Research in Science Education (2021) 51:1073–1091
https://doi.org/10.1007/s11165-020-09925-x

Do Not Just Do Science Inquiry, Understand It! The Views of Scientific Inquiry of Israeli Middle School Students Enrolled in a Scientific Reserve Course

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Published online: 23 March 2020

Abstract
Understanding the nature of science and scientific inquiry constitute foundation stones in scientific education in general and in scientific literacy in particular. Therefore, students must develop informed perceptions regarding science inquiry in order to be scientifically literate. The current study's purpose was to examine students' perceptions regarding science inquiry (SI). This would provide deep description of students' naïve and informed perceptions of SI, and also locate flawed thinking patterns regarding SI. The unique contribution of the research is expressed in both mapping the concepts about knowledge of scientific research in Israel and extracting and naming the concepts that the students have. The research population included 446 students in grades 7–8. This research chose a quantitative research approach. The study used a questionnaire called VASI (Views About Science Inquiry). This is a research questionnaire intended to diagnose students' perceptions regarding science inquiry. The study's findings indicate that most of the students do not develop informed understanding regarding the aspects of science inquiry. The aspects about which the students' have the most informed responses among the students are that the question motivates the inquiry and that the study's conclusions should match the data collected. The conclusion arising from the findings is that the students lack scientific perceptions regarding a significant proportion of the aspects of science inquiry, which raises the great importance of focused instruction of the aspects of science inquiry in class. Therefore, perhaps training teachers professionally to teach science inquiry directly in the classroom may develop the student's' scientific perceptions.

Keywords Nature of science · Scientific literacy · Scientific inquiry

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Introduction

An important goal of science education is to develop learners with scientific literacy. In other words, to prepare the citizens of the future to live in a society where science and technology occupy a significant place in public policy and in private life (OECD 2009; Lederman et al. 2014). One of the central goals of scientific education in grades 1–12 is developing the students' perceptions regarding science inquiry. However, understanding science inquiry is a research subject that is almost never studied by academics compared with research into the practical performance of science (Lederman et al. 2014, 2019). The concept nature of science (NOS) refers to the characteristics of scientific knowledge that are derived from the way in which scientific knowledge develops (Lederman 2006, Lederman et al. 2014). The concept science inquiry (SI) refers to the processes that scientists use that lead to the creation of new scientific knowledge (Lederman et al. 2014). The importance of knowledge about science inquiry was also expressed by the American Association for the Advancement of Science (AAAS), noting that students must acquire knowledge about science inquiry in order to become scientifically literate (AAAS 1990, 1993).

Science Inquiry

During the past century, science inquiry has stood at the center of science education. Science inquiry is the consistent process of asking questions about the nature of the world in order to discover and create new scientific knowledge (Gaigher et al. 2014; Lederman et al. 2014). Many studies conducted around the world show that junior high school students lack knowledge of science inquiry, such as a recent international research study performed in 18 countries about seventh grade students' understanding of science inquiry (Lederman et al. 2019). There too, it was found that the students had very little knowledge of science inquiry. Often, the learner's knowledge about science inquiry is not directly evaluated because it is assumed that students who conduct science inquiry in practice will also develop understanding about it. However, conducting science inquiry in practice is limited to activities that take place in the classroom, in an accessible atmosphere, and depending on resources such as time, space, and equipment. In contrast, focused instruction of knowledge about science inquiry is not restricted in this way and contributes to the development of scientific literacy (Gaigher et al. 2014).

Science Literacy and Its Contribution to Developing Scientific Abilities

Scientific literacy is identified according to the OECD (OECD 2009) as the individual's scientific knowledge and its usage to identify questions, acquire new knowledge, explain scientific phenomena, and formulate evidence based on conclusions about subjects related to science. Nuangchalerm (2010) defines scientific literacy as the ability to use scientific knowledge and the style of scientific thought for personal and social purposes. He claims that the focus on achieving scientific literacy derives from understanding the importance of the essence of science and the need to develop personal characteristics and to acquire skills and values that reflect the existing thought and scientific knowledge. Another significant layer that contributes to scientific literacy of the student is the knowledge of scientific inquiry (Gaigher et al. 2014; Lederman et al. 2014). In most education systems around the world, the purpose is to enhance citizens with scientific literacy, citizens who will be able to understand science, participate in political discussions related to science, and draw conclusions based on evidence (OECD 2009; Lederman et al. 2014). The purpose of the current study is to examine the perceptions of students about SI.

The importance of this study is that so far, according to Author and colleagues (Lederman et al. 2014), few studies have been conducted regarding SI. Therefore, the study's results may add to existing knowledge about the perceptions of students regarding SI. Moreover, it may contribute significantly to scientific Education and thus lead to students achieving scientific literacy. It is worth mentioning that one of the major goals of the Israeli science curriculum (Ministry of education 2018) is scientific literacy, based on the fact that science and technology are part of our daily life. Furthermore, they are essential for the existence, development of people and society in the modern world. Accordingly, it is necessary to develop technological and scientific literacy for the entire student population in all sectors as part of the general education required today and in the future.

In addition, the program maintains the unique character of each of the disciplines (science—including chemistry, biology, and physics; and technology, including engineering) and regarding the content (phenomena, processes, and principles) of each of these disciplines, and regarding the essence of science and technology and their methodological aspects. This science curriculum is mandatory in Israel, meaning, all the students in Israel learn science according to it. The special contribution of this work to the existing body of research is a mapping of student perceptions, or in other words, as opposed to previous work, we not only quantify perceptions but also give definitions of each one and what it entails.

Research Goal and Research Question

The goal of the current study was to give an updated picture of the perceptions of Israeli students regarding science inquiry and to locate their naïve thinking patterns about science inquiry.

Therefore, the study specifically asks:

How do Israeli students in STEM-oriented curricula present aspects of Scientific Inquiry as identified by the VASI framework?

The Research Question leads to revealing the perceptions of 7th and 8th grade students regarding science inquiry, and also false perceptions in understanding knowledge about science inquiry. The study's results, appearing below, are based on various aspects of science inquiry, on which the VASI questionnaire the students received was based, and on the question examining each aspect. The discussion section then focuses on three key aspects of science inquiry in considering the results and their implications.

Literature Review

Theoretical Framework for Understanding the Aspects of SI

The field of research about the perceptions of students regarding science inquiry is sparse. This results from the common perception that performing scientific research necessarily leads to understanding science inquiry out of understanding the nature of science (Lederman et al. 2014). Recent studies (Antink-Meyer et al. 2016; Gaigher et al.

2014; Mojekwu 2015), using the VASI questionnaire (Lederman et al. 2014), sketch a preliminary picture regarding students' perceptions about SI. The VASI questionnaire that was used in this study was developed from the VOSI questionnaire (Schwartz et al. 2008). The VOSI questionnaire included a collection of evaluation tools that were developed in order to assess students', teachers', and scientists' understanding about the essence of the science inquiry. The first version of the questionnaire included five open questions and was performed as a "paper and pencil" questionnaire examining five aspects of the science inquiry. The answers were classified as "not clear", "naïve", "knowledgeable", and "mixed". After the ranking and analysis of many responses and items in this questionnaire, it was determined that it did not evaluate the comprehensive list of the aspects of inquiry, as later defined in the VASI questionnaire. Therefore, it was decided that an updated version of the questionnaire was required, which led us to develop the present questionnaire—The VASI questionnaire.

Here is the theoretical framework constituting a foundation for understanding the aspects of SI, and the main perceptions found among students regarding the following aspects:

Scientific Investigations All Begin with a Question, but Do Not Necessarily Test a Hypothesis

Science inquiry in practice is embodied in several ways, including observation, conducting experiments, and collecting data for analysis (AAAS 1990; NRC 2000). Asking questions is necessary in order to develop scientific thinking habits. The ability to ask well-defined questions, even for people who do not eventually become scientists, is an important component of scientific literacy and will make them into critical consumers of scientific knowledge (Lederman et al. 2014).

There Is No Single Set or Sequence of Steps Followed in All Investigations

Scientists use different types of inquiry, based on the questions to which they are seeking answers. The inquiry types include describing objects, events, and organisms; classifying them; and conducting logical tests (experimentation) (AAAS 1990). Thus, "students should be given an opportunity to design and perform several different types of inquiry, including laboratory experiments and field observations" (ibid., 61). In accordance with this goal, following the focused teaching of this aspect in the classroom, it is recommended to check how well the students understand that there is no single scientific method for inquiry (NRC 2000). Sometimes, it appears, even if this is not stated directly, that science instruction in school is actually the scientific method, since there is an over-reliance on designing experiments.

Scientists Performing the Same Procedures Do Not Necessarily Obtain the Same Results

Science has a subjective component. In other words, ideas and observations in science are theory-dependent. Potentially, this fact has both positive and negative implications in scientific research (McComas 2008). Scientists are no different to other experts in their level of objectivity. They carefully analyze the evidence and procedures in order to reach conclusions (McComas 2008). Students have to understand that scientific data are not self-standing but can be interpreted in different ways (Lederman et al. 2014).

Inquiry Procedures Can Influence Results

The procedure selected for the scientific study can influence the results. The operation of variables, data collection methods, and the way the collected data are measured and analyzed—all these can influence the conclusions the researchers reach. For example, a common study in high school biology classes examines plants' root cells in order to identify cells in various stages of mitosis. The procedures the students employ undoubtedly influence the type of data they collect, and thus also the conclusions they reach. However, it is not sufficient that the students be skilled in analyzing and interpreting data, they also have to be capable of comparing the results obtained from different analysis systems produced through a range of science inquiry methods (Achieve Inc., NGSS 2013).

Research Conclusions Must Be Consistent with the Data Collected

Any research conclusion must be supported by the evidence arising from the data collected. The students have to understand that the strength of the scientists' argument is a function of the quantity of evidence supporting it. The validity of the arguments is also strengthened by the suitability of the research method to the research question. In other words, the arguments should be reflected in the data collected. Scientific knowledge has an empirical basis, and thus, all explanations are anchored in the data, which enables the scientists to develop them (Lederman et al. 2014). This idea is also included in the international standard document of the NGSS (Achieve, Inc., NGSS, 2013), which argues that students are supposed to establish explanations supported empirically and to deal with arguments derived from the evidence.

Explanations Are Developed from a Combination of Collected Data and What Is Already Known

Inquiries are founded upon existing knowledge and conclusions even if they are derived from empirical data and based on previous studies and scientific knowledge. Students engaged in scientific activities meeting the NGSS international standard should understand this. Also, they should understand that scientists have to recognize when there is a gap between conclusions with evidence and support and existing scientific knowledge. Scientists interpret their findings in light of what is already known and understood (Lederman et al. 2014). Therefore, scientists develop explanations while using observations (evidence) and what is already known to them about the world (scientific knowledge) (NRC 2000).

Scientific Data Are Not the Same as Scientific Evidence

Data and evidence have strictly different roles within science inquiry. Data are observations gathered by scientists during the research. They can take various forms, such as numbers, descriptions, photographs, audio recordings, physical samples. In contrast, evidence is the outcome of the data analysis and interpretation processes that follow the data, and directly related to specific questions and claims (Lederman et al. 2014)

Methodology

Research Approach

This study is a quantitative study that involved the interpretation of written responses in order to quantify the proportions of students with naïve and informed perceptions of SI. The students' answers on the questionnaires were verbose, and all the answers to a particular question regarding an aspect of SI were divided into six categories. The categories of this study were based on the categories developed in the VASI questionnaire. The study expands our insights and understanding of the mechanisms that explain the students' perceptions regarding SI using their replies to the questionnaire. All the answers to a particular question examining a specific aspect of SI were divided into six categories, with each category ranked from 1 to 6: categories 1–2 represented informed perceptions, categories 3–4 represented mixed perceptions, and categories 5–6 represented naïve perceptions (except in aspects 1 [question 3], aspect 6, and aspect 7, where there was a different division of categories). The categories were designed based on the students' answers and using the theoretical framework proposed by Lederman et al. (2014).

Research Population

The research population includes 446 students in the 7th and 8th grade studying in science reserve or scientific classes in junior high schools in the Jewish sector, 123 of the students were boys and 323 were girls. The schools were in the South (4 schools), Center (4 schools), and Jerusalem region (2 schools). All the students who participated in the research are part of a scientific reserve program. This is a program for excellence in science and technology aimed at increasing significantly the number and the level of students who graduate high school with a high-quality scientific-technological matriculation certificate. In order to achieve this goal, junior high school students with a potential for excellence in mathematics, technology, and science are exposed to a challenging and interesting program with a high level in science, technology, and mathematics. The unique curriculum includes enrichment in biology, chemistry, physics, technology, and mathematics. It is important to note that these are not enhancement students but ordinary students who have good achievements at the scientific subjects and who are directly to study the scientific orientations at high school, students in STEM-oriented curricula.

Research Tools

The study used a tool called the VASI (Views About Science Inquiry) questionnaire, developed by Lederman et al. (2014). This is a research questionnaire aimed at discerning students' perceptions regarding SI. In order to ensure the reliability of the research tool, it should be applied to a large number of respondents. The questionnaire is composed of eight open questions to which the students have to reply in answers ranging from one sentence to several paragraphs. Each of the eight questions deals with a particular aspect of SI where the students have to develop an informed understanding of science inquiry. The time available for answering is unlimited, but students usually finish the questionnaire in 30–45 min. In a preliminary study we conducted, in which we gave the VASI questionnaire to 100 seventh-grade students, we received for question 5, dealing with the aspect "Inquiry procedures are guided by the question asked", confused and incomprehensible answers from a few students, most of the students did not even answer this question. We decided to remove this question from the questionnaire. In retrospect, it turns out that it was a mistake to omit the question, and we should have left it in to examine the data in the entire chosen population.

Here are the aspects of SI on which the VASI questionnaire is based:

1. Scientific investigations all begin with a question, but do not necessarily test a hypothesis.
2. There is no single set or sequence of steps followed in all investigations.
3. Inquiry procedures are guided by the question asked.
4. Not all scientists performing the same procedures may get the same results.
5. Inquiry procedures can influence results.
6. Research conclusions must be consistent with the data collected.
7. Explanations are developed from a combination of collected data and what is already known.
8. Scientific data are not the same as scientific evidence.

Data Analysis

The questionnaire given to the students contains seven open questions. The students wrote their answers on the questionnaire, and after all the data were collected, we placed the student's answers into categories based on the categories developed in the VASI questionnaire. The distribution of the student's answers for each question was also examined.

The questionnaire used in the current study omitted the question dealing with the aspect: *The inquiry question guides the inquiry procedures* (question 5 in the original questionnaire, Lederman et al. 2014). The answers to the VASI questionnaire are of three types: informed answers, naïve answers, and mixed answers. 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" (Lederman et al. 2019).

Validity and Reliability

Validity

The VASI questionnaire was translated into Hebrew and the translation was validated by three scholars with a PhD in science pedagogy to arrive at a precise translation and formulation of the questionnaire. In addition, we used a procedure of back-translation. During the pilot, we conducted with the group of 100 7th grade students, we gave the students two versions of the translation of the questionnaire to check which phrases are suitable, and we had a discussion during the performance of the questionnaire in order to verify that they actually do understand the question. This study collected data using questionnaires distributed to 7th–8th grade students. The students' answers were analyzed using coding tables that phrased the categories for each question. Each answer was inserted into a given category. After the data collection process, in collaboration with the supervisor, the matching of the data received from the questionnaires and the perceptions phrased in each category was tested.

Reliability

The study gave the questionnaires to the students in their natural environment. The data published in research literature and the data gathered through the questionnaire were used to compose coding tables for each question. The table for each question contained six categories, each one representing a student's perception regarding the aspect of SI examined by that question. Each category includes a definition and examples of representative quotations. The data analysis in the categories was performed in parallel by the research supervisor and the researcher. At the end of each of the data analysis stages and the construction of the coding tables, a meeting was held with the supervisor to strengthen the reliability of the results. The inner reliability was determined by the three scholars mentioned above. They examined the students' answers by analyzing the questionnaires to verify that the categories, the student's answers, and the findings in the literature are adequate.

Findings

The findings below are arranged according to the seven aspects. N = naïve; M = mixed; I = informed.

> Aspect 1: *Scientific investigations all begin with a question, but do not necessarily test a hypothesis.*

This aspect was examined in questions 1a and 3, testing whether students understand that science inquiry starts with a question (Fig. 1).

The findings regarding the students' answers to question 1a and question 3 show an apparent contradiction. In question 3, most of the students (55.7%) had an informed perception regarding this aspect (categories 1–3). An example of this appears in the following statement:

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed birds that 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.

3. 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? Give an example.

Fig. 1 VASI questions regarding aspect 1

Table 1 Range of students' answers referring to the aspect "Scientific investigations all begin with a question, but do not necessarily test a hypothesis" (question 1a). $N = 420$

Category	Answers %
1. Controlled surroundings (I)	4.9
2. Question motivates inquiry (I)	7.8
3. Inquiry stages noted systematically (M)	15.4
4. Data collected systematically (M)	18.8
5. Faulty perception of science inquiry (N)	27.5
6. Studying connected variables is science inquiry (N)	19.5

"Yes, because we can't know what data to collect, what to compare, and what to conclude" (K2,49).

In other words, they believed that scientific inquiry must start with a scientific question. In contrast, in question 1a, only 12.7% of the students had an informed perception. An example of this appears in the following statement: "This experiment did not isolate the variables through which the person could examine the influencing factor, because he took different types of birds and different types of food, so we cannot know what influenced the results" (A2, 1). This means that they understood the nature of scientific questions in research. Tables 1 and 2 sample the range of students' answers referring to this aspect.

Aspect 2: There is no *single set or sequence of steps followed in all investigations.*

This aspect was examined in question1b and question 2, testing whether the students understood that science inquiry practice can be conducted in different ways (Fig. 2).

The findings from the students' answers to question 1b and question 2 show that the distribution of the answers to question 2 is similar to that of question 1b. Students' answers to question 2 show that 27.5% of the students had informed perceptions, meaning that they understood that science inquiry practice can be conducted using several methods. An example of this appears in the following statement: "I think so. You can do an observation and you can do an experiment, and apart from that you can present the inquiry in different ways. Inquiry A: the person did an experiment with two materials to test whether one reacted with the other, and was correct. This is how he answered his inquiry question. Inquiry B: The person observed the decomposition of the material under identical conditions for 3 weeks and reached the conclusion that they change shape" (J2,18). A total of 21.9% had naïve perceptions. An example of this appears in the following statement: "There are many methods: A. Inquiry

Table 2 Range of students' answers referring to the aspect "Scientific investigations all begin with a question, but do not necessarily test a hypothesis" (question 3). $N = 393$

Category	Answers %
1. Inquiry question blends with specific knowledge (I)	6.7
2. The question motivates inquiry (I)	37.6
3. Scientific inquiry involves setting a question and finding an answer (I)	11.4
4. The scientific question is essential for planning the experiment (M)	13.0
5. The inquiry process is systematic (M)	2.9
6. Scientific inquiry does not have to start with a question (N)	16.3

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

2. Do you think that scientific investigations can follow more than one method?
   a. If no, please explain why there is only one way to conduct a scientific investigation.
   b. If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

Fig. 2 VASI questions regarding aspect 2

operating according to all stages of inquiry. B. Inquiry using different sources of information" (A2,14). Students' answers to question 1b show that 38.3% of the students had informed perceptions. An example of this appears in the following statement: "The researcher observed different types of birds, he didn't do or plan anything. He observed, so it's not an experiment" (J2,12). A total of 25.3% had naïve perceptions. An example of this appears in the following statement: "Yes, because observing birds is considered an experiment" (A2,20). Tables 3 and 4 sample the range of students' answers referring to this aspect.

Aspect 3: *Not all scientists performing the same procedures may get the same results.*

This aspect was examined in question 4a, asking whether the students understand that performing similar procedures does not necessarily lead to the same results (Fig. 3).

The findings show that most of the students have a naïve perception regarding this aspect, meaning that they believe that similar data collection procedures necessarily lead to the same results; example of this appear in the following statement: "Yes, because if they did the same things they should reach the same conclusions, because each question usually has one correct answer" (H1,9). Table 5 shows the range of students' answers referring to this aspect.

Aspect 4: *Inquiry procedures can influence results.*

This aspect was examined in question 4b, testing the students' perceptions about the influence of the inquiry procedures over the results of the inquiry and the conclusions drawn from it (Fig. 4).

The findings show that most of the students (43.6%) have an informed perception regarding this aspect. An example of this appears in the following statement: "Not necessarily, because their actions were different and it's possible that despite the identical

Table 3 Range of students' answers referring to the aspect: there is no single set or sequence of steps followed in all investigations (question 1b). $N = 426$

Category	Answers %
1. Experiment-controlled surroundings (I)	12.3
2. External intervention (I)	26.0
3. Science inquiry as observation (M)	18.1
4. Experiment as a process of science inquiry (M)	13.6
5. Faulty reference to experiment as science inquiry (N)	20.8
6. Observation is an experiment (N)	4.5

Table 4 Range of students' answers referring to the aspect: *there is no single set or sequence of steps followed in all investigations* (question 2). $N = 322$

Category	Answers %
1. SI includes multiple methods with special features (I)	9.6
2. Multiple methods in science inquiry (I)	17.9
3. Multiple methods in science inquiry (some incorrect) (M)	16.1
4. Fixed structure of science inquiry (M)	6.5
5. There is only one method-controlled experiment (N)	3.6
6. There is only one method/there are multiple methods (all incorrect) (N)	18.3

question studies can go in different directions and their conclusions can be different" (E1,7). Some of the students (18.6%) have a naïve perception regarding this aspect. An example of this appears in the following statement: "Yes, the answers in nature are fixed, it's like solving an arithmetic exercise (one answer in different ways), for example: the distance between the earth and the sun is fixed" (D1,5). Table 6 samples the range of students' answers referring to this aspect.

Aspect 5: *Research conclusions must be consistent with the data collected.*

This aspect was examined in question 5, testing whether the students understood that the study's conclusions should be consistent with the data collected (Fig. 5).

The findings show that most of the students had an informed perception regarding this aspect. An example of this appears in the following statement: "Answer B, because according to the table, 0 minutes of light give the highest height and the more the light increases, the lower the height" (D2,23). In contrast, a few students had a naïve perception about this aspect, meaning that they referred only to previous knowledge about photosynthesis and not to the data the researcher gathered (which appeared in the table), or argued that there was no connection between growth and light, despite the data appearing in the table. An example of this appears in the following statement: "Answer C because the data are that the plant's growth changes without any connection to the minutes of light each day" (M2,36). Table 7 samples the range of students' answers referring to this aspect.

Aspect 6: *Explanations are developed from a combination of collected data and what is already known.*

This aspect was examined in question 6, testing whether the students had a scientific perception whereby a scientific explanation develops from including new data with previous knowledge (Fig. 6).

4 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

Fig. 3 VASI questions regarding aspect 3

Table 5 Range of students' answers referring to the aspect: *all scientists performing the same procedures may not get the same results* (question 4a). $N = 416$

Category	Answers %
1. The influence of the researcher's interpretation on the experiment's results (I)	22.8
2. Different results stemming from different information sources. (I)	2.7
3. Different results stemming from different research conditions. (M)	10.7
4. Different results stemming from different data. (M)	4.5
5. Different results stemming from errors (N)	12.5
6. Similar procedures = identical results (N)	39.8

The findings show that one third of the students (33.6%) had naïve perceptions regarding this aspect. An example of this appears in the following statement: "Because it's more logical that animals' legs would be thick and large and would connect to the hip. It's more logical that animals' arms would be thin and shorter and connect to the ribs. B. In pictures and movies about dinosaurs" (C1,30). Table 8 samples the range of students' answers referring to this aspect.

Aspect 7: *Scientific data are not the same as scientific evidence.*

This aspect was examined in question 7, examining whether the students understand the differences between scientific data and scientific evidence (Fig. 7).

The findings show that 42.1% of the students had a naïve perception regarding this aspect. An example of this appears in the following statement: "Evidence—a thing that you can see and that can be debated, data—a thing that is given and cannot be debated" (J2, 1). Table 9 samples the range of students' answers referring to this aspect.

Discussion

This research intends to diagnose students' perceptions regarding science inquiry. The study's findings indicate that most of the students do not develop informed understanding regarding the aspects of science inquiry during middle school. We have chosen to discuss the findings for three central aspects in relation to the curriculum in Israel: Aspects 3 and 6, which are not covered by this curriculum, and aspect 5. Israeli students are often exposed to questions relating to this aspect during their science studies in middle school. The discussion of the study is presented according to selected aspects of SI.

Aspect 3: Scientists performing the same procedures do not necessarily obtain the same results.

4. 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.

Fig. 4 VASI questions regarding aspect 4

Table 6 Range of students' answers referring to the aspect: *inquiry procedures can influence results* (question 4b). $N = 376$

Category	Answers %
1. Different inquiry procedures create different databases (I)	3.4
2. Different procedures lead to different conclusions (I)	43.6
3. Different results stemming from different data (M)	4.7
4. Different results stemming from different interpretations (M)	5.6
5. Different results stemming from different conditions (N)	8.3
6. Only one possible result (N)	18.6

The current study found that the common perception among the students was that similar procedures in science inquiry practice necessarily lead to identical results. In other words, the students believed that science was objective and not subject to interpretation resulting from the scientists' own views and areas of knowledge. These findings are consistent with the research

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 per week)
0	25
5	20
10	15
15	5
20	10
25	0

a. Given these data, explain which of the following conclusions you agree with. Plants grow taller with more sunlight.

Plants grow taller with less sunlight.

Or

The growth of plants is unrelated to sunlight.

b. Why did you select this conclusion?

c. Are the data what you expected? Why or why not?

Fig. 5 VASI questions regarding aspect 5

Table 7 Range of students' answers referring to the aspect: *research conclusions must be consistent with the data collected* (question 5). $N = 437$

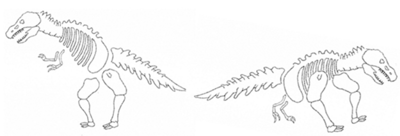
Category	Answers %
1. The data are consistent with the conclusions (with explanation) (I)	52.1
2. The data are consistent with the conclusions (no explanation) (I)	20.6
3. The plant's growth relates to various factors (M)	2.5
4. Reference to exception data (M)	6.3
5. No connection between growth and light (N)	12.3
6. Reference to previous knowledge (photosynthesis) (N)	4.0

literature (Antink-Meyer et al. 2016; Mojekwu 2015) and were supported by studies conducted in China Zhejiang, China Shanghai, China Beijing, Egypt, and France (Lederman et al. 2019) as shown in Table 10. We could say that this naïve approach probably results from the way science and SI are treated in the written and digital media.

The findings of the current study also show that less than one third of the students had an informed perception whereby the researcher's interpretation influences the experiment's results. This finding can be explained by the fact that students are rarely exposed to examples of different interpretations of the same dataset, since science classes hardly ever teach the skills of interpreting results. Furthermore, the science procedure taught in class commonly leads the students to just one conclusion, and often, there is no room for different interpretations of the results of science inquiry in the processes of teaching and learning science inquiry (Bell et al. 2003). Also, the students are not usually exposed, during their studies, to the history of science, and, hence, do not know how science develops and builds. The history of science presents many examples of interpretations of the same dataset. Studies conducted regarding the connection between the history of science and the understanding of the nature of science have shown that students learning the history of science have better understanding of the nature of science (Monk and Osborne 2006).

Aspect 5: The study's conclusions should be consistent with the data collected.

The fossilized bones of a dinosaur have been found by a group of scientists. The scientists put the bones together into two different possible arrangements.



a. Describe at least two reasons why you think most of the scientists agree that the animal in *skeleton 1* had the best positioning of the bones?
b. Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?

Fig. 6 VASI questions regarding aspect 6

Table 8 Range of students' answers referring to the aspect: *explanations are developed from a combination of collected data and what is already known* (question 6). *N* = 427

Category	Answers %
1. Inquiries are guided by existing knowledge about dinosaurs (I)	13.4
2. Inquiries are guided by existing knowledge about animal anatomy (I)	11.9
3. Internal logic about external features and general scientific knowledge (M)	12.1
4. Internal logic about external features and non-scientific knowledge that makes sense (M)	24.6
5. Reference to the physical dimension only, without explanation or connection to science or dinosaurs (N)	20.6
6. Faulty arguments regarding the arrangement of bones and the sources of information / no source of information (N)	13.0

In the current study, the students were requested to choose an appropriate conclusion from the table of data resulting from a scientific experiment dealing with photosynthesis. The study's findings show that most of the students (72.7%) had an informed perception regarding this aspect, meaning that they understood that the study's conclusions should be consistent with the data collected.

These findings are consistent with the research literature. Gaigher and colleagues (Gaigher et al. 2014) found that 60% of students had an informed perception regarding this aspect and were supported by studies conducted in Australia, Germany, and Taiwan (Lederman et al. 2019) as shown in Table 11, which have had similar trends. Presumably, most Israeli students had mastered this aspect of SI because the question appearing in the questionnaire is very similar to many questions appearing in nationwide examinations such as the Meitzav, TIMSS (Mullis and Martin 2014), and PISA examinations (OECD 2009). The students are familiar with the practice of this type of question.

Aspect 6: Explanations develop from the inclusion of new data collected with previous knowledge.

The study's findings indicate that most commonly of the students had no experiences of analogies and exposure to different types of inquiry from the worlds of geology, archeology, and paleontology. In other words, the students did not understand the process of developing scientific knowledge in the world—a combination of data collected with existing knowledge from various fields. The students wanted to express their general knowledge about dinosaurs. They understood the question more as a type of "what can I learn about dinosaurs" rather than "what can I learn about scientists studying dinosaurs". These findings were supported by studies conducted in England and Sweden (Lederman et al. 2019) as shown in Table 12. The fact that children are exposed to dinosaurs in the electronic and written media can explain the

7. Please explain if "data" and "evidence" are different from one another.
Give an example to "data":____
Give an example to "evidence":______________________________________

Fig. 7 VASI questions regarding aspect 7

Table 9 Range of students' answers referring to the aspect: *scientific data are not the same as scientific evidence* (question 7). $N = 343$

Category	Answers %
1. Evidence and data—correct definitions with/without concrete examples (I)	3.6
2. Evidence is proof (correct definition of data) (I)	6.7
3. Evidence—in the context of crime (correct definition of data) (M)	16.3
4. Evidence—in the context of vision (correct definition of data (M)	8.1
5. Evidence = data (N)	3.6
6. Faulty evidence and data (N)	38.5

students' diversion from discussing the question about research into dinosaurs to understanding what would be good for dinosaurs. The implications of these conclusions show that it is worth including interdisciplinary instruction in science teaching, such as the instruction of geology and archeology. Also, it is important to expose the students to actual studies and inquiry processes that the scientists conduct when attempting to develop new scientific knowledge.

Similar trends were found in Israel regarding the aspects of inquiry discussed above, although the populations examined were different: students studying in an ordinary class (Lederman et al. 2019), and STEM-oriented students in this research. It is possible to explain this in light of the fact that the teaching of science inquiry practice in Israeli junior high schools does not present aspects of scientific inquiry directly. In the formal document of the Israeli Ministry of Education about the process of scientific research "Learning Through Research – focused teaching of the scientific inquiry skills – measurements, observation and experiment" (Ministry of Education 2018), the main purpose of the document is described as: "internalizing of thought skills (asking questions, making assumptions, comparing, analyzing results, drawing conclusions, generalizing, writing an argument, presenting and representing information, identifying reason and result relations)". Then, the logical use of these in the process of scientific inquiry requires an awareness and planned integration of focused teaching of these skills in ordered spiral learning on the continuum of ages from the 1st to 9th grade. All the students in Israel are exposed to the process of the scientific inquiry and to thinking skills derived from it but do not learn about the knowledge of scientific inquiry directly, hence the naïve conceptions of the students.

Table 10 Set of data from each country/region for aspect 3 (Lederman et al. 2019) compared to the current study

Aspect 3: scientists performing the same procedures do not necessarily obtain the same results				
Country/region	*n*	N	M	I
China Beijing	166	57.8	31.3	8.4
China Shanghai	106	57.8	38.8	2.4
China Zhejiang	106	50.0	11.3	33.0
Egypt	109	51.0	23.0	23.0
France	109	47.0	38.0	3.0
Israel	92	46.4	17.8	20.7
Israel—current study	446	52.3	15.2	25.5

Table 11 Set of data from each country/region for aspect 5 (Lederman et al. 2019) compared to the current study

Aspect 5: the study's conclusions should be consistent with the data collected.

Country/region	*n*	N	M	I
Australia	108	24.0	21.0	52.0
Germany	96	28.1	19.8	52.1
Taiwan	167	24.5	22.8	49.7
Israel	92	24.3	21.7	44.2
Israel—current study	446	16.3	8.8	72.7

Summary

In this study, an attempt was made to map and examine the perceptions of middle school students in Israel based on the understanding of the importance of knowledge of scientific inquiry to produce students who are literate in the sciences. This unique contribution provides precise classification of the perceptions expressed in each aspect. Through these perceptions, it is possible to discover naïve perceptions the students have regarding their understanding of SI, and they can also serve as a foundation for developing curricula and other pedagogical tools for focused instruction of the aspects of science inquiry both Israel and other countries in the world.

The common assumption that students who learn scientific contents and skills and who experience scientific activities in laboratories will demonstrate understanding and knowledge of scientific inquiry has been weakened. This is supported by this study as well as other studies around the world (Antink-Meyer et al. 2016; Gaigher et al. 2014; Lederman et al. 2014; Lederman et al. 2019; Mojekwu 2015), which have examined students' perceptions about scientific inquiry using the VASI questionnaire (Lederman et al. 2014) whose questions are based on aspects of scientific inquiry. The results of this study found that students in Israel who learn in STEM-oriented classes lack knowledge and understanding of scientific inquiry in many aspects of scientific inquiry. Similar findings received in an international collaborative investigation of students' understanding of scientific inquiry (Lederman et al. 2019) reveal that grade seven students have very little understanding about scientific inquiry.

A significant insight that arises from this study is that learning scientific contents and scientific activities in depth and on a wide scale, such as in the Israeli curriculum, does not necessarily lead to scientific literacy. It seems that in order to reach a change in students' perceptions about scientific inquiry, it is worth specifically designing focused learning opportunities in the classroom about the aspects of scientific inquiry. It is advisable that these opportunities emphasize the way scientific inquiry develops with concrete examples from the

Table 12 Set of data from each country/region for aspect 6 (Lederman et al. 2019) compared to the current study

Aspect 6: Explanations develop from the inclusion of new data collected with previous knowledge.

Country/region	*n*	N	M	I
England	103	24.3	48.5	1.9
Sweden	126	36.5	20.6	8.7
Israel	92	46.0	30.1	15.2
Israel—current study	*n*	N	36.7	25.3

history of science that are connected to the contents learned in class. It seems that learning about how scientists work can produce informed perceptions about the aspects of scientific inquiry. One likely approach is for teachers to train professionally to design learning experiences about SI to develop the students' scientific perceptions in order to be scientifically literate citizens.

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