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Completing the progression establishing an international baseline of primary, middle and secondary students' views of scientific inquiry

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Completing the progression establishing an international baseline of primary, middle and secondary students' views of scientific inquiry

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ABSTRACT

Knowledge of scientific inquiry (SI) is considered essential to the development of an individual's Scientific Literacy (SL) and therefore, SI is included in many international science education reform documents. Two previous large scale international studies assessed the SI understandings of students entering middle school and secondary students at the end of their formal K-12 science education. The purpose of this international project was to use the VASI-E to collect data on what primary level students have learned about SI in their first few years of school. This study adds to previous research to bridge the landscape of SI understandings now with representation from primary, middle and high school samples. A total of 4,238 students from 35 countries/regions spanning six continents participated in the study. The results show that globally, primary students are not adequately informed about SI for their age group. However, when compared with the students in the previous international studies (grades seven and 12), the primary students' understandings were surprisingly closer to the levels of understanding of SI of the secondary school students than those in the seventh grade study.

ARTICLE HISTORY

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KEYWORDS

Scientific inquiry; international investigation

Introduction

The intent of this collaborative project is to report on primary students' understandings of scientific inquiry (SI) across the globe. Two previous international studies of grades seven and 12 students have been conducted (Lederman et al., 2019, 2021), that helped establish the trajectory of SI understandings from the beginning of middle school to the end of high school. But what about younger students? What were their understandings of SI and how do they compare to the middle level international sample? Previously, a study of this young population's views about scientific inquiry had not been possible because of the lack of a developmentally appropriate valid and reliable instrument to measure their understandings about SI. The development of the Views About Scientific Inquiry – Elementary (VASI-E) is included in this paper and is the instrument used to collect the data for this study. The first two international studies found that students' understanding of SI slightly improved from grades seven to 12. However, on average, 12th graders showed less than 45% understanding of all aspects of SI they exited secondary school. The focus of this research is to establish an understanding of what elementary students know about SI as a precursor for the two previous research investigations. 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 possible baseline of SI understandings worldwide. A systematic review of roughly 20 years of research looking at secondary students' understandings of SI in relation to laboratory work found that these connections are not being made and there is a great deal of research still needed (Gericke et al., 2022). A smaller scale study done in China revealed that understandings of SI aspects do not progress in a linear fashion from one grade band to the next (Gai et al., 2022).

Why should students understand SI, 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. Scientific inquiry is this process. The content standards for science as inquiry for grades K-12 advocate the merit of students developing (a) the abilities necessary to do inquiry and (b) understandings about scientific inquiry (NRC, 2000). Six years later the Organization for Economic Cooperation and Development proposed a definition of literacy which they use to frame their Program for International Assessment (PISA). They defined literacy as a students' ability to understand, use and reflect on written texts in order to achieve one's goals and to participate in society (Organization for Economic Cooperation and Development, 2006). Situated within science education a proposed description of scientific literacy where real world situations as related to science and scientific issues become relevant (Roberts & Bybee, 2014). Together both of these indicate that literate people are expected to apply the knowledge to make everyday decisions. Thus, by grade 12, students need to be able to not only 'do' inquiry, but also 'know' about scientific inquiry (SI). Although students personally participating in scientific inquiry investigations is important, it is often found that students can engage in inquiry investigations without knowing how and why scientists go about their work (Ann Haefner & Zembal-Saul, 2004; Leonard et al., 2009). The efficacy of such implicit approaches to developing understandings of SI and Nature of Scientific Knowledge (NOSK), have been called into question by a growing body of research (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Lederman, 2012). Therefore, it is important to identify and intentionally teach the aspects of SI that can serve, to develop informed views about inquiry with the major endpoint desired of the development of a scientifically literate citizenry.

The aspects of SI that follow are accessible and reasonably appropriate in the context of K-12 science education and are derived from various reform documents (Akerson & Bartels, 2023). Specifically, students should develop an informed understanding that: scientific investigations begin with a question but do not necessarily test a hypothesis; there is no single set or sequence of steps followed in all investigations (science can be conducted in many ways e.g. experimental, observational, descriptive, and correlational); inquiry procedures are guided by the question(s) asked; all scientists performing the same procedures may not get the same results; inquiry procedures can influence results; research conclusions must be consistent with the data collected; scientific data are not the same as scientific evidence; and explanations are developed from a combination of collected data and what is already known. The youngest students in primary grades are still capable of learning about SI, but not all of the aspects are age appropriate.

Although students should know these eight aspects of SI by the time they finish 12th grade, not all of these aspects can be taught to students who are in primary grades (Donohue et al., 2020; Lederman, 2009). The aspects that are appropriate for students in primary grades are as follows;

- all investigations begin with a question,
- scientists collect empirical data to answer their questions,
- procedures are guided by the question asked,

- data and prior knowledge are used to answer questions,
- and there is no one single scientific method.

These aspects of SI are aligned with what is typically advocated in science education reform documents (Akerson & Bartels, 2023), and is the focus of the VASI-E questions. They are not meant to be a definitive list of outcomes with respect to inquiry, but there is little debate about the importance of these aspects of scientific inquiry. Research has shown they are accessible to precollege students within the context of existing standards across the globe (Akerson & Bartels, 2023; NGSS Lead States, 2013). It is key that by the time students leave their required formal education they should have both an understanding of both what SI is, and how it is conducted. The understandings of these both lead towards Scientific Inquiry Literacy (SIL) (Schwartz et al., 2023).

Development, validity and reliability of the VASI-E

The instrument used in this study was a newly developed instrument based on prior research on assessing SI. The VASI (Lederman et al., 2014) allows researchers to assess grade five and above understandings of eight aspects of SI through a written open-ended instrument. The VASI (Appendix A) instrument was considered not appropriate for elementary students in this study due to face validity and developmentally appropriate aspects of SI. This large-scale study of elementary students' understandings of SI, warranted the creation of a paper and pencil instrument for students who are in the elementary grades that can express themselves in writing (typically grades two through five). Therefore, the VASI-E (Appendix B) was created based on the aspects of SI that young children can understand and connecting it to real world examples that are appropriate for young children (crayons, birds, and balls). The first step in this instrument adaptation was to identify the aspects of SI that are appropriate for primary grades. These aspects were selected by the previous studies on young children's understandings of science (Bartels & Lederman, 2022; Lederman & Bartels, 2018). The aspects are: scientific investigations begin with a question, multiple methods, procedures are guided by the questions asked, conclusions must be consistent with the data collected, and explanations are developed from data collected and prior knowledge. The aspects of SI that are not appropriate for students in primary grades are: same procedures do not necessarily have same results, procedures can influence results, and data and evidence are not the same. See figure one for the aspects of SI appropriate for 6–12 students as well as those that are appropriate for primary grade students and the alignment of the VASI-E to the aspects of SI.

Once the aspects of SI were identified that were appropriate for primary grade children the questions from the VASI relating to those aspects were extracted (questions 2, 3, 4 and 6). This left questions one, five and seven from the original VASI. These questions were then adapted for the age level of the students. Question one was revised to include a picture of birds so that students could visualise the difference between the beaks and part 'C' was revised to be question four on the VASI-E. This question asked students about different types of balls and if bouncing a ball is a 'scientific investigation.' Question five of the VASI was revised from utilising car tires as an example to asking students about melting crayons as a more universally understood childhood experience.

The final question on the VASI, question seven, was revised to ask students how scientists know that dinosaurs existed if they are not around anymore. Followed up by how scientists think dinosaurs looked and to explain how they are able to make inferences on how dinosaurs may have looked. Once the questions were written the face validity needed to be revised to be appropriate for young children. This includes the type of font, text size, with enough room for students to respond in both writing and drawings. Face validity was determined by three elementary school teachers.

This new instrument was then piloted with 61 third grade students from classrooms in three different US cities. Each student was interviewed, and revisions were tested with another group of 18 elementary students to produce the final valid and reliable version of the VASI-E used in this study.

Statement of the problem

The present study sought to examine primary school students' understandings about SI utilising the VASI-E, at the completion of their third school year. This study provides data on what, if anything, students around the world know about SI as they head into upper elementary grades and beyond. This study looks to establish a baseline for the two previous international studies of what students know about SI that were conducted with middle and secondary level students (Lederman et al., 2019, 2021; Eroğlu & Bektaş, 2022; Gyllenpalm et al., 2022).

Method

Sample

There were a total of 35 primary research sites participating in this study, typically two contact people in each research site. The primary contacts were selected based on the documented active research programmes of the people in each country or prior participation in other international VASI studies. The research sites were: Australia ($n = 111$), Bhutan ($n = 131$), Brazil ($n = 160$), Bulgaria ($n = 100$), Chile ($n = 132$), China (Beijing) ($n = 127$), China (Changchun) ($n = 104$), China (Hebei) ($n = 187$), China (Hong Kong) ($n = 102$), China (Zhejiang) ($n = 166$), Colombia ($n = 100$), England ($n = 107$), Finland ($n = 125$), France ($n = 104$), Germany ($n = 99$), Greece ($n = 100$), Japan ($n = 152$), Korea ($n = 119$), Lebanon ($n = 100$), Netherlands ($n = 128$), Peru ($n = 108$), Philippines ($n = 100$), Singapore ($n = 100$), South Africa ($n = 152$), Spain (Basque Country) ($n = 137$), Spain (Burgos) ($n = 121$), Spain (Sevilla) ($n = 110$), Sweden (Stockholm) ($n = 110$), Sweden (Kalmar) ($n = 100$), Taiwan ($n = 134$), Thailand ($n = 108$), Turkey ($n = 193$), US ($n = 330$). The total sample size of elementary school students was 4,238 students. The students who were selected for this study were either completing their third year of school and or beginning their fourth year depending on the country/region's academic year. On average the students were nine years old. Each research site selected a sample that was representative for their region; selection was based on average academic ability, representative diversity of the region and socioeconomic background. It is important to note that, because of differences across countries/regions, the sample size is not the number of students, but rather the number of countries/regions.

Table 1. Complete set of data from each country/region for each aspect of SI.

		Start with a Question (%)			Multiple Methods (%)			Conclusions must be consistent with Data C. (%)			Procedure are Guided by the Question Asked (%)			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
Australia	111	14.4	45.0	40.5	45.9	48.6	5.4	21.6	41.4	36.9	17.1	62.2	20.7	21.6	43.2	35.1
Bhutan	131	51.1	23.7	25.2	48.9	27.5	23.7	46.6	19.1	33.6	49.6	15.3	30.5	45.8	21.4	32.8
Brazil	160	33.8	31.9	34.4	51.3	28.8	19.4	25.6	30.6	43.8	30.0	41.9	26.9	25.6	30.6	43.8
Bulgaria	100	16.0	14.0	70.0	27.0	9.0	64.0	12.0	10.0	78.0	25.0	6.0	69.0	12.0	9.0	79.0
Chile	132	65.2	25.0	9.8	48.5	44.7	6.8	28.8	3.0	68.2	53.0	31.8	15.2	68.9	3.8	27.3
China Beijing	127	17.3	74.0	8.7	41.7	52.0	6.3	15.0	26.8	58.3	23.6	64.6	11.8	33.1	54.3	12.6
China Changchun	104	67.3	26.0	6.7	59.6	35.6	4.8	14.4	13.5	72.1	53.8	31.7	14.4	32.7	41.3	26.0
China Hebei	187	94.1	5.9	0.0	97.3	2.7	0.0	28.3	28.3	43.3	88.8	11.2	0.0	23.5	64.2	12.3
China Zhejiang	166	27.1	69.9	2.4	36.7	56.0	7.2	3.6	69.9	26.5	5.4	92.8	1.2	22.9	75.9	1.2
Colombia	100	53.0	46.0	1.0	73.0	21.0	6.0	61.0	26.0	13.0	60.0	34.0	6.0	61.0	26.0	13.0
England	107	3.7	57.0	39.3	21.5	63.6	15.0	13.1	37.4	49.5	4.7	54.2	41.1	14.0	36.4	49.5
Finland	125	15.2	60.0	24.0	36.0	55.2	6.4	17.6	22.4	57.6	10.4	48.8	39.2	17.6	22.4	57.6
France	104	61.5	20.2	18.3	89.4	5.8	4.8	28.8	6.7	64.4	63.5	16.3	20.2	56.7	10.6	32.7
Germany	99	52.5	43.4	4.0	79.8	16.2	1.0	17.2	25.3	54.5	55.6	15.2	27.3	56.6	38.4	2.0
Greece	100	51.0	43.0	6.0	53.0	43.0	4.0	20.0	38.0	42.0	41.0	43.0	16.0	19.0	49.0	32.0
Hong Kong	102	27.5	45.1	27.5	41.2	47.1	11.8	16.7	35.3	48.0	39.2	33.3	27.5	21.6	62.7	15.7
Japan	152	21.7	57.2	19.1	21.1	56.6	19.7	17.8	46.7	27.0	18.4	59.2	13.2	25.0	47.4	18.4
Korea	119	16.0	53.8	30.3	54.6	37.8	7.6	3.4	54.6	42.0	34.5	17.6	47.9	3.4	54.6	42.0
Lebanon	100	75.0	24.0	1.0	77.0	16.0	7.0	65.0	28.0	7.0	89.0	10.0	1.0	65.0	28.0	7.0
Netherlands	128	64.1	34.4	0.8	71.9	21.1	3.1	29.7	26.6	41.4	66.4	28.9	3.1	38.3	57.8	1.6
Peru	108	45.1	21.6	38.2	68.6	35.3	1.0	67.6	10.8	19.6	68.6	2.9	23.5	35.3	47.1	15.7
Philippines	100	29.0	51.0	19.0	28.0	55.0	17.0	13.0	67.0	12.0	16.0	62.0	21.0	13.0	67.0	12.0
Singapore	100	6.0	54.0	40.0	11.0	71.0	18.0	9.0	64.0	27.0	9.0	44.0	47.0	9.0	64.0	27.0
South Africa	152	78.9	14.5	6.6	90.1	7.2	2.6	59.2	34.9	5.9	90.8	3.3	5.9	71.7	3.3	25.0
Spain Burgos	102	32.4	45.1	22.5	46.1	41.2	12.7	17.6	47.1	35.3	37.3	51.0	11.8	17.6	47.1	35.3
Spain País Vasco	137	36.5	46.0	17.5	46.7	42.3	10.2	27.7	37.2	34.3	48.2	40.1	11.7	35.8	29.2	34.3
Spain Sevilla	110	39.1	30.0	30.9	70.0	13.6	13.6	22.7	74.5	1.8	54.5	15.5	28.2	22.7	74.5	1.8
Sweden Kalmar	100	53.0	3.0	43.0	35.0	50.0	15.0	10.0	4.0	86.0	43.0	30.0	25.0	10.0	4.0	86.0
Sweden Stockholm	110	16.4	51.8	31.8	45.5	37.3	17.3	4.5	30.0	65.5	23.6	44.5	31.8	6.4	66.4	27.3
Taiwan	134	14.9	47.8	36.6	17.9	38.8	43.3	26.1	16.4	57.5	21.6	32.1	45.5	26.1	52.2	21.6
Thailand	108	76.9	22.2	0.9	56.5	40.7	2.8	66.7	32.4	0.9	85.2	13.9	0.9	65.7	33.3	0.9
Turkey	193	79.3	2.1	18.7	82.9	1.6	15.5	60.6	8.8	30.6	73.6	7.3	19.2	62.7	6.2	31.1
United States	330	3.0	43.9	53.0	9.4	58.2	32.4	10.0	40.6	49.4	7.0	49.7	43.3	10.0	41.8	48.2

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

Data collection

To begin data collection all sites needed to be trained to administer and analyse the VASI-E. The contact people across the six continents were responsible for: completion of training in the coding of the VASI-E, language translation/back translation for VASI-E validity, selection of a representative, sample, data collection (including paper and pencil assessments and individual interviews), data analysis, and the writing of location specific aspects of the results. The selection and training of the contact people for the scoring of the VASI-E were completed by the first four authors of this paper. This research began with an initial face to face meeting at a large international science education research meeting in March of 2019 . There, the initial timeline of the study was laid out (although the international pandemic delayed data collection in many sites). Then individual meetings were arranged and conducted via videoconferencing between each site and the primary researchers. The first meeting involved learning to administer and score the VASI-E. The subsequent virtual meetings involved scoring at least 10 of the sites' VASI-Es between the project researchers and each research site until a confirmed 80% or greater inter-rater agreement was established. If additional meetings were needed, they were scheduled on a case by case basis.

Each student was given a VASI-E to complete in a 30-min time period. The VASI-E was given in the students' language of science instruction. When the language spoken was not English, the instrument was translated and then back translated to verify the accuracy of the translation. The translation and back translation procedures followed well-established standards (Maneersriwongul & Dixon, 2004; Organization for Economic and Co-operation and Development [OECD], 2017). The full VASI-E instrument in different languages is available online.

Individual country/region findings

Table 1 displays the findings from each country/region. Researchers from each site collected and analysed their own data after the training on the VASI-E administration and scoring. The table lists each country/region and the percentage of their sample that is naive, mixed and informed.

General findings

The results from this study show that primary level students around the world have an overall naïve view of SI in terms of the developmentally appropriate aspects for which they were assessed. The aspects of SI that were analysed were, science starts with a question, multiple methods of conducting science, conclusions must be consistent with data

Table 2. The worldwide average of findings for each aspect of SI in 3rd.

Aspect of SI	No Answer (%)	Naïve (%)	Mixed (%)	Informed (%)
Starts with a Question	0.2	40.0	37.0	22.7
Multiple Methods	0.5	49.9	35.9	13.7
Conclusions Consistent with Data Collected	1.1	26.4	32.3	40.3
Procedures are Guided by the Question Asked	1.1	41.6	34.6	22.7
Conclusions are Developed from Data and PK	1.0	31.4	39.6	28.0

Table 3. The worldwide average of findings for each aspect of SI in 3rd, 7th grade, and 12th grade.

	3rd Grade ($n = 4238$)				7th Grade ($n = 2634$)				12th Grade ($n = 3917$)			
Aspect %	NA	Naïve	Mixed	Informed	NA	Naïve	Mixed	Informed	NA	Naïve	Mixed	Informed
Starts with a Question	0.2	40.0	37.0	22.7	5.5	43.9	29.9	20.7	2.8	40.2	21.3	35.6
Multiple Methods	0.5	49.9	35.9	13.7	5.8	54.4	33.8	6.0	2.3	42.7	40.2	14.8
Conclusions Consistent with Data Collected	1.1	26.4	32.3	40.3	6.4	39.7	20.6	33.3	3.4	40.4	15.8	40.4
Procedures are Guided by the Question Asked	1.1	41.6	34.6	22.7	7.6	44.8	20.1	27.5	5.0	36.8	13.6	44.6
C nclusions are Developed from Data and PK	1.0	31.4	39.6	28.0	9.9	41.3	37.9	10.9	5.3	26.2	40.8	27.7

Note: NA = No Answer.

collected, procedures are guided by the question asked and conclusions are developed from data collected and previous knowledge. See Table 2 below for full worldwide percentages. These results are understandable since science is not a priority academic discipline in the early primary grades and often there tends to be greater focus on language literacy and mathematics in these beginning grades. However, for each country or region in the study, there were some students who held more informed understandings than others. These variations differed from place to place depending on the teaching context, curriculum, and student backgrounds.

There were instances in which averages were better than 'naïve' on a particular SI aspect. For example, for the aspect 'conclusions need to be consistent with the data collected', only 26.4% of students assessed showed naive views. The most confusing aspect of SI for students was one that considered the possibility of there being multiple methods of doing scientific investigations. 49% of students felt experimentation was the only legitimate method that scientists use to do their work. The remaining aspects: SI starts with a question, procedures are guided by the question asked and conclusions are developed from data and prior knowledge had percentages in the 20s for the informed category.

The big picture: the progression of SI understandings

The findings of this study of primary level students' SIL supply important data for researchers to understand the progression of SIL of students as they move through their formal education. They add to what previous large scale international studies have revealed about middle and secondary level students' SIL (Lederman et al., 2019 & Lederman et al., 2021). Collectively these three studies illustrate a cross-sectional picture of the state of SIL globally as students progress through different stages of their science education. Table 3 below displays the data for only the aspects of SI that are appropriate for primary, middle level and secondary level students involved in the three different international studies.

An analysis of the global averages of informed understandings of each aspect revealed both expected and unexpected results. For the aspect *begins with a question*, 22.7% of primary level students held informed understandings, where this percentage decreased slightly in middle level (20.7%). The percentage of informed understandings increased to 35.6% of secondary students who held informed understandings globally.

The aspect of *multiple methods* followed a similar pattern with primary informed understanding at 13.7% and decreasing in middle level 6.0%. The secondary understanding (14.8%) was higher than middle level understanding but very similar to the percent of primary students who understood this aspect.

The aspect of SI, *conclusions are consistent with data collected,* had an increase from primary (6.4%), to middle (33.3%) to secondary (40.4%) in the percentage of informed students. This increase in understanding is what one would expect to see due to increased schooling but this still leaves roughly 60% of the secondary students who are not informed on this aspect.

The aspect of SI, *procedures guided by the question asked,* also had a similar trajectory. From 22.7% of primary students informed on this aspect to 27.5% in middle school to 44.6% in secondary understanding this aspect of SI. Also leaving the majority of students at the secondary level not informed on this aspect of SI.

Conclusions based on data collected and what is already known, 28% of the primary students globally held informed views but the percentage of middle level students decreased (10.9%). The secondary students who held informed views were relatively the same as percentage as the primary students (27.7%).

Three studies later

The intention of this research is to continue to inform the progression of the previous two studies which allows for a fuller picture of SI knowledge from grades three to 12 worldwide. This study has been replicated three times with three different grade levels, seventh, 12th and now third grade. Cross sectional data from around the world was collected to establish understandings of SI for third graders. In the 12th grade study a Chi square analysis was selected to determine if there were statistically significant differences in understandings for each aspect of SI between the seventh and 12th grade samples (Lederman et al., 2021). This study showed statistically significant differences in favour of the students in 12th grade,

Table 4. Chi Squares per each aspect in each category comparing 3rd and 7th grade

		Naive		Mixed		Informed	
Aspect	*df*	χ^2	*p*	χ^2	*p*	χ^2	*p*
Starts with a Question	1	77.348	.000	274.540	.000	147.998	.000
Multiple Methods	1	113.320	.000	185.562	.000	267.403	.000
Conclusions Must be Consistent with Data Collected	1	0.923	.337	480.434	.000	210.832	.000
Procedures are Guided by the Question Asked	1	92.225	.000	459.655	.000	49.180	.000
Explanations are Developed from Data and Previous Knowledge	1	23.949	.000	167.014	.000	572.266	.000

Note: *p* value significant at the $p < .05$ level.

but there was no discernible progress in students' comprehension of SI between the seventh grade and 12th grades.

For this study we looked to see if there were any differences between the international sample of grade three and grade seven students for the aspects of SI that are appropriate for the primary level students. A Chi-Square analysis was completed comparing the aggregated data for each accessible SI aspect (begins with a question, multiple methods, conclusions consistent with data gathered, procedures guided by the question asked and explanations are developed from data and prior knowledge) for each category (naive, mixed and informed) between grades three and seven. A Chi square analysis statistical test was selected because this test allows comparisons between categorical variables. In this case, Chi Square was used to compare the percentages of students with naïve, mixed and informed views between 3rd and 7th graders. There were a total of 15 Chi square analyses. However, given the descriptive and exploratory nature of this investigation, the increased error rate is justified. The results of the statistical analyses are reported in Table 4. According to the data all aspects of SI were statistically significant ($p < 0.05$) from grades primary sample to the middle level sample. This significance may be due to the large sample size and multiple Chi-Square (type I error), as the percentages do not show much difference between 3rd graders. There was a higher percentage of informed 3rd graders in all aspects of SI except *guided by the question asked.* For the aspect *starts with a question,* 22.7% of the third graders were informed compared to 20.7% of the seventh graders. For the aspect of *multiple methods of conducting science,* 13.7% of the third graders were informed compared to 6% of the seventh graders. For the aspect, *conclusions consistent with data collected,* 39.7% of third graders were informed compared to 33.3% of seventh graders. The final aspect that the third graders out performed the seventh graders was *conclusions are based on data and previous knowledge,* where 28% of the third graders were informed compared to 10.9% of the seventh graders. The number of students with informed views for their age is still negligible and well below the desired amount of the sample in most of the aspects evaluated. This lends itself to many more questions about the nature of the science education that is happening in classrooms globally between grades three to seven.

Conclusions and implications

Intuitively, one would expect students' SI knowledge would grow and become more sophisticated as they advanced through school and learned more science. This notion is not supported by the data from this and the other large scale international studies (Lederman et al., 2019; Lederman et al., 2021). There was a slightly positive trend of secondary students being more informed about conclusions needing to be consistent with the data collected and that procedures are guided by the question asked. But overall, an analysis of the progression of understandings of primary, middle and secondary level students shows consistent evidence of the lack of Scientific Inquiry Literacy (SIL). This could be explained by a study that looked at textbooks and found that although national standards find the teaching of SI to be important they are not addressed in textbooks (Dogan, 2021). Additionally studies have demonstrated when both pre-service and inservice teachers were able to participate in laboratory experiences but could not intentionally reflect on SI aspects themselves (Metin Peten, 2022; Molefe & Aubin, 2021). It is not surprising when textbooks and teachers do not address SI worldwide that students' understanding would be not at the desired level. It is clear that no matter where students live worldwide, understandings of scientific inquiry are not cultivated. Even more unexpected is the data that indicated a less informed trend of middle level students' understandings for some aspects than primary level students. Future research is needed to determine why this occurring and how to reverse it. Internationally, science standards stress the importance of Scientific Literacy as an outcome for K-12 and recommend the inclusion of scientific inquiry as an integral component of science education. Needed are outcomes that also support students' understanding about scientific inquiry. SIL, a combination of doing and knowing about science inquiry (Schwartz et al., 2023) should be one focus of science education initiatives if the universal goal of Scientific Literacy is to be achieved.

Ethical approval

This study met the ethics requirements for human subjects research. Each country/region underwent individual internal review boards (IRB) at their home institution. This was to ensure that the laws and regulations of each site were upheld.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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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. https://doi.org/10.1002/1098-2736(200012)37:10<1057::AID-TEA3>3.0.CO;2-C
Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, *37*(4), 295–317. https://doi.org/10.1002/(SICI)1098-2736(200004)37:4<295::AID-TEA2>3.0.CO;2-2
Akerson, V. L., & Bartels, S. L. (2023). Elementary science teaching: Toward the goal of scientific literacy. In N. Lederman, D. Zeidler, & J. Lederman (Eds.), *Handbook of research on science education* (pp. 528–558). Routledge.
Ann Haefner, L., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, *26*(13), 1653–1674. https://doi.org/10.1080/0950069042000230709
Bartels, S., & Lederman, J. S. (2022). What do elementary students know about science, scientists, and how they do their work? *International Journal of Science Education*, *44*, 627–646. https://doi.org/10.1080/09500693.2022.2050487

Dogan, O. K. (2021). Methodological? Or dialectical?: Reflections of scientific inquiry in biology textbooks. *International Journal of Science and Mathematics Education*, *19*(8), 1563–1585. https://doi.org/10.1007/s10763-020-10120-7

Donohue, K., Buck, G. A., & Akerson, V. (2020). Where's the science? Exploring a new science teacher educator's theoretical and practical understandings of scientific inquiry. *International Journal of Research in Education and Science*, *6*(1), 1–13. https://doi.org/10.46328/ijres.v6i1.571

Eroğlu, S., & Bektaş, O. (2022). The effect of 5E-based STEM education on academic achievement, scientific creativity, and views on the nature of science. *Learning and Individual Differences*, *98*, 102181. https://doi.org/10.1016/j.lindif.2022.102181

Gai, L., Li, Y., Zheng, C., Wei, B., Jiang, Z., & Lederman, J. S. (2022). The progression of students' views about nature of scientific inquiry. *International Journal of Science Education*, *44*(17), 2508–2540. https://doi.org/10.1080/09500693.2022.2138623

Gericke, N., Högström, P., & Wallin, J. (2022). A systematic review of research on laboratory work in secondary school. *Studies in Science Education*, *59*(2), 245–285.

Gyllenpalm, J., Rundgren, C. J., Lederman, J., & Lederman, N. (2022). Views about scientific inquiry: A study of students' understanding of scientific inquiry in grade 7 and 12 in Sweden. *Scandinavian Journal of Educational Research*, *66*(2), 336–354. https://doi.org/10.1080/00313831.2020.1869080

Lederman, J. S. (2009). *Teaching scientific inquiry: Exploration, directed, guided, and opened-ended levels*. Retrieved from https://ngl.cengage.com/assets/downloads/ngsci_pro0000000028/am_lederman_teach_sci_inq_scl22-0439a.pdf

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* [Paper presentation]. Annual Meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

Lederman, J. S., & Bartels, S. L. (2018). Assessing the ultimate goal of science education: Scientific literacy for all!. In S. Kahn (Ed.), *Toward inclusion of all learners through science teacher education* (pp. 277–285). Sense Publishers. https://doi.org/10.1163/9789004368422_030

Lederman, J. S., Lederman, N., Bartels, S., Jimenez, J., Akubo, M., Aly, S., Bao, C., Blanquet, E., Blonder, R., de Andrade, M. B. S., Buntting, C., Cakir, M., EL-Deghaidy, H., ElZorkani, A., Gaigher, E., Guo, S., Hakanen, A., Al-Lal, S. H., Han-Tosunoglu, C., … , Zhou, Q. (2019). An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline. *Journal of Research in Science Teaching*, *56*(4), 486–515. https://doi.org/10.1002/tea.21512

Lederman, J. S., Lederman, N. G., Bartels, S., Jimenez, J, Acosta, K., Akubo, M., Aly, S., Andrade, M. A. B. S., de Atanasova, M., Blanquet, E., Blonder, R., Brown, P., Cardoso, R., Castillo-Urueta, P., Chaipidech, P., Concannon, J., Dogan, O. K., El-Deghaidy, H., Elzorkani, A., … , Wishart, J. (2021). International collaborative follow-up investigation of graduating high school students' understandings of the nature of scientific inquiry: Is progress being made? *International Journal of Science Education*. 43, 991–1016. https://doi.org/10.1080/09500693.2021.1894500

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. https://doi.org/10.1002/tea.21125

Leonard, J., Boakes, N., & Moore, C. M. (2009). Conducting science inquiry in primary classrooms: Case studies of two preservice teachers' inquiry-based practices. *Journal of Elementary Science Education*, *21*(1), 27–50. https://doi.org/10.1007/BF03174714

Maneersriwongul, W., & Dixon, J. K. (2004). Instrument translation process: A methods review. *Journal of Advanced Nursing*, *48*(2), 175–186. https://doi.org/10.1111/j.1365-2648.2004.03185.x

Metin Peten, D. (2022). Influence of the argument-driven inquiry with explicit-reflective nature of scientific inquiry intervention on pre-service science teachers' understandings about the nature of scientific inquiry. *International Journal of Science and Mathematics Education*, *20*(5), 921–941. https://doi.org/10.1007/s10763-021-10197-8

Molefe, L., & Aubin, J. B. (2021). Exploring how science process skills blend with the scientific process: Pre-service teachers' views following fieldwork experience. *South African Journal of Education*, *41*(2), 1–13. https://doi.org/10.15700/saje.v41n2a1878
National Research Council. (2000). *Inquiry and the national science education standards*. National Academy Press.
NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.
Organization for Economic and Co-operation and Development. (2017). *PISA 2015 technical report*. OECD Publishing. http://www.oecd.org/pisa/sitedocument/PISA-2015-Technical-Report-Chapter-5-Translation.pdf
Organization for Economic Co-operation and Development. (2006). *Assessing scientific, Reading and mathematical literacy: A framework for PISA 2006*. OECD Publications.
Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 559–572). Routledge.
Schwartz, R. S., Lederman, J. S., & Enderle, P. E. (2023). Scientific inquiry literacy; The missing link on the continuum from science literacy to scientific literacy. In N. Lederman, D. Zeidler, & J. Lederman (Eds.), *Handbook of research on science education* (Vol. III, pp. 749–782). Routledge.

Appendixes

Appendix A: VASI questionnaire

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.
   (a) 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?'
6. Team A went back to the lab and tested various tires' performance on one type of road surface.
7. Team B went back to the lab and tested one tire brand on three types of road surfaces.
8. Explain why one team's procedure is better than the other one.
9. The data table below shows the relationship between plant growth in a week and the number of minutes of light received each day.

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

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:

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

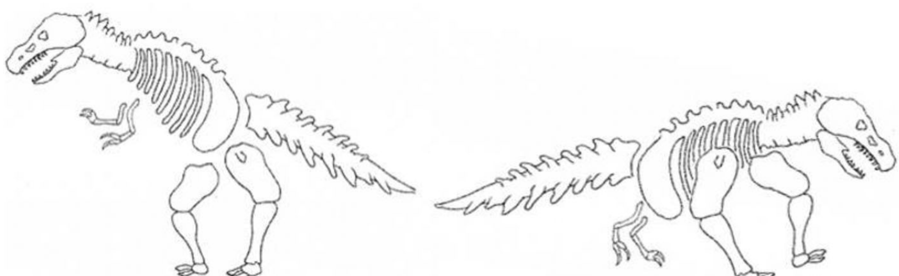

Figure 1 Figure 2

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?

Knowledge About Scientific Inquiry	VASI Item
Scientific investigations begin with a question	1a, 4a, 4b
Multiple designs can be used to solve scientific investigations	1a, 1b
Inquiry procedures are guided by the question asked	3, 4b
*Same procedures do not necessarily have same results	X
*Procedures can influence results	X
Conclusions must be consistent with data	2a, 2b
*Data and Evidence are not the same	X
Explanations are developed from collected from data and prior knowledge	2a, 2b

* These aspects about scientific inquiry are not assessed on the VASI-E because they were found to be too difficult for students of this age group to fully understand and/or experience.

Figure 1. *VASI-E Alignment.* * These aspects about scientific inquiry are not assessed on the VASI-E because they were found to be too difficult for students of this age group to fully understand and/or experience.

Appendix B: VASI-E questionnaire

1. There was a lady who travelled around the world looking at birds. She saw that birds had many different types of beaks. Some beaks were long and thin. Some beaks were short and tiny. Some were very big and thick. She also saw that birds ate many different kinds of food.

She asked, 'Is there a connection between the shape and size of birds' beaks and the types of food they ate?'

So then she went out and observed many more birds to try to answer her question.

(a) Do you think she was working like a scientist? Why or why not?

(b) Do you think she was doing an experiment? Why or Why not?

1. (a) How do scientists know that dinosaurs really lived if there are no dinosaurs around anymore and no one has ever seen them?
   (a) What do scientists think dinosaurs looked like? Why do they think they look this way?
2. Two groups of students wanted to see if different coloured crayons melted faster than other colours.
   *Group **A** put 3 different coloured crayons under one type of hot light.
   *Group **B** put red crayons under 3 different types of hot lights.

   Which group has the better plan? Explain why.

1. Here is a picture of different balls.

(a) If a friend picked up one ball and bounced it, would they be doing a science investigation? Explain why or why not?

(b) Describe a science investigation you could do with the balls.