Chemistry Teachers’ Views about Scientific Inquiry: A Study in East Java Province of Indonesia

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Abstract. Scientific inquiry is a part of scientific literacy which is probably one of the main goals of science education. This paper reports a preliminary study on chemistry teachers’ understanding about scientific inquiry carried out using a Questionnaire of Views about Scientific Inquiry (VASI) with background of chemistry knowledge. Sample of the study is 32 chemistry teachers of senior and vocational high schools. Results showed that (1) the chemistry teachers held more informed views than science teachers reported in the previous study and (2) the pattern of chemistry teachers’ understanding about aspects of scientific inquiry is the same as senior high school students’ understanding. These indicate that (1) the complexity of learning material people learned may be influences their inference ability and (2) the first year university chemistry students’ understanding of scientific inquiry are the strengthening of the perception they get from their teachers when they were school students.

1. Introduction

Scientific inquiry has became a perennial focus of science education. Scientific inquiry refers to the combination of general science process skills such as such as observing, inferring, classifying, predicting, measuring, questioning, interpreting and analysing data with science content, creativity, and critical thinking to develop scientific knowledge [1,2]. Various reform school curriculums (e.g., [4-9] emphasize the development of students’ ability to do scientific inquiry.

The National Science Education Standards (NSES) describes scientific inquiry as ‘diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work’ [3]. While [10] differentiates three meanings of scientific inquiry, i.e., what scientists do (e.g., conducting investigations using scientific methods), how students learn (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a pedagogical approach that teachers employ (e.g., designing or using curricula that allow for extended investigations). However, whether it is the scientist, student, or teacher who is doing inquiry, the activity of scientific inquiry has several core components. The NSES describes these core components from the learner's perspective as "five essential features of classroom inquiry" (Table 1) [4].
In school curricula, scientific inquiry is essential to development of a scientific-literate population [11]. Scientific literacy requires an understanding of the processes of science or knowledge about scientific inquiry [3, 1]. There is an international consensus about the aspects of scientific inquiry that should be learned by students [12]. [1] identified eight aspects of scientific inquiry: (1) all scientific investigations begin with a question and do not necessarily test a hypothesis; (2) there is no single scientific method; (3) inquiry procedures are guided by a 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. These aspects were used as the framework for development of the views about scientific inquiry (VASI) questionnaire, i.e., an instrument used to assess respondents’ understandings about scientific inquiry.

In Indonesia, the ideal of a scientifically literate population is one of the visions embraced by the minister of education and culture when launched the applied curriculum of 2013 in 2012. Following the educational reforms, some researches on scientific inquiry and scientific literacy were undertaken in Indonesia [13-17]. These researches showed that respondents have limited exposure to doing inquiry and understanding about scientific inquiry. However, no research among reported above involves respondents of chemistry teacher and using chemical knowledge-based VASI questionnaire. The current paper aims to investigate Indonesian chemistry teachers’ understanding about scientific inquiry using chemical knowledge-based VASI questionnaire, to provide a baseline of chemistry teachers’ knowledge about scientific inquiry, and to interpret results in terms of Indonesian reform curricula. Such a baseline could inform Indonesian policy-makers in future planning towards developing teachers’ knowledge about inquiry. This may enhance chemical literacy of the chemistry teacher, improve their performance in science and science instruction, and ultimately contribute to improve chemical literacy of Indonesian young generation.

Scientific Inquiry in Indonesian School Curricula of 2013

The new curriculum, known as the School Curricula of 2013, was developed in response to the development of education and society, one of which was the low scientific literacy achievements of Indonesian students in the survey of Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) [6]. The low achievement of scientific literacy is due in part to differences between the competencies assessed in TIMSS and PISA and the competencies set by the Indonesian curriculum. The 2013 curriculum is designed to produce Indonesian students who are faithful, productive, creative, innovative and affective and able to contribute to the life of the society, nation, state and world civilization. To achieve this goal the 2013 curriculum specified three dimension of learning outcomes: attitude, knowledge, and skills [8]. The learning outcome of scientific knowledge is described as follows:

The students have factual, conceptual, procedural, and metacognitive knowledge at the level of technical, specific, detailed and complex with regard to science, technology, art, culture, and the humanities and are able to relate that knowledge to the context of themselves, family, school, the surrounding community and natural environment, nation, state, and regional and international regions.

The statement of learning outcome "has factual, conceptual, procedural, and metacognitive knowledge ... and is able to relate that knowledge to the context of self, society and natural environment ..." is a hallmark of scientific literacy [18].

The 2013 curriculum suggests a scientific and thematic approach as an official instructional approach and discovery/inquiry-based instruction as an instructional strategy [9]. Scientific inquiry approach is the use of scientific inquiry as a pedagogical approach [10]. The scientific inquiry approach of instruction, known as the process standards, establishes five principal of students’ learning experiences [7] which are observing, asking questions, investigating, associating, and communicating.
The detail of these students' learning experience of the process standards and their correspondence with "five essential features of classroom inquiry" [4] is shown in Table 1.

**Table 1.** Correspondence between the process standards [7] and the essential features of classroom inquiry [4].

| Features of classroom inquiry [4] | Process standards [7] | Students’ activities |
|----------------------------------|-----------------------|----------------------|
| Observe                          | Read, hear, pay attention, and see (with or without tools) |
| Learners are engaged by scientifically oriented questions | Ask question(s) | Asking questions, can also be hypotheses, which will be solved through investigation (survey or experiment) |
| Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions | Investigate | Reviewing of literatures (reading resources other than textbooks); observing objects / events / activities; interviewing resource persons; doing experiments |
| Learners formulate explanations from evidence to address scientifically oriented questions | Associate | Processing the collected data; explaining evidence; deepening and extending the constructed knowledge; comparing conclusions and explanations constructed by the inquiry with those written in the textbook or other sources |
| Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding | | |
| Learners communicate and justify their proposed explanations | Communicate | Presenting observations, conclusions, and explanations orally, written, or other means |

2. **Method**

This research applied a cross-sectional survey design [19] in which the researchers collect data on the respondents' understanding about scientific inquiry at a certain time. The research instrument was an open-ended questionnaire of views about scientific inquiry (VASI) on chemistry knowledge (Appendix). This questionnaire was adapted from the similar questionnaire of biological knowledge developed by [1]. Content validation, face validation, and construct validation had been conducted to the original instrument. Table 2 presents the distribution of eight scientific inquiry aspects in seven open-ended questions.

The research on chemistry teachers' understanding about scientific inquiry was carried out using a survey technique. The survey was conducted to the 32 of chemistry teachers consortium of Trenggalek Regency, East Java. All of respondent teachers have teaching experienced more than 5 years and come from senior and vocational high schools.

Data analysis is carried out by grouping respondents' answers based on their suitability with the VASI assessment rubric (Table 3). Respondents' answers are grouped into three categories that indicate the level of understanding, namely (1) naive; (2) partially informed; and (3) informed.

**Table 2.** The Distribution of Scientific Inquiry Aspects in VASI Questionnaire

| Number of Items | Scientific Inquiry Aspect No | Description |
|-----------------|-----------------------------|-------------|
| 1a, 1b, 1c      | 2                           | There is no single scientific method |
| 1a, 2           | 1                           | Scientific investigations all begin with a question, but do not necessarily test a hypothesis |
| Number of Items | Scientific Inquiry Aspect No | Description                                                                 |
|-----------------|-----------------------------|-----------------------------------------------------------------------------|
| 3a              | 4                           | All scientists performing the same procedures may not get the same results   |
| 3b              | 5                           | Inquiry procedures can influence the results                                |
| 4               | 7                           | Scientific data are not the same as scientific evidence                      |
| 5               | 3                           | Inquiry procedures are guided by the question asked                         |
| 6               | 6                           | Research conclusions must be consistent with the data collected              |
| 7               | 8                           | Explanations are developed from a combination of collected data and what is already known |

Data analysis is done by grouping respondents' answers to their suitability with the VASI assessment rubric (Table 3). Respondents' answers are grouped into three categories indicating the level of understanding, namely (1) naive; (2) partially informed; and (3) informed.

**Table 3. Example of Scoring Rubric of Items of VASI Questionnaire with Chemistry Knowledge Background**

| Inquiry Aspect | Categories |
|----------------|------------|
| **Question number** | Informed | Partially Informed | Naïve |
| There is no single scientific method | | | |
| 1 | The following three answers must be appropriate: | Only contains one of the following mistakes: | Problem 1c is answered with, “Yes, there is one scientific method only.” |
| 1a | Yes, the investigation is scientific since it aims to explain the natural phenomena | - | Or: contains more than one mistake, for example, the question number 1b is answered with, “yes, experiment,” and number 1c is answered with, “Both examples are experiments or non-experiments.” |
| 1b | No, it is not experiment as there is no manipulation of variable | Yes, it is experiment | |
| 1c | Yes, investigation can follow different methods: experiment, practice or action research, observation, literary or theoretical study, and survey | No, there is one investigation method generally applied | |
| | Showing two examples of investigation methods, one following the experimental design and the other a non-experimental design | Or: showing two examples of experimental design | |
| | All scientists performing the same procedures may not get the same results | Or: showing two examples of non-experimental design | |
| 3a | The difference in the scientists’ background and knowledge could cause the different interpretation to | The condition of imperfect experiment | The same procedure always results in similar outcome |
| | | | |
3. Results and Discussion

The 2013 curriculum was developed in response to an international survey of students' scientific literacy. Therefore this curriculum places scientific literacy as one of the learning outcomes. As part of scientific literacy, knowledge about scientific inquiry is automatically also to be one of school learning outcomes. In addition, students' understanding about scientific inquiry helps them develop their knowledge of scientific literacy, including chemical literacy.

In designing scientific inquiry-based instruction, teachers need to have a good understanding about scientific inquiry. Therefore, the development of teacher professionalism requires adequate information regarding their understanding about scientific inquiry. This article presents the results of a survey on chemistry teachers' understanding about scientific inquiry conducted using a VASI questionnaire. Figure 1 shows the result.

Figure 1 shows that: (1) most of chemistry teachers had the uninformed (partially informed and naïve) understanding about scientific inquiry aspects; (2) the lowest understanding was the aspect of "the same procedures may not result in the same conclusions"; and (3) the highest understanding was the aspect of "procedures are guided by the question". The chemistry teachers' understanding about each aspect of scientific inquiry are described as follows.

**Aspect 1: Scientific investigations all begin with a question**

Observation is part of a scientific investigation, but observation without guiding question is not a scientific investigation [1]. [4] asserted that scientific investigations involve debriefing process and comparing obtained answers with already-known knowledge. Scientific investigation always involves asking and answering questions, and comparing the obtained answers with knowledge understood by the scientific community [4]. The majority of chemistry teachers (69%) have a correct understanding of the role of questions in scientific inquiry. They understand that scientific inquiry must begin with questions to guide inquiry in achieving its goals. Nineteen percent of teachers have an understanding that scientific inquiry begins with observing natural phenomena. While the other thirteen percent of teachers have not been able to provide sufficient reasons for their answers.

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### Inquiry Aspect Categories

| Question number | Informed | Partially Informed | Naïve |
|-----------------|----------|--------------------|-------|
| Inquiry procedures can influence the results | the same data so that it results in different outcome | could cause different result | |
| 3b. | Different procedure would result in the various data that will produce unlikely results | Different results are mainly caused by the unsimilar interpretation | There is only one investigation result that is possibly out of its procedure |

The results of identification and categorization of respondents' answers are then described in accordance with the measured of VASI aspects.
Figure 1. Chemistry teachers' understanding about scientific inquiry aspects
Aspect 2: There is no single scientific method
There were various scientific methods that can be used in scientific investigation. There was no single scientific method that commonly used for all types of investigation. The majority of chemistry teachers (75%) have an understanding that scientific investigations can be carried out with various methods. They also understand that investigation and experiment are two different scientific methods. Experiments examine the relationships between variables while investigations do not have to examine the relationships between variables. Experiment is a part of the investigation [1,20], it is an investigation that involves variable manipulation. There is only one teacher (3%) who states that scientific investigation can only be done by one method.

Aspect 3: Inquiry procedures are guided by the question asked
The majority of chemistry teachers (78%) have an understanding that investigation procedures are developed based on question asked. There are no chemistry teacher has understanding with the naïve category. Some teachers (22%) have understanding with the partially informed category.

Aspect 4: All scientists performing the same procedures may not get the same results
Scientists may come to different interpretations of the same data [1]. Therefore, two scientists working on the same procedure may end up with different results. This difference according to 47% of chemistry teachers was caused by human error. This understanding is the partially informed category. Other teachers (44%) have the understanding that different scientists who carry out the same research procedure must produce the same or identical conclusions. This understanding is in the naïve category. The rest (9% of chemistry teachers) have an understanding with informed category; the differences of conclusion of research conducted by different scientists are caused by the differences of the scientists' background and point of view.

Aspect 5: Inquiry procedures can influence the results
All scientific investigation procedures–modifying variables, collecting data, measuring and analysing variables–could influence investigation’s conclusions and results [1]. The majority of chemistry teachers have an understanding that the investigation procedure does not affect the results. This naïve category of understanding is owned by 56% of chemistry teachers. Conversely, only 19% of teachers can provide the right reasons why the results of the investigation are influenced by the procedures used. While 25% of the others could not provide an explanation so that it was included in the partially informed category.

Aspect 6: Research conclusions must be consistent with the data collected
As many as 46% of teachers understand that concentration is directly proportional to the rate of reaction, but they have not been able to provide an explanation. This understanding is partially informed category. Only 26% of teachers were able to provide complete explanation, while other 26% gave statements only without providing evidence or supporting theory.

Aspect 7: Scientific data are not the same as scientific evidence
Scientific data are observations collected by scientists during investigation, while evidence is the result of evaluation, analysis, and interpretation of the collected data [21,1]. The number of chemistry teachers who have understood this concept is 28%. They are able to explain the difference between scientific data and scientific evidence. The majority of teachers (47%) have partially informed view. They are able to distinguish between the scientific data and the scientific evidence, but they can not be able to show what is the reason. Some of them have an understanding that scientific evidence is the result of experiments in the laboratory, while scientific data is product of the literature review. Some have an understanding that the data can be changed so that it requires further testing, while the scientific evidence has been tested and can not be changed. While the remaining (25%) have a naïve category understanding, they have the perception that scientific evidence is identical to the scientific data and can not be distinguished one another.

Aspect 8: Explanations are developed from a collected data and what is already known
As scientists did, students also should be able to explain the natural phenomena or data that are related with the phenomena by using already-known scientific knowledge [1]. The number of chemistry teachers who have understanding with the informed category is 39%. They are able to provide the right
answers with appropriate data and theory support. Forty-five percent of teachers understand the position of the data in constructing explanations, but they have not been able to explain the role of the theory. This understanding is classified as partially informed. Whereas the remaining (16%) have not been able to provide appropriate statements and reasons about the provided data so it is more suitable to be classified into naïve category.

The aspect of scientific inquiry that is well understood by chemistry teachers is the third aspect, namely inquiry procedures are guided by the question asked. The number of teachers who have an understanding with the informed category is 78% and no teacher has a naïve category. This aspect is basically how researchers develop investigative procedures. With more than 5 years of teaching experience, teachers certainly have the understanding and skills to develop investigation procedure well. Moreover, they implement the Curriculum of 2013 which places scientific inquiry as the official instructional approach.

The weakest understood of scientific inquiry aspect is the fourth aspect, which is all scientists performing the same procedure may not get the same results. The number of teachers who have an understanding with the informed category is only 9%. This aspect is not easy to understand, because it involves the assessment of respondents to the scientists. Two different scientists can provide different interpretations to the same data [1]. This can be caused by the educational background and the mindset of scientist. Of course, the results of social research are far more varied than the results of science research. This is due to the differences of each scientists' points of view.

Table 4. The Comparison of the Percentage of Respondents Having the Informed View of Scientific Inquiry Aspects in Any Research

| Researchers    | Respondents            | % The Lowest Informed Aspect | % The Highest Informed Aspect | Mean |
|----------------|------------------------|-----------------------------|-------------------------------|------|
| [1]            | Class 8                | 1                           | 6                             | 5.75 |
| [20]           | Class 11               | 2                           | 6                             | 4.40 |
| [24]           | Class 8-9              | 7                           | 0                             | 2.30 |
| [17]           | Class 11               | 7                           | 3                             | 2.96 |
| [16]           | Natural Sciences       | 5                           | 0                             | 2.68 |
| Teachers       |                        |                             |                               |      |
| [22]           | First Year- University | 4                           | 8                             | 3.50 |
| This research  | Chemistry Teachers     | 4                           | 9                             | 3.78 |

Overall, the chemistry teacher's understanding of aspects of scientific inquiry is not satisfactory. Their average score is 42.58 from a maximum of 100. However this score is much higher than the average score of the science teacher's aspects of scientific inquiry scores (16.88 of the maximum score 100) [16] (Table 4). The score is also better than the average score of first-year university chemistry students (35.00 of the maximum score of 100) (Muntholib et al., 2018). Another interesting finding is the similarity of aspects of scientific inquiry with the highest and lowest average scores between chemistry teachers and first-year university chemistry students. The lowest respondents average score is the aspect of 'the same procedure may not result in the same conclusions', while the highest respondents average score is the aspect of 'procedures are guided by the question asked'. This shows that the understanding of scientific inquiry of the first year chemistry students of semester 2 is the strengthening of the perception they get from their teachers at school study. The first-year university chemistry students' achievement (average score of 35.00) is higher than the senior high school students' achievement (average score of 29.69). In the university, the students get feedback and reflection from their experience in doing inquiry in secondary education. The feedback and reflection they received in lecturing refined and improved their understanding of scientific inquiry. Reinforcement, feedback, and structured instruction are components of effective instruction [23].
4. Conclusion and Recommendation

Our survey originally aimed to establish a baseline of chemistry teachers’ knowledge about scientific inquiry and therefore the data collected do not provide information about how this understanding developed. It was a surprising result to find that respondents are reasonably well informed compared with the previous evidence that science teachers’ knowledge about scientific inquiry were very-low [16]. However, chemistry teachers’ knowledge about inquiry does not develop through their engaging in investigations but rather through the discussion among them. It is therefore possible that chemistry teachers may develop informed views about inquiry from discussions with others and literatures without their engagement in inquiry activities. We believe that the existence of scientific approach as process standards in instruction of the school curricula of 2013 may have prompted many teachers to discuss, in an attempt to teach the curriculum. If this is the case, our result can be explained in terms of teachers’ engagement in discussions even though they may not have had opportunities to undertake investigations themselves.

The results of our study have important implications for the development of scientific literacy. The achievement of informed views about scientific inquiry may be also a realistic target for poorly resources education. Research on how knowledge about inquiry actually develops in classrooms should be undertaken, and the effects of a non-laboratory scientific inquiry approach may be of particular interest.

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Appendix: Example of Items of Views About Scientific Inquiry (VASI) Questionnaire

The following questions ask for your view about Science and Scientific Inquiry. There is no right or wrong answer.

1. A person who is interested in the nature of material observes the boiling point of petroleum compounds (hydrocarbons). He notes that compounds with relative molecular masses (Mr) which are relatively close each other, have adjacent boiling points. For example, at room temperature, all compounds of LPG (relative molecular mass of 16-58) are gas; all of the premium constituent compounds (relative molecular mass of 72-156) are liquids; and all wax constituent compounds (relative molecular mass of 242-482) are solids. The person is wondering, is the boiling point of...
hydrocarbons related to the relative molecular weight? To answer it he collects the boiling points of various hydrocarbon compounds. After analyzing the data that can be collected, he concludes that the boiling point of the hydrocarbon compound is related to the relative molecular weight of the compound.

(a) What is your opinion? Is the investigation conducted by the person stated in the passage included in scientific investigation?
   i) If it is “yes”, Explain, why it is included in scientific investigation!
   ii) If it is “not”, Explain, why it is not included in scientific investigation!

(b) If in point (a), you answer “yes”, is the investigation carried out by that person included in experiment?
   i) If it is “yes”, Explain, why it is included in experiment!
   ii) If it is “not”, Explain, why it is not included in experiment!

(c) What is your opinion? Can scientific investigation be only undertaken using one type of scientific method?
   i) If it is “yes,” Explain, why there is only one scientific method that could be used to conduct scientific investigation!
   ii) If it is “not,” please show two investigations with different methods! Explain the difference of both scientific methods and why both of them are considered scientific investigation!

2. (a) If some different scientists ask for “the same scientific question” and collect data using “the similar procedure (working mechanism),” will they obtain the same conclusion?
   i) If it is “yes,” explain your reason!
   ii) If it is “not,” explain your reason!

(b) If some different scientists ask for “the same scientific question” and collect data using “the different procedure (working mechanism),” will they obtain the same conclusion?
   i) If it is “yes,” explain your reason!
   ii) If it is “not,” explain your reason!