricular prescriptions, the science classes in most cases are teacher-centered with few opportunities to develop scientific thinking or skills. For this study, a sam- ple of 142 students from two co-educational public and one funded school from Santiago, Chile answered the instrument. The schools were chosen because public schools (44%) and funded schools (51%) comprise 95% of the school system in Chile. These schools provide education to low-income students with similar academic backgrounds. After students answered the questionnaires, they were analyzed and scored by two researchers. Then, 20% of students were interviewed considering the different students' views of SI aspects. The results show that most of the seventh grade Chilean students demonstrated a naïve or mixed knowledge of SI. The most informed views were for *conclusions consistent with data collected* where only 26.1% of the students were able to read the chart and extract information. For seven SI aspects, 50% of the Chilean students demonstrated naïve views. With respect to *Multiple* *methods* (75.4%) were categorized as “naïve.” The idea of “one scientific method” is not new in the Chilean context. Even science textbooks and teachers continue transmitting that idea to students. Overall the results suggest that students are committed to a stepwise single scientific method that they have learned in science, and they assume certain levels of intuitive coherence among the steps. Simultaneously, they rarely have opportunities to develop their own research questions and design investigations to answer those questions. As a result, they are not explicitly aware of the relationship between research results and the procedures utilized.

4.4 Egypt

In the science standards in Egypt (Centre for Curricula and Material Development, 2016) there are some standards related to “doing” SI yet it is rare that teachers engage students in inquiry in practice or stress an "understanding" SI. There are standards that emphasize constructing explanations and others that explicitly include "inquiry" in the statement of the standards. However, teachers mainly emphasize science content knowledge by lecturing. It is not common to find explicit standards where students should be asking questions and even fewer standards related to students carrying out investigations. For this study, the sample consisted of 109 students from co-educational public schools across Egypt. All students were from a similar ethnicity background, socioeconomic level, and in reading abilities. Students were asked to be involved in the study voluntarily after parents signed con- sent forms. The results show that at least half of the seventh grade students in Egypt showed "naïve" answers for five of the eight SI aspects. The aspect of SI that had the highest percentage of "informed" responses was *conclusions consistent with data collected* with 34% informed versus 50% with naïve answers. In general, it is possible to conclude that the students have some understanding of SI aspects. However, they seem confused and their ideas are a little distorted, as shown in their answers which are fragmented and inconsistent. A possible explanation of these results is that teach- ing science in the Egyptian context is based mainly on teacher-centered approaches where there is a little opportunity is provided to students for hands-on activities, group work, or critical and creative thinking. Classes are usually overcrowded and laboratory experiences are minimal. The curriculum emphasizes content over skills and it is test driven with an emphasis on grades and passing exams. There are some efforts done by individual teachers who try to shift to more student-centered approaches, yet with limited facilities, and a constraining curriculum their efforts and impact seem to be limited.

4.5 England

Science teaching in elementary schools in England is governed by the National Curriculum (Department for Education, 2013). By the last years of elementary school, students are expected to be able to make their own decisions about setting up and conducting scientific inquiries, but there is no specific mention of understanding the nature of SI. Science itself is taught in a wide variety of ways with the majority of schools teaching some form of science weekly and around two-thirds combining this with other types of activity such as dedicated science weeks, science days and visits (Wellcome Trust, 2017). For this study, the sample comprised 103 students of mixed ability and mixed gender from two schools. One school was situated in a more affluent, central urban area and one in a less affluent, suburban area though both were cited in the same city in the South West of England. The students came from families representing a wide range in socio-economic status though, given the high number of independent schools in the city. After answering the questionnaires, three researchers participated in the process of scoring. Finally, 20% of students were selected for interviews according to their score in the VASI questionnaire. The results show that most of the seventh grade students from England demonstrated mixed and naive understandings of SI aspects as measured by the VASI. The percentage representing informed answers showed that only in three aspects, the informed views were over 20% of the sample. In general, the results show how students' views about SI are heavily influenced by the structured approach to practical science found in many UK schools. Students will often be asked to repeat an experiment at least three times making sure they redo the method as accu- rately as possible to enhance the reliability of their results. They take pride in achieving consistency and ‘a fair test’. This results in them being familiar with the idea that the methods used by a scientist will affect its outcomes but not with the understanding that different scientists may view these out- comes differently.

4.6 Finland

The Finnish primary science curriculum (FNBE, 2014) emphasizes some competencies related to "doing" inquiry, such as evaluating and designing scientific inquiry or interpreting data and evidence scientifically. However, there are no specific aims for "understanding" inquiry. In the classroom, the curriculum guide emphasizes that teachers should use an inquiry orientation in teaching and learning of science, but there are no research outcomes focusing on teaching and learning of science in elementary school. On the other hand, many elementary teachers who say they use an inquiry orientation follow a rather guided inquiry methodology. In other words, the teaching is consequently rather implicit. Therefore, although conducting an inquiry, or using the process skills of science often does not result in students knowing how and why scientists go about their work. For this study, data were collected (n = 149) from one big middle school and it well represents Finnish seventh grade students in terms of gender, socioeconomic level, and reading abilities. The questionnaires were analyzed by two researchers and 20% of the students were interviewed according to a diversity of outcomes in the VASI. The results show that Finnish students hold mainly naïve and mixed conceptions with regard to the aspects of SI assessed by the VASI questionnaire. The aspects where a majority of the students did well were; *Data does not equal evidence* (47%) and *conclusions consistent with data collected* (40.3%). In this latter aspect, students showed similar numbers for naïve answers (40.9%). These aspects are addressed in both mathematics and science classes in Finland. Additionally, they are heavily emphasized on the PISA exam. In general, it was found that the items that are reflected on the PISA exam are heavily emphasized in school and therefore students did well on them in the VASI. It should also be noted that students do not often engage in designing SI and also did not do well in understanding how scientists go about constructing a question or a procedure.

4.7 France

The French national curriculum for elementary school (BOEN, 2015) guides the acquisition of knowledge, skills, and culture that each French student must reach at the end of compulsory education. In spite of *Understanding* of inquiry not explicitly included among the competencies, students have to be familiar with “the practice of scientific and technological approaches”, “the appropriation of tools and methods”, “the practice of languages”, and “the use of numerical tools”. Moreover, science is taught mostly by using an inquiry approach where students have to be able to do inquiry. For example, students have to propose, with the help of the teacher, an approach to solve a problem or answer a question, formulate or test a hypothesis or interpreting results and drawing conclusions. For this study, 109 students were selected from a public school in Bordeaux, France. Two researchers analyzed the survey and, finally, 20% of the students were chosen to participate in the interviews according to their scores on the VASI questionnaire. The results show that French students appeared to have a rather low understanding of SI as measured by the VASI. The majority fall in the naïve and mixed categories. The consistency of conclusions with data collected is one key feature of the “La Main à la Pâte” approach (Charpak, 1998), which is recommended concerning the teaching of science in schools since 2002. Most primary school teachers come from a nonscientific background. It can thus be conjectured that many of them are not at ease with explanations developed from data and using a diversity of methods. But, the poor score of pupils on the latter refers more to their inability to justify their answers than to their belief in a single method. These results are in agreement with the result of national studies, such as CEDRE-2013 (DEPP, 2014) according to which only 9,9% of the pupils have mastered the principles of scientific investigation by the end of primary school.

4.8 Germany

For German early elementary school, national science education standards are not available, but only curricula for each federal state. However, after fourth grade, science education is supposed to contrib- ute to scientific literacy as defined by the National Science Education Standards (Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland [KMK], 2005a, 2005b, 2005c). Scientific inquiry (SI) is included in national science education standards as one of four areas of competency (Neumann, Kauertz, & Fischer, 2010). However, most of the standards address inquiry skills rather than understandings about SI (Wellnitz et al., 2012). Elementary science is taught within the more general subject “Sachunterricht” that includes scientific, social-scientific, geographical, historical and technical perspectives. Elementary science education focuses on the doing of inquiry rather than on the understanding of SI (Gesellschaft für Didaktik des Sachunterrichts, 2013). For this study, data from 97 students were gathered from three schools offering an academic track (disciplinary science courses) and from one mixed track school (integrated science courses) in the German federal state of Schleswig-Holstein. The schools were selected to cover the range of achievement levels in the school system of the federal state. After students answered the surveys, they were analyzed and scored by three researchers. Then, 20% of the students were interviewed, these interviews were conducted in only two schools based on the rating of the students' understanding of scientific inquiry. The results show that seventh grade students hold naïve views in four aspects of SI, mixed views for two aspects, and two informed views. The most informed views corresponded to *conclusions consistent with data collected* (52.1%) and *procedures are guided by the question asked* (47.9%), It seems that students show a high sensitivity for logical and conclusive arguing and reasoning. The most naïve answers were expressed for *same procedures may not get the same results* (62.5%), *data does not equal evidence* (45.8%), *begins with a question* (41.7%), and *procedures influence results* (39.6%). It seems the students' views are influenced by the idea of “truth” in science. Science education in Germany seldom conveys the view that there are wrong and one correct solution to a problem. These results are understandable considering the German National Science Education Standards (Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland [KMK], 2005a, 2005b, 2005c) which emphasize the importance of scientific competences, such as doing inquiry. Students are expected to develop the ability to pose hypotheses, plan and perform investigations, control variables and analyze data. However, students have not been chal- lenged to question the use of these ideas. Moreover, these aspects are unlikely to have been taught in school and it appears that the educational system lacks students' explicit reflection of their views and beliefs. The focus in the German educational system seems to be to convey appropriate knowledge and has an emphasis on the mastering of skills and abilities related to autonomous knowledge acquisition and the correct implementation of working procedures.

4.9 Israel

Israel has a centralized science curriculum, consisting of objectives, content and pedagogical issues, and practical activities (Ministry of Education of the People's Republic of China, 2017a, 2017b), but there are no current science standards for elementary school. The inquiry is one of the objectives of the science curriculum for elementary school as well as in secondary school, however, the focus is mostly on "doing" inquiry (Ministry of Education, Pedagogical Secretariat, 2018). Students are exposed to scientific concepts and phenomena through inquiry and the teachers use textbooks and teacher guidebooks. On the other hand, the teachers' enactment of inquiry is not always followed as recommended in the curriculum. For this study, 92 seventh grade students were selected to participate.

The sample was students of teachers who participated in professional development workshops in Weizmann Institute. Once the surveys were collected, two researchers analyzed them. Stu- dents from the sample were selected for interviews (20%) according to the teachers´ recommendations. The results show that seventh grade Israeli students showed naïve views in six of eight aspects of SI. Students held informed views for two aspects: *Procedures guided by the question asked* (44.9%) and *conclusions consistent with data collected* (44.2%). During the interview process, students were asked if they referred to “Data collected” or “Data analysis”, however, they did not know how to differentiate between the two. The most naïve aspects according to the analysis of stu- dent answers were *multiple methods* (47.8%), *same procedures may not get the same results* (46.4%), *explanations are developed from data and what is already known* (46%)*, procedures influence results* (45.7%), and begin *with a question* (44.2%). Some students said that scientists may do various experiments in their laboratories with the materials and instruments which they have, and see what they get. They do not necessarily develop a question. *Data does not equal evidence* also showed that 39% of the students' held naïve views. Additionally, during the interviews, students tried to explain the mean- ing of data/evidence, but they were quite confused about it. It appears that students, in general, learned these concepts, but they did not really assimilate them correctly. Furthermore, the inquiry approach to teaching and learning is not done in a thorough manner. The inquiry procedures were somehow “transmitted” in a declarative way, and the inquiry concepts were somehow neglected. In that case, the teachers' preparation is the key to what happens in the classroom, and to how their stu- dents perceive the scientific process as well as science phenomena. Finally, the science curriculum for sixth to eighth grades includes mainly biology topics and emphasizes the nature of science as well as inquiry procedures and skills. We, therefore, believe that quite a few students were correct about some categories, but when interviewing students, we found out that they just repeated what they were told in class, rather than really understanding the issue.

4.10

4.11 Mainland China

4.11.1 Beijing

Learning science through inquiry is advocated in the national science curriculum standards for an elementary school in Mainland China (Ministry of Education of the People's Republic of China [MOE], 2001). Based on the standards, SI is one of the three dimensions around which national science curriculum for primary education is built. In this dimension, process skills are the main focus. However, two aspects of understanding about inquiry, “the inquiry methods are guided by the question asked” and “evidence and logical deduction are important for scientific inquiry” are mentioned. Since the national science curriculum standards for elementary school were issued, more and more teachers in Beijing have tried to integrate hands-on activities and lab work into their science classroom teaching. In spite of much effort for providing students opportunities to do inquiry, teachers do not actively help students reflect about nature of scientific inquiry. In this study, samples came from two public middle schools. One is located at 5 km away from the center of the city and the other is 11 km away. Most of the students are enrolled in schools near they live. Public schools are selected because most of the elementary and middle schools are run by the government in Mainland China (Ministry of Education of the People's Republic of China, 2017a, 2017b). Two classes in each public school are involved in this study. Three researchers analyzed and scored the questionnaires and a class from the school closer to the city center was selected for the individual interviews. Thus, it is important to note that although 20% of the students were interviewed, all those who were interviewed were from the same school for logistical reasons. The results show that Chinese students from Beijing hold mostly mixed views of the SI aspects. The aspects for which students views were informed: *procedures are guided by the question* *asked,* with 57.2% of the students providing explicit correct explanations; *conclusions consistent with data collected,* with 36.7% holding informed views, and 46.4% demonstrating mixed views for this same aspect. One possible reason for these informed views is that these particular aspects of SI are mentioned to some extent in the national curriculum standards. Teachers in this region provide opportunities for students to identify variables related to a research question, control variables, and develop a conclusion based on the data collected. The most naïve views reported were for *same procedures may not get the same result* (57.8%), where most students mentioned only the "error" to justify differences among results. Additionally, more than half of the stu- dents held mixed views for the other five aspects. These results may have occurred because there is no emphasis on explicit understanding about these aspects of SI in the national standards (Ministry of Education of the People's Republic of China [MOE], 2001). Furthermore, the aspects for which students did not do well are not mentioned in the standards. These results also might be related with the eastern philosophies of education, such as Confucianism (Lee & Sriaman, 2013). It is a common belief that Chinese students are rote learners and choose a passive approach to learning. Lau, Ho, and Lam (2015) pointed out that students from Western countries are relatively better at understating the scientific process and nature of science, while East Asian students are relatively better in science con- tent than science process. Last but not least, the grade one through six national science curriculum standards in Mainland China were just revised in 2017. Since the students involved in this study only had learning experiences guided by the previous standards issued in 2001, the focus of the revised standards have not had enough longevity to have any impact on students' understandings of scientific inquiry.

4.11.2 Shanghai

As the rest of mainland China, Shanghai science education follows the national science curriculum standards for elementary school (Ministry of Education of the People's Republic of China [MOE], 2001). In this context, SI is present in the standards mostly related to research skills. In other words, the focus is on "doing" inquiry. For this study, 106 students from one co-educational private school completed the VASI. The school serves students from middle socioeconomic levels. Once the questionnaires were answered by the students, they were analyzed and scored by two researchers. Finally, 20% of students were selected according to the diversity in their answers to be interviewed. The results showed that students from Shanghai showed low levels of understanding of SI in all the aspects considered in the VASI questionnaire. At best, no more than 30% of the students showed informed views for some aspects. Many possible factors can explain the results. First, in Shanghai, SI is not sufficiently used in science classrooms. Seventh grade students learn science through lectures instead of inquiry activities because teachers feel that inquiry activities require more time and longer time for the teachers to prepare. Second, it was not until 2001 that the reform of basic education started in China and SI began to be promoted. Third, science teachers have different understandings of SI and this contributes to students' misunderstanding of scientific inquiry. Finally, high stakes paper and pencil examinations are still very important with respect to assessing students' science achievement. These examinations do not stress higher level thinking, and as long as students continue to receive high scores there is little effort Thus, as long as students get good scores, there is little instructional effort to require students to understand scientific inquiry.

Zhejiang

The Science curriculum Standard for Full-Time Schools of Compulsory Education [2011] empha- sizes the importance of SI. “Doing” and “understanding” inquiry are both stressed and described as objectives for the content of the science curriculum, as well as a teaching method. This revised curriculum also stresses the idea of an integrated curriculum, however, Zhejiang province has been implementing it for nearly 20 years with mixed results. Because primary school science has received more and more attention, some schools have begun to recruit science teachers majoring in science. Previously it was common for primary science teachers to major in other subjects, such as Chinese, Mathematics, or Music. For this study, the sample ($n = 106$) was selected from two urban and one rural school of different socioeconomic levels in three cities in Zhejiang province. Students answered the questionnaires and four researchers participated during the scoring process. Later, 20% of the students were interviewed to ensure the accuracy of the scoring of the VASI. The students were chosen randomly based on the various levels of understanding of SI. In general, students from Zhejiang showed informed views in four aspects of SI. They also held mixed views for two SI aspects and naïve views for another two SI aspects. In particular, the most informed views were for *Procedures are guided by the question asked* (60.4%), *begin with a question* (59.4%), *explanations are developed from data and what is already known* (50%), and *conclusions consistent with data collected* (41.5%). One of the possible reasons for these results is that SI is described as both objectives and content of the science curriculum in the standards. These four aspects are also stressed in the integrated science text- book. Aspects that showed the most naïve responses were: *Same procedures may not get the same results* (50%) where half of the students provided inadequate answers and reasons. The same results are seen with respect to *Procedures influence results* (36.8%), however, in this case, the percentage of naïve answers is similar to the informed answers (32.1%). Additionally, *multiple methods* (70.8%), and *data does not equal to evidence* (64.1) revealed mostly mixed views. The possible reason was that these two aspects are not explicitly mentioned by science curriculum standards or the integrated science textbook.

4.12 New Zealand

New Zealand has a national curriculum that includes science as one of the eight learning areas (Ministry of Education, 2007). These areas are very broadly defined, and it is up to each school to develop a set of learning experiences considered appropriate for their students and community. The curriculum, therefore, is very nonprescriptive. Elementary teachers are generally responsible for teaching all eight learning areas and the majority of these teachers do not have science-specific training beyond their own school experiences and a single science education course included in their pre- service teacher education. The science learning area has at its heart students' development of attributes that reflect those of a scientifically literate citizen and at the primary level, the expectation is that students understand some aspects of SI such as, the importance of asking questions for scientists. However, despite the curriculum guidelines, there is a generally widespread lack of priority placed on science, and a number of national initiatives have recently been implemented to support school science. Of particular relevance to this study was the publication of five “science capabilities for citizenship” (Ministry of Education, 2015) with a range of supporting resources provided to support teachers to develop programs that will contribute to students' “functional knowledge of science”. For this study, 87 students from two co-educational state secondary schools located in small towns in the mid-North Island region of New Zealand were selected. School selection was not only convenient but also purposeful. The schools represented “typical” schools from a mid-socio-economic area with 21% representation from indigenous people and mixed academic abilities. After answering the questionnaire, follow-up interviews were conducted with 18 of the students (21%) to check that the survey data scoring had been accurate. These students were selected to ensure a widespread across the range of responses. The results show that New Zealand seventh grade students tend to hold naïve views in almost every aspect of SI. Students provided more informed answers in relation to *begin with a question* (26.4%) and *procedures are guided by the question* (25.3%). However, the same SI aspects showed 37.9% and 48.3% of naïve answers respectively. This result suggests that while students may have some understanding of the purposeful nature of scientific investigations, this understanding is not always modeled in science classrooms. On the contrary, two aspects showed over 70% naïve views. *Explanations are developed from data and what is already known* (78.2%) and *same procedures may not get the same results* (71.3%), where most students suggested that different conclusions would result from the same procedures because of experimental error and/or experimental variation. Overall, although the New Zealand Curriculum in science sets expectations related to understanding key aspects of SI, science often has low status in the curriculum of many primary schools. The causes are multiple but contributing factors include the lack of systemic support for teaching science by way of inservice professional development; as a result, primary teachers possess a low sense of self- efficacy in science teaching. The introduction of national standards in numeracy and literacy, with a consequent shift in focus on these areas, has resulted in less emphasis on other areas, including sci- ence. The New Zealand government has responded to concerns about students' engagement and achievement in science, as measured by national and international testing, with a number of initiatives including a nation-wide 'Plan for Science in Society'.

4.13 Nigeria

Recently in Nigeria, there has been a review of the Universal Basic Education Curriculum (Federal Ministry of Education, 1999) by the Nigerian Education Research and Development Council (Igbokwe, 2015), however, despite that there is a curriculum in place, there is not a readily accessible detailed roadmap for teachers. Additionally, "understanding" of inquiry is not included in what stu- dents are expected to know or learn in Elementary classrooms. There is, however, some effort toward the inclusion of the "doing" of inquiry, but even this is not strongly followed in every school. Elementary science teachers are provided with schemes of work and stipulated textbooks from the State Ministries of Education, which in turn draw from the Federal Ministry of Education. Students are taught as a whole class with few instances of small group activities, and very rare field trips. They read from the texts, the blackboard, and sometimes, the teacher asks students to repeat what he/she reads aloud and requires them to write down what is said in their notebooks. For the VASI study, 102 students were selected from seven geopolitical regions in Nigeria. This sample was convenient and co-educational private and public schools are represented. After completing the VASI, students' responses were analyzed and scored, and inter-rater agreement was established with a team of six experts. Afterward, 20% of the students were purposefully selected for interviews. The results show that Nigerian students from seventh grade mostly hold naïve views on six aspects of SI. They also showed an informed understanding in two aspects. For the most informed aspects, 54.9% showed informed views on *procedure influence results* and 36.3% for *data does not equal evidence.* Students showed most naïve views on *same procedures may not get the same results* (77.5%), *multiple methods* (68.6%) *procedures are guided by the question asked* (61.8%), *explanations are developed from data and what is already known* (60.8%), *begins with a question* (57.8%), and *conclusions con- sistent with data collected* (42.2%). One possible explanation for the results could be that the instruc- tional system is one that emphasizes direct and strictly guided instruction. In their learning experiences, students have some familiarity with following laid down steps and structures of organi- zation for scientific ideas. Considering the aspect *same procedures may not get the same results* (77.5%) naive, it is possible to infer coherence between this and their largely formal view of the influ- ence of procedures on results.

Students may see a paradox in how one could assert that procedures influence results, and then simultaneously hold the view that the same procedures may not get the same results. So, they may have been operationalizing the logic that the same procedures yield the same results.

4.14 South Africa

The National Natural Science Curriculum (Department of Basic Education (DBE), 2011) prompts teachers to use inquiry-based approaches to teaching science beginning in Grade 7. The curriculum implicitly promotes knowledge about the inquiry by providing a list of science process skills, including a detailed description of each skill. However, actual teaching about SI may vary among schools and teachers. Most of the primary science teachers have not majored in science subjects, and most of the schools do not have laboratories, resulting in a reality that doing inquiry is seldom achieved. It is possible that the emphasis on investigations in the curriculum and textbooks, combined with the culture of avoiding hands-on practical work in many schools may result in a theoretical emphasis on scientific investigations. For the VASI study, 106 students were selected to participate. A team of three researchers analyzed the answers. For interviews, 20% of students were selected according to differences in outcomes in the VASI. The results show that seventh grade students showed mostly naïve and informed views of SI. Students were considered informed for *begins with a question* (48%), *conclusions consistent with data collected* (48%), and *procedure influence results* (39%). Furthermore, more complex aspects involving human imagination and creativity, such as *same procedures may not get the same results* (57% naive), and *procedures are guided by the question asked* (53% naive) hold mostly naïve views. Also, *data does not equal evidence* (51%) showed mostly naïve views. The poor understanding of this aspect may be understood in terms of inadequate vocabulary due to second lan- guage usage. Overall, over the past 20 years, education in South Africa has been subject to three cur- riculum changes, seeking a balance between learning content and skills development. Throughout the curriculum changes, conducting investigations remained a focus, although the reality of poorly trained teachers often limits opportunities for learners to conduct investigations. Nevertheless, the curriculum and textbooks have placed a strong emphasis on asking questions, collecting data and making conclusions. It is therefore plausible that teachers emphasize these ideas even though learners themselves seldom have opportunities to engage practically in the inquiry. Therefore, learners may develop some unexpected understanding of some inquiry aspects emphasized by the curriculum, as argued in an earlier South African study using Grade 11 learners (Gaigher, Lederman, & Lederman, 2014). It is thus not surprising that learners in the current study are best informed on aspects focused on questions, data, and conclusions, while aspects involving the human mind in relating these ideas are poorly understood.

4.15 Spain

In Spain, the Andalusian curriculum and the Organic Law of Education (LOE, 2006) have adopted the framework agreed by the Council and the European Parliament (EU, 2006a, 2006b) in which scientific competence is emphasized as one of the eight key competencies for the scientific literacy of citizens and Science has been one of the compulsory subjects in all the corresponding curricula. There are no explicit references about the understanding of SI, although it is possible to find general objectives and content related to "knowing how to do research" or doing inquiry. The teaching of primary science takes place in the context of a subject called "Natural Sciences", however, there is a documented lack of interest in Science (Confederación de Sociedades Científicas de España [COSCE], 2011; Vázquez & Manassero, 2011) attributed to the lack of connection between the subject and daily life, adequate teaching methodologies that include experimental and research strategies, and lack of knowledge on the part of teachers of the ideas of students about Science for the planning of teaching among others (García & Orozco, 2008). For the study, 159 seventh grade students were selected from three co-educational public schools. Students were asked to participate voluntarily, and the VASI questionnaires were analyzed and scored by a team of three researchers. Finally, a subsample of 20% of students was selected for interviews based on their VASI scores. The results show that Spanish students hold a naïve understanding of all the aspect of SI. In all of them, at least half of the sample showed naïve views. Students showed the most informed answers in two aspects, *conclusions consistent with data collected* (37.7%) and *procedures are guided by the question asked* (32.1%). Additionally, the most naïve views are found in *multiple methods* (83.6%), *data does not equal evidence* (78%), *explanations are developed from data and what is already known* (73.6%) students expressed difficulties interpreting the information in charts. One of the reasons for these results is the lack of students' understanding about science and SI. Students seem able to use scientific reasoning, but they are unable to understand the phenomena that affect them in their daily lives. Another reason that may explain these results is related to teaching methods and content. These include the lack of SI as relevant to the science curriculum content, lack of adequate understanding of the aims and objectives to facilitate student inclusion in science lectures, resistance against reforms and educational innovations, lack of an explicit and reflective teaching of SI, lack of effective teach- ing approaches to teaching of SI, and performing SI reflective activities.

4.16 Sweden

Science as a subject is compulsory in the Sweden educational system from first grade (Skolverket, 2011) and understanding of inquiry is included in an unspecific way. The curriculum emphasizes three learning goals in terms of "methods and ways of working" in science. From fourth grade, the curriculum is divided into physics, chemistry, and biology and each subject includes four goals under the topic "methods and ways of working”. The curriculum includes general statements about understanding the nature of SI in the subjects, however, the emphasis in the curriculum is on doing science rather than understanding inquiry. Additionally, teaching practices vary among teachers and are not prescribed in any detail on a national level. There seems to be little or no systematic teaching recommendations regarding the nature of SI, but there is an increasing awareness of teaching about “fair tests”, essentially dealing with control of variables in an experiment. In terms of the sample, 126 lower secondary school students from five different schools located in the Stockholm area participated in the study. The schools were chosen to represent a spread of socioeconomic variables and students' general aptitude based on comparison with socioeconomic indices provided by the municipality and the averages scores on national tests in math and Swedish (science test scores were not available). After administrating the VASI, two researchers analyzed the tests, and a 20% subset of students were interviewed based on a spread of understandings. The results show that the students hold naïve understandings of the aspects of SI assessed by the VASI questionnaire. The most informed are observed in *begins with a question* (29.4%) and *conclusions consistent with data collected* (28.6%) aspects. Similar values for naïve answers are shown in the same aspects (30.2% and 30.2% respectively). The most naïve views are found in *data does not equal evidence* (55.6%), *procedures are guided by the question asked* (42.9%). In general, the term “science” and “scientific” does not seem to be used that much in science education at this level in Sweden, but the reason may be that the school subject is often called “nature orientation”, or “nature orientation subjects”. In other schools, science is broken down into biology, chemistry, and physics and this is how students and teachers would refer to them.

Therefore, unless SI is addressed as an explicit topic, which seems rare, words like "science" and "scientific" may not be used in any systematic way in these schools. Stu- dents do not seem to have had any systematic teaching regarding the nature of SI and a related concept such as experiment. In spite of this many students still seem to have a fair understanding of the basic principles of an experiment as involving some active manipulation to test how one thing affects another. Evidence and data were terms virtually all students had difficulties within the Swedish con- text and the interviews indicated that these were not used or addressed in their science class. Finally, students tend to relate research and inquiry to their own school tasks such as laboratory work and finding information on the Internet rather than SI per se.

4.17 Taiwan

Currently Taiwan's national education curriculum guidelines are under reform and SI has become the major theme of Grades 1–12 in the science curriculum (National Academy for Educational Research, 2015). In addition, guidelines for Grades 1–9 for science include the components of doing SI in the competence indicators of students' learning (Ministry of Education, 2003). Documents for curriculum development have also shown much emphasis on epistemic understandings about scientific knowledge and practices. In the past decade, some professional development programs regarding SI have been sporadically organized by knowledgeable science educators. However, in reality, school teachers oftentimes are not proactive in teaching SI because textbooks do not adequately present those topics. The threes participating researchers used a sample for this study of 167 students from seven public junior high schools located in the north, central, and southern regions of Taiwan. After collecting and screening students' written responses, 33 students were purposively selected for interviews based on the diversity of responses. The results show that the students hold mostly mixed views about the aspects of SI. Overall, at least one-third of the students showed mixed views in six aspects. The most informed aspects, c*onclusions consistent with data collected* and *same procedures may not get the same results to* show 50% of informed answers for each one. The aspect with the most naïve views corresponds to *explanations are* *developed from data and what is already known* (41.9%) followed by *multiple methods* (37.1%). The naïve views of the former may be owing to students' unfamiliarity with the dinosaur scenario that has not been included in elementary science text- books. The naïve view that a single set of steps must be followed in science apparently comes from the figures presented in the first unit of biology textbooks. In Taiwan, science textbooks are shaped by national science curriculum guidelines, which are now under reform and the teaching of SI will be emphasized much more.

4.18 Turkey

Turkey has a national curriculum for every subject area that is compulsory in all primary schools (MEB, 2013). The curriculum for science classes for primary schools for grades 3–8 was updated in 2017. This curriculum focuses on knowledge, skills, effective, and science-technology-society- environment. The "skills" area is the most relevant to the inquiry. The inquiry is included in the introductory section of the curriculum, but not many references to inquiry exist in the science objectives for each grade. The curriculum states that the science-teaching environment should be based on an inquiry approach, however, the objectives of the curriculum emphasized only the doing of inquiry. Understanding of the inquiry process is not stressed in the curriculum, textbooks and science activities. Moreover, science instruction is mostly teacher and textbook-centered. Also, most teachers' knowledge of inquiry is limited. Finally, because of the high-stakes test-based educational system in Turkey, most teachers focus on solving multiple-choice test items rather than inquiry.

For this study, a sample of 268 students from four schools in Istanbul and Ankara participated in the study. All the schools are in the low/middle socioeconomic status region and the students were simi- lar in achievement level representing most of the population in Turkey. Their questionnaires were scored by a team of five researchers. A subgroup of 20% of the sample was voluntarily interviewed. The results show that most of the students hold naïve views for each aspect of SI. The best- understood aspects were *conclusions consistent with data collected* (26.5% informed) and *explanations are developed from data and what is already known* (13.8% informed). However, these results contrast with the percentage of naïve answers for the same aspects (54.5% and 48.5% respectively) and this may be due to rote learning activities which are not uncommon in typical Turkish science classrooms. In contrast, *procedures are guided by the question asked* was the poorest understood aspect of inquiry with 72.8% showing naïve views. In general, the results indicate that the science curriculum and science education as a whole in Turkey does a poor job of preparing students for understanding SI. An explanation for the results focuses on "teaching to the test." Since there is a high stakes exam at the end of middle school, teachers tend to ignore emphasizing the SI process and give drill instruction about how to read graphics and interpret a given set of data. So, data interpretation and drawing conclusions are explicitly taught while the process of scientific inquiry is ignored.

4.19 United States

In the United States, each state has local control over their adopted standards. Some version of the K-12 Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) has been adopted by 38 of 50 states in the U.S. Understandings about SI are not clearly emphasized in the NGSS, although they were emphasized in the previous National Science Education Standards (National Research Council, 1996). The NGSS primarily focus on students' understandings of science content and how scientists do their work. The understandings of SI are not explicitly distinguished from students doing SI. There were two cities selected for this study, both are in NGSS adopted states. These cities are large urban areas (one in the Midwest and the other in the Southeast of the US). The grade seven students from the two regions were asked to complete the VASI. Approximately 20% of the participants were interviewed based on their written responses. It was determined that interviews and written responses were consistent. Data from each school were analyzed separately to identify any region-based differences. No significant differences were found; thus, the data are combined to present the final results. Overall, the results demonstrate a lack of sufficient understanding of all targeted SI aspects, with 50% or more of the participants falling within the naïve range. Participants were most challenged with *multiple methods* (74.4% naive), *Explanations are developed from data and what is already known* (70.7%) and *data does not equal evidence* (72% naive). Within the informed range, a few participants demonstrated some understanding of *conclusions consistent with data collected* (34.1% informed). Those who responded appropriately to this aspect were clear to connect the claim with available evidence. However, others either did not provide any evidence, basing their claim on their preconceived assumptions; or connected their claim only to those data that supported their claim, ignoring data that do not align. Regarding *the influence of procedures on results*, many participants expressed that the only way the same procedures would lead to different results was through an error. Overall, the US students were naïve in their understanding of SI. This is probably due to the lack of explicit instruction given to SI in the elementary level classroom. In short, it is assumed that students will learn about scientific inquiry simply by doing inquiry.

5 CONCLUSIONS

Overwhelmingly, the results from this study show that students around the world have an overall inadequate understanding of scientific inquiry, although there were instances in which students in a country did better than “naïve” on a particular aspect of SI. This is consistent with the few studies (i.e. because a valid and reliable instrument, was not available) that have been done with secondary students, preservice and inservice teachers (Lederman & Lederman, 2004; Schwartz, Lederman, & Lederman, 2008). Nevertheless, these findings are significant because this is the first global and systematic assessment of the highly valued educational outcome of understandings of scientific inquiry. Given the 18 independent samples from each of the countries/regions, it would be inappropriate to make blanket inferences about why these results were found. Obviously, there are numerous reasons for these results due to the obvious differences in teaching, curriculum, standards, and cultures of the various countries/regions involved in this study. However, there are some common themes gleaned from the context-specific information received from each of the research sites and reported in the previous sections for each of the reporting countries/regions. These themes are (1) lack of standards specifying understandings about SI, (2) teaching that does not make understandings about SI explicit, (3) science teaching that emphasizes only the doing of science, and (4) teaching that does not emphasize an inquiry approach. Given the reported context of science teaching in the countries/regions involved in this investigation, the findings are not surprising. In some cases, students rarely, if ever, have the opportunity to actually conduct scientific investigations. It is clear that no matter where students live worldwide that understandings of inquiry are not cultivated. Again, it is important to note that no statistical comparisons were made among the countries for the purpose here was just to get a baseline of beginning middle school students' understandings. Statistical comparisons across countries would be inappropriate because of the previously noted differences that exist with respect to curriculum, teaching approach, and cultures across the 18 countries/regions included in this investigation. As mentioned previously, the sample is really a composite of 18 separate samples. As humans, we are all too often tempted to compare our own country's performance against other countries, but this is really inappropriate and unfair. It is important to note that despite all of the possible differences across countries/regions with respect to curriculum, teaching approach, and cultures the results are quite consistent with respect to students' lack understanding about inquiry and there seem to be some clearly common themes to explain the results.

Completion of elementary school is about halfway through a student's schooling and the data collected in this study indicate that most students hold a naïve view of most of the aspects of SI in seventh grade. These findings are not surprising as a cross-sectional study conducted in the US found that students' understandings of SI do not increase between grades one to five and in the case of some aspects their understandings decrease through elementary school (Bartels & Lederman, 2017). Some may argue that the students in this investigation will have plenty of time to improve their understandings and are not that poor considering that students have just completed elementary school. However, previous studies have found that very young children (grade one and above) are able to adequately understand several aspects of scientific inquiry; science begins with a question, there is no single scientific method and conclusions are based on data gathered and what is already known (Lederman, 2012). Another study looked at grade one students' understandings of SI who came from very different cultural backgrounds, this study found that after explicit and reflective science instruction grade one students could understand aspects of SI regardless of their initial SI understandings (Lederman et al., 2013). Students should, at the very least, have informed views of at least some of the aforementioned aspects by grade seven.

The interpretation of the results could rightfully be viewed as a conflict between having a perspective of a glass half full versus a glass half empty. Whether these results are viewed negatively or positively will ultimately be decided by how each country/region views the developmental level of their students and future studies on what students know when they exit high school, a study that we are just completing with 25 countries/ regions.

Again, an important caveat, other than avoiding the temptation of comparing countries/regions, is that the primary goal of this investigation was to establish an initial baseline of what students understand about scientific inquiry. Understandings of scientific inquiry are a highly prized goal of science education throughout the world and it is a significant component of scientific literacy (Roberts, 2008). It is quite possible that not all countries/regions will care equally about each of the eight aspects of SI investigated here. Consequently, they may not be concerned that their students do not know the difference between data and evidence. Nevertheless, the results of this investigation provide an empirically based "call to action." Although the samples for each location were of convenience, this investigation provides data on some aspects that are assured of concern and importance to certain countries/regions and the results can lead to changes in curricula, science teaching and policy decisions at the local, state/provincial, and national policy decisions in science education.

6 IMPLICATIONS FOR FUTURE RESEARCH

Currently, the 18 countries/regions involved in this investigation, along with an additional seven countries/regions are looking at graduating high school students' understandings of SI. This will pro- vide information about how, and if, students' understandings of SI become more sophisticated as they proceed through middle and high school. It will also help decide what levels of understanding are appropriate to expect of students at the beginning of seventh grade. The final piece of students' trajec- tories of SI understandings can be completed by assessing elementary students' understandings of SI earlier in elementary school. The results from all three of these studies combined will elucidate a full progression of students' SI understandings from beginning elementary school to the completion of high school around the world. As mentioned earlier, some may argue that doing scientific inquiry is of ultimate importance (Duschl & Grandy, 2013), and doing of inquiry will necessarily lead to under- standing about the inquiry. This implicit development of knowledge about inquiry is not supported by any existing research. More importantly, we argue that understandings about scientific inquiry are a necessary and critical component to the achievement of scientific literacy. The general citizenry needs to make informed decisions about scientifically based personal and societal decisions, and these decisions are based on their knowledge about how scientific knowledge is developed (i.e. scientific inquiry).

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000). The Influence of history of science courses on students' views of nature of science. Journal of Research in Science Teaching, 37(10), 1057–1095.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elemen- tary teachers' conceptions of nature of science. Journal of Research in Science Teaching, 37(4), 295–317.

American Association for the Advancement of Science. (1993). Benchmarks for science literacy. New York: Oxford University Press. Australian Curriculum and Reporting Authority (ACARA). (2015). Australian Curriculum: Science F-10. Sydney: Commonwealth of Australia.

Bartels, S. L., & Lederman, J. S. (2017, April). A cross-sectional study of elementary students' understandings of nature of science and scientific inquiry. A paper presented at the annual meeting of the National Association for Research in Science Teaching confer- ence, San Antonio, TX.

BOEN. (2015). Bulletin Officiel de l'Education Nationale. Numéro spécial no11 du 26 novembre 2015: Programmes d'enseignement de l'école élémentaire et du collège (NOR MENE1526483A) [In French].

BRAZIL. (1998). Ministério da Educação e Cultura (p. 1998). Parâmetros

Curriculares Nacionais para o Ensino de Ciências. Brasí- lia: MEC.
BRAZIL. (2014). Ministério da Educação e Cultura Plano Nacional da Educação (p. 2014). Brasília: MEC.
Centre for Curricula and Material Development. (2016). Science Standards and indicators for school level education. Egypt: Ministry of Education Retrieved from: http://moe.gov.eg/ccimd/pdf/Matrix_science_curriculum.pdf
Charpak, G. (1998). La Main à la Pâte, Histoire des sciences à l'école primaire. Paris: Flammarion.
Confederación de Sociedades Científicas de España [COSCE]. (2011). Informe ENCIENDE. Enseñanza de las ciencias en la Didáctica Escolar para edades tempranas en España. Madrid: COSCE.
Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. Journal of Research in Science Teaching, 42(3), 337–357.
Department for Education. (2013). The National Curriculum in England: Science Program of Study. Retrieved from https://www.gov. uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study
Department of Basic Education (DBE). (2011). Curriculum and Assessment Policy Statement Grades 7 – 9, Natural Sciences. Pretoria: Department of Basic Education.
DEPP (2014). CEDRE-2013 'Grande stabilité des acquis en sciences en fin d'école depuis 2007' 'Strong stability of the pupils' results in science at the end of primary school since 20070. Information Note of DEPP (Direction of Evaluation, Prospective and Perfor- mance), No27, July 2014, p. 3.
Duschl, R. A., & Grandy, R. (2013). Two views about explicitly teaching nature of science. Science & Education, 22(9), 2109–2139.
EU. (2006a). Competencias clave para el aprendizaje permanente. Un marco de referencia europeo. Anexo a la Recomendación del parlamento europeo y del consejo sobre las competencias clave para el aprendizaje permanente.
EU. (2006b). Recomendación del parlamento europeo y del consejo sobre las competencias clave para el aprendizaje permanente.

Federal Ministry of Education. (1999). UBE Universal Basic Education for Nigeria. Proceedings of the Education Mini Summit. Zaria: Ahmadu Bello University Press Limited.

Finnish National Board of Education [FNBE]. (2014). The national core curriculum for basic Education. Helsinki: Finnish National Board of Education Retrieved from http://www.oph.fi/ops2016

Gaigher, E., Lederman, N. G., & Lederman, J. S. (2014). Knowledge about inquiry:

A study in South African high schools. International Journal of Science Education, 36(18), 3125–3147.

García, M., & Orozco, L. (2008). Orientando un cambio de actitud hacia las Ciencia Naturales y su enseñanza en Profesores de Educación Primaria. Revista Electrónica de Enseñanza de las Ciencias, 7(3), 539–568.

Grisay, A. (2003). Translation procedures in OECD/PISA 2000 international assessment. Language Testing, 20(2), 225–240.

Guillemin, F., Bombardier, C., & Beaton, D. (1993). Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. Journal of Clinical Epidemiology, 46(12), 1417–1432.

Hambleton, R. K. (2002). Adapting achievement tests into multiple languages for international assessments. In A. C. Porter &

A. Gamoran (Eds.), Methodological advances in cross national surveys of educational achievement. Washington, DC: National Academy Press.

Hambleton, R. K., & Patsula, L. (1998). Adapting tests for use in multiple languages and cultures. Social Indicators Research, 45(1–3), 153–171.

Hammer, D., & Elby, A. (2009). Tapping epistemological resources for learning physics. Journal of the Learning Sciences, 12(1), 53–90. https://doi.org/10.1207/S15327809JLS1201_3

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Maestre (Ed.), Transfer of Learning from a modern multidisciplinary perspective (pp. 89–119). Greenwich, CT: Information Age Publishing.

Igbokwe, C. O. (2015). Recent curriculum reforms at the basic education level in

Nigeria aimed at catching them young to create change. American Journal of Educational Research, 3(1), 31–37.

Lau, K. C., Ho, S. C., & Lam, Y. P. (2015). Effective classroom pedagogy and beyond for promoting scientific literacy: Is there an east-asian model? In M. S. Khine (Ed.), Science education in East Asia: Pedagogical innovations and research-informed practices (pp. 13–40). Switzerland: Springer.

Lederman, J. S. (2012). Development of a valid and reliable protocol for the assessment of early Childhood students' conceptions of Nature of Science and scientific Inquiry. A Paper Presented at the Annual Meeting of the National Association of Research in Sci- ence Teaching, Indianapolis, IN.

Lederman, J. S., Bartels, S. L., Liu, C., & Jimenez, J. (2013). Teaching Nature of Science and scientific Inquiry to diverse classes of early primary level students. A Paper Presented at the Annual Conference for the National Association of Research in Science Teaching, San Juan, PR.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry- The views about scientific inquiry (VASI) questionnaire. Journal of Research in Science Teaching, 51(1), 65–83.

Lederman, N. G. (2010). A powerful way to learn. Science and Children, 48(1), 8–9.

Lederman, N. G., Antink, A., & Bartos, S. (2012). Nature of science, scientific inquiry, and socio-scientific issues arising from genet- ics: A pathway to developing a scientifically literate citizenry. Science & Education, 23(2), 285–302.

Lederman, N. G., & Lederman, J. S. (2004). Project ICAN: A professional Development project to promote teachers' and students' knowledge of Nature of Science and scientific enquiry. In Proceedings of the 11th Annual SAARMSTE Conference. Cape Town, South Africa.

Lee, K., & Sriaman, B. (2013). An Eastern learning paradox: Paradoxes in two Korean mathematics teachers' pedagogy of silence in the classroom. Interchange, 43(2), 147–166.

Organic Law of Education [LOE] 2/2006, 3rd May. (2006). Boletín Oficial del Estado, Number. 106, pp. 17158–17207. Retrieved from http://www.boe.es/boe/dias/2006/05/04/pdfs/A17158-17207.pdf

Maneersriwongul, W., & Dixon, J. K. (2004). Instrument translation process: a methods review. Journal of Advanced Nursing, 48(2), 175–186.

McKenzie, P., Kos, J., Walker, M., & Hong, J. (2008). Staff in Australia's Schools 2007. Canberra: DEEWR.

MEB. (2013). Ministry of national Education, curriculum for Science classes for primary schools. Ankara: MEB. MINEDUC. (2012). Bases Curriculares

Educación Básica. Santiago: Ministerio de Educación.

Ministry of Education. (2003). Grade 1–9 science and technology curriculum guidelines. Taipei, Taiwan: MOE. Ministry of Education. (2007). The New Zealand curriculum. Wellington: Learning Media.

Ministry of Education. (2015). Introducing five science capabilities. Retrieved from http://scienceonline.tki.org.nz/ Science-capabilities-for-citizenship/Introducing-five-science-capabilities

Ministry of Education of the People's Republic of China. (2017a). Educational Statistics in 2016: Number of Students in Primary Schools. Retrieved from http://en.moe.gov.cn/Resources/Statistics/edu_stat_2016/2016_en01/201708/t20170823_311723. html

Ministry of Education of the People's Republic of China (2017b). Educational statistics in 2016: Number of students in junior sec- ondary schools. Retrieved from http://en.moe.gov.cn/Resources/Statistics/edu_stat_2016/2016_en01/201708/t20170823_ 311737.html

Ministry of Education of the People's Republic of China [MOE]. (2001). National Science curriculum standards for the full-time com- pulsory Education (Grades 3–6). (Trial Version). Beijing: Beijing Normal University Press (in Chinese).

Ministry of Education, Pedagogical Secretariat. (2018). Up-dated curriculum for science and technology in secondary school in Israel (in Hebrew). Retrieved from http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/MadaTechnologya/ tochnitLimudim/hatab+tl.htm

National Academy for Educational Research. (2015). Grade 1–12 curriculum guidelines: Learning area of natural science (draft). Taipei, Taiwan: National Academy for Educational Research.

National Research Council. (1996). National science education standards. Washington, DC: National Academies Press.

National Research Council [NRC]. (2000). Inquiry and the national science education standards. Washington, D.C.: National Acad- emy Press.

National Research Council [NRC]. (2011). A framework for K-12 science education:

Practices, crosscutting concepts, and core ideas. Washington, DC: National Academy Press.

Neumann, K., Kauertz, A., & Fischer, H. E. (2010). From PISA to standards - the impact of large scale assessments on science educa- tion research in Germany. International Journal of Science and Mathematics Education, 8(3), 545–563.

NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: National Academies Press

Available online at www.nextgenscience.org/next-generation-science-standards

Organization for Economic and Co-operation and Development (OECD). (2017). PISA 2015 technical report. Paris: OECD Publishing Retrieved from http://www.oecd.org/pisa/sitedocument/PISA-2015-Technical-Report-Chapter-5-Translation.pdf

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about science" should be taught in school science?

A Delphi study of the expert community. Journal of Research in Science Teaching, 40(7), 692–720.

Roberts, D. A. (2008). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), Handbook of Research on Science Education (pp. 729–780). Mahwah, NJ: Routledge.

Gesellschaft für Didaktik des Sachunterrichts. (2013). Perspektivrahmen Sachunterricht. Julius Klinkhardt. Retrieved from http:// www.gdsu.de/wb/pages/perspektivrahmen-sachunterricht.php

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap

between nature of science and science inquiry. Science Education, 88, 610–645.
Schwartz, R. S., Lederman, N. G., Khishfe, R., Lederman, J. S., Matthews, L., & Liu, S. (2002). Explicit/reflective instructional attention to Nature of Science and scientific Inquiry: Impact on student Learning Paper Presented at the Proceedings of the 2002 Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC.

Schwartz, R. S., Lederman, N. G., & Lederman, J. S. (2008). An instrument to assess views of scientific inquiry: The VOSI question- naire. Paper Presented at the International Conference of the National Association for Research in Science Teaching, Balti- more, MD.
Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland [KMK]. (2005a). Bildungsstan- dards im Fach Biologie für den Mittleren Schulabschluss (Jahrgangsstufe 10). Neuwied: Luchterhand.
Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland [KMK]. (2005b). Bildungsstan- dards im Fach Chemie für den Mittleren Schulabschluss (Jahrgangsstufe 10). Neuwied: Luchterhand.
Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland [KMK]. (2005c). Bildungsstan- dards im Fach Physik für den Mittleren Schulabschluss (Jahrgangsstufe 10). Neuwied: Luchterhand.
Showalter, V. (1974). Program objectives and scientific literacy. Prism II, 2, 1–6.
Skolverket. (2011). Läroplan för grundskolan, förskoleklass och fritidshemmet. (The Swedish National Agency of Education, (2011).
Curriculum for compulsory school, preschool and leisure time centers). Stockholm: Edita.
Sodian, B., Zaitchik, D., & Carey, S. (1991). Young children's differentiation of hypothetical beliefs from evidence. Child Develop- ment, 62, 753–766.
Tytler, R., & Peterson, S. (2003). Tracing young children´s scientific reasoning.

Research in Science Education, 33, 433–465.

Vázquez, A. & Manassero, M. A. (2011). El descenso de las actitudes hacia la ciencia de chicos y chicas en la educación obligatoria. Ciencia & Educaçao, 17(2), 249–268.

Welch, W. W. (1979). Twenty years of science curriculum development: A look back. In D. C. Berliner (Ed.), Review of Research in Education (pp 282–308) (Vol. 7, p. 282). Washington, DC: AERA.

Wellcome Trust. (2017). State of the nation report of UK primary science education. Retrieved from https://wellcome.ac.uk/sites/ default/files/state-of-the-nation-report-of-uk-science-education.pdf

Wellnitz, N., Fischer, H. E., Kauertz, A., Mayer, J., Neumann, I., Pant, H. A., … Walpuski, M. (2012). Evaluation der Bildungsstandards. Eine fächerübergreifende Testkonzeption für den Kompetenzbereich Erkenntnisgewinnung. Zeitschrift für Didaktik der Nat- urwissenschaften, 18, 261–291.

Wong, S. L., & Hodson, D. (2009). From the horse's mouth: What scientists say about scientific investigation and scientific knowledge. Science Education, 93(1), 109–130.

Wong, S. L., & Hodson, D. (2010). More from the horse's mouth: What scientists say about science as a social practice. International Journal of Science Education, 32(11), 1431–1463.

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