INTERNATIONAL STUDY OF SEVENTH GRADE STUDENTS' UNDERSTANDINGS OF SCIENTIFIC INQUIRY: THE CASES OF ISRAEL AND SOUTH AFRICA

Rachel Mamlok-Naaman, Ron Blonder
Department of Science Teaching. Weizmann Institute of Science. Israel.
rachel.mamlok@weizmann.ac.il
Estelle Gaigher
Department of Science, Mathematics and Technology Education. University of Pretoria. South Africa.
Estelle.Gaigher@up.ac.za
Anne-marie Hattingh, Gillian kay
School of Education. University of Cape Town. South Africa.

ABSTRACT: Although understanding of scientific inquiry (SI) is included in science education reform documents around the world, virtually nothing is known about middle school students' understandings of scientific inquiry. This is partially due to the lack of any valid assessment tool. However, a valid and reliable assessment has recently been developed and published. The Views About Scientific Inquiry [VASI]) (Lederman et. al., 2014). The purpose of this international project was to acquire the first baseline data on what middle school students know. In many countries, science is not formally taught until middle school, which is the rationale for choosing seventh grade students for this investigation.

KEYWORDS: Scientific Inquiry; Assessment; Knowledge of Inquiry

OBJETIVES: Currently there is an agreement among Science Education's researchers that one of the main objectives of Scientific Literacy is that all students have a better understanding of Scientific Inquiry or SI (Abd-el-khalick, 2014; Crawford, 2014). According to Schwartz, Lederman, and Crawford (2004), SI is related to the specific aspects of the process of development of scientific knowledge, including the conventions for the acceptance and utility of scientific knowledge. SI in Science Teaching is evidenced directly in pedagogical proposals that adopt research as models of teaching and learning.

Lederman, Lederman, Bartos, Bartels, Meyer, and Schwartz (2014) published the VASI questionnaire – The Views about Scientific Inquiry. In this work, the researchers presented the elaboration, development and analysis of a questionnaire that evaluates the students understanding of SI. The authors list eight aspects that Basic Education students should develop about SI. These aspects were elaborated by the reformulation of previous data collection instruments and new theoretical studies, resulting in an open questionnaire with seven questions about SI. The eight aspects are:

(1) scientific investigation always begins with a question, and does not necessarily test a hypothesis; (2) there is no single set of steps followed in all investigations (i.e. There is no single scientific method); (3) inquiry procedures are guided by the question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry procedures can influence results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and (8) explanations are developed from a combination of collected data and what is already known (Lederman et al, 2014, p. 68).

SAMPLE, METHOD, DATA COLLECTION AND ANALYSIS

Case of Israel

The students were from four classes in two high schools located in the central part of Israel. All students were between 12 and 13 years old (7th grade), from middle to upper socioeconomic levels, with good reading comprehension abilities. Each student was given a VASI to complete in a 60-minute time period. The VASI was given in the students' language of science instruction. After administration of VASI, the responses were coded by the contact people for each country. Each student was given a code of Naïve, Mixed or Informed for each aspect of SI. When assessing each aspect of SI, views were categorized into one of four categories: informed, mixed, naïve, and unclear. 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 labeled as "informed". If, by contrast, a response was either only partially explicated, and thus not totally consistent with the targeted response, or if a contradiction in the response was evident, a score of "mixed" is given. A response that was 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". Lastly, for scores that were incomprehensible, unintelligible, or that, in total, indicated no relation to the particular aspect, a categorization of "unclear" was assigned. At least 20% of the students were interviewed to ensure that the coding of the VASI was accurate. The interviews were recorded and transcribed. The inter rater reliability of the VASI was 80% or better for each site.

The Department of Science Teaching at the Weizmann Institute of Science is in charge of Four National Centers for Science - the National Center for Biology Teachers, the National Center for Chemistry Teachers, the National Center for Physics Teachers, and the National Center for Junior High School Teachers. In addition, the department of science teaching leads a special MA program (Rothschild-Weizmann program) for science teachers, and in-service professional development courses. We approached a few science teachers who participate in the academic or in the professional development courses at the Department of Science Teaching at the Weizmann Institute of Science and told them about the VASI survey. Two of the teachers who work in schools which function as junior high and high schools as well (grades seven to twelve) were chosen to take part in the survey. The main reasons were: the schools are located in the central part of Israel, and may serve as representatives of our country: the schools contain a heterogeneous population of students, from middle to upper level socioeconomic levels.

Case of South Africa

The sample was purposefully and conveniently selected from primary schools in two South African cities. Two large cities, Cape Town and Pretoria, were conveniently selected as the researchers are employed at universities in these cities. Cape Town and Pretoria have very different ethnic populations;

Pretoria is in the North of the country, having a majority Black population, while Cape Town is in the South having a large coloured population.

Three schools were selected to obtain a sample of approximately 100 learners. The selection of schools was purposeful, to represent learners from lower middle class families, and to include learners from all race groups. The final sample consisted of 106 learners, 45 from Cape Town and 61 from Pretoria. The Pretoria site had two schools with a majority of Black learners and a small number of Coloured, White and Asian learners. The Cape Town site had one school with a majority of Coloured learners and a small number of Black and White learners. In the two Pretoria schools, most learners were not English first language speakers. However, all the learners preferred to use the English questionnaire even though translations into five African languages were available. The learners from the Cape Town school were mostly from English speaking homes.

The extremes that characterize the South African population are not included, as the large black rural population and the upper classes are not represented. Instead, the sample represents the urban lower middle class. The differing compositions of the samples at the two sites reflect the racial profiles of the two cities. However, the Pretoria site is a more accurate reflection of the South African population.

The data from the two sites were combined to merge the diversity in the two cities. Taken separately, results may be a misrepresentation of ethnic influences in the two cities due to the non-random sampling. The data were coded by three researchers, two in Cape Town and one in Pretoria. All questionnaires were electronically exchanged to enable researchers to discuss learners' answers and reach consensus during the initial stages of coding.

The data were coded by four members from one department. Each student was given a VASI to complete in a 60-minute time period. The VASI was given in the students' language of science instruction. After administration of VASI, the responses were coded by the contact people for each country. Each student was given a code of Naïve, Mixed or Informed for each aspect of SI. When assessing each aspect of SI, views are categorized into one of four categories: informed, mixed, naïve, and unclear. If a respondent provides a response consistent across the entire questionnaire that is wholly congruent with the target response for a given aspect of SI they are labeled as "informed". At least 20% of the students were interviewed to ensure that the coding of the VASI was accurate. The interviews were recorded and transcribed. The inter rater reliability of the VASI was 80% or better for each aspect.

RESULTS AND CONCLUSIONS OF CASE OF ISRAEL

The science curriculum for junior high schools in Israel (6^{th} - 8^{th} grades) includes mainly biology topics, and emphasizes the nature of science as well as inquiry procedures and skills. We therefore believed that quite a lot of students were correct about some categories, but when interviewing a few students who answered the questionnaire (in order to triangulate the data which they received), we found out that they just repeated what they were told in class, rather than really understanding the issue.

Around 45% of the students claimed that "Procedures are guided by the question asked", around 22% of the students claimed that "Procedures influence results", and around 18% claimed "Same procedures may not get the same results". It was difficult to draw conclusions from these findings. In addition, the students' answers during the interviews were very dull. Most of the interviewed students said that "It is self-evident", or "The scientists need to plan according to what they would like to achieve"… The interviews did not convince us that the students really understood what they answered in the questionnaire.

Many students were less sure about "Begins with a question". The teachers interviewed a few students, and following is an exemplary answer:

> "Scientists may do various experiments in their laboratories with the materials and instruments which they have, and see what they get. They do not necessarily invent a question".

Around 43% claimed that "Conclusions consistent with data collected". During the interviews they were asked if they referred to "Data collected" or "Data analysis", and they did not know how to differentiate between the two. However, only around 17% of the students claimed that "Data does not equal evidence", only around 15% claimed that using multiple methods for the same research questions may lead to the same conclusions. In addition, only 15% answered that "Explanations are developed from data and what is already known". During the interviews they tried to explain the meaning of data/evidence, but they were quite confused about it. We could conclude that they learned these concepts, but did not really assimilate them correctly.

Our assumptions are described above. However, we concluded that the inquiry approach to teaching and learning is not done in a thorough way. To our opinion, the inquiry concepts were somehow "transmitted" in a declarative way, and the inquiry procedures were somehow neglected. As mentioned above, the curriculum emphasizes the nature of science as well as inquiry procedures and skills, but no doubt the teachers need better preparation in order to cope with this subject.

RESULTS AND CONCLUSIONS OF CASE OF SOUTH AFRICA

The aspect 'Procedures are guided by the question asked' was poorly understood, showing 30 % informed views and a high naïve count of 55%. 'Data does not equal evidence' was very poorly understood, showing only 18% informed views and a high naïve count of 58%. Least understood was 'Explanations are developed from data and what is already known', showing only 16% informed views. Best understood was 'All investigations start with a question', indicated by 48% informed views. 'Multiple methods' was also poorly understood with 24% informed views. 'Same procedures may not get the same results' was poorly understood, indicated by 26% informed views combined with a high naïve count of 57%. 'Procedures influence results' was better understood showing 38 % informed views whereas 'Conclusions consistent with data', was second best understood, showing 46% informed views.

Learners in the current study were best informed on straightforward aspects such as 'All investigations begin with a question' and 'Conclusions must be consistent with data collected'. More complex aspects involving human imagination and creativity, such as 'Multiple methods' 'Same procedures may not get the same results' and Procedures are guided by the question asked' were poorly understood. This trend may be understood in terms of the South African curriculum, as explained below. Also, the poor understanding of 'Data does not equal evidence' may be understood in terms of inadequate vocabulary due to second language usage.

Over the past 20 years, education in South Africa has been subject to three curriculum changes, seeking a balance between learning content and skills development. Throughout the curriculum changes, conducting investigations remained a focus, although the reality of poorly trained teachers often limits opportunities for learners to conduct investigations. Nevertheless, throughout the changes, the curriculum and textbooks have placed a strong emphasis on asking questions, collecting data and making conclusions. It is therefore plausible that teachers emphasize these ideas even though learners themselves seldom have opportunities to engage practically in inquiry. Therefore, learners may develop some unexpected understanding of some inquiry aspects emphasized by the curriculum, as argued in an earlier South African study using Grade 11 learners (Gaigher, Lederman, & Lederman, 2014).

REFERENCES

Abd-El-Khalick, F. (2014). The Evolving Landscape Related to Assessment of Nature of Science. In Lederman, N.G. Lederman and Abell, S.K. (Eds.), *Handbook of Research in Science Education*, Volume II. (pp. 621-650). New York, NY, USA: Routledge.

Crawford, B. (2014). From Inquiry to Scientific Practices in the Science Classroom. Lederman, N. G., & Abell, S. K. (Eds.). *Handbook of Research on Science Education* (Vol. 2). Routledge. (pp. 515–542).

Gaigher, E, Lederman, N., & Lederman, J. (2014) Knowledge about Inquiry: A study in South African high schools, *International Journal of Science Education*, 36:18, 3125-3147, DOI: 10.1080/09500693.2014.954156

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.

Schwartz, R. S., Lederman, N., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and science inquiry. *Science Education, 88*, 610-645.