Science Teachers’ Understanding of Scientific Inquiry In Teacher Professional Development

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Abstract. Inquiry is a main goal of science education reform around the world. This study investigated science teachers’ understanding of scientific inquiry in teacher professional development program. The content of the program was focused on the nature of science and scientific inquiry. The program was conducted once in a week, every Saturday for 4 weeks, so it took about 30 hours. Twenty five science teachers from 3 districts with 5-25 years’ experience were followed this program. Views About Scientific Inquiry modified was administered to all participants before and after TPD. VASI consists of 8 questions: 1) Scientific investigations all begin with a question and 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) 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. Then, all responses are categorized as informed, partially informed, and naive. Results indicated that most of science teachers were not have good understanding of scientific inquiry. 30 hour teacher professional programs led to small measurable enhancements in teachers’ understanding of scientific inquiry. Based on these findings, preservice and in-service program should focus on science education reform include scientific inquiry.

1. Introduction
Inquiry-based learning is a main focus in science education include science curriculum in Indonesia. Science education program inquiry-based is a main focus of National Science Education Standards and Project 2061’s Benchmarks for Science Literacy (Colburn, 2000). Even though inquiry is considered as a science teaching process, many teachers do not apply in their classroom. Lederman (2009) stated that inquiry is a complex concept and have facets and nuances so teachers confuse about inquiry meaning. Reasons for teachers do not apply inquiry in their classroom are their believe that inquiry just for students with upper ability, teachers need more time to prepare inquiry-based teaching, inquiry is difficult to manage, and there is a tend to teach science fact, and the objective of science is to prepare for continuous learning (Colburn, 2000). The research of science teachers at Bandung area Indonesia showed the similar results. Teachers’ views that the main objective of science learning was concept understanding so the students passed in national exam, inquiry teaching need more time, and teachers believe that their students could not yet to follow inquiry-based learning (Adisendjaja, 2010). Basic abilities that students need to do inquiry are propose a natural phenomenon question, plan and do investigation, use equipment’s to collect data, use data to develop explanation, communicate explanation investigation and explanation (NSES, NRC, 1996). These components indicate that
scientific investigation begin with a question then plan investigation to answer question followed by data collecting and analyses to make an evidence-based conclusion. Science education reform around the world emphasize on science development that consistent to scientific practices and constructivist perspective (Hodson, 1998; Driver et al., 1996; NRC, 1996; AAAS, 1993). The National Science Education Standards [NSES] (NRC, 1996) stated that students must develop understanding what science is and what is not science, science do and not science do, and how science contribute to culture. Without values understanding and assumption of knowledge and its process, learners develop a small image science that consists of isolated facts and avoid contexts that science relevant and can be applied (Lederman, 1998; Schwab, 1962). Reform endeavor should continue to valid science curriculum from philosophical aspects (Hodson, 1988) and develop learner epistemology of science (Schwartz et al. 2004).

Scientific inquiry refers to characteristics of scientific knowledge development includes consensus in development, receiving, and using of scientific knowledge (Schwartz, et al. 2004). Inquiry needs assumption identification, use logical and analytical thinking and judge alternative explanation (NRC,1996). Scientific inquiry consists of many methods in scientific investigation (myth of scientific method), scientific investigation understanding in relation to present knowledge, argumentation role in new knowledge development and receiving, data anomaly understanding, the difference between data and evidence, group review role and communication in negotiated scientific knowledge in social order (Buxner, 2014).Students should understand scientific inquiry aspects include (Lederman, et al. 2014): 1) scientific investigation do not need test a hypothesis, begins with question, 2) many methods in scientific investigation, 3) scientific procedure is guided by a question, 4) scientists perform the same procedures will not reach the same result, 5) inquiry procedure affects results, 6) conclusion should be consistent to collected data, 7) scientific data different from scientific evidence, 8) explanation is developed of collected data and what has been known.

2. Problem
Based on background information above, the problem is “how teachers understanding’s about scientific inquiry before and after teacher professional development?”

3. Method
The impact of Teacher Professional Development(TPD)on teachers understanding’ of scientific inquiry is the objective of this research. So the assessment was applied before and after TPD as pretest and posttest. Science teachers’ views were explored by modified Views About Scientific Inquiry Questionnaire (VASI) (Lederman, 2009; Lederman et al. (2014). The rule of pretest and posttest referred to Lederman, et al. (2002), then, all answer were checked then grouped to informed, partially informed and naive category refers to Abd-El-Khalick & Akerson (2009). Some science teachers were interviewed to avoid misinterpretation during checking the answer so can lead to misleading conclusion. After finish check all responses, all answers were classified to informed if the answer parallel to constructivist view’ about science; partially informed if part of an answer parallel to constructivist view’ but still has unparalleled to science contemporor; naive category if answer was unparalleled to science contemporor view’. Then, each category was percentage.

4. Participant
Twenty five science teachers consist of 23 women and 2 men participated in TPD come from three districts at Bandung area West Java Indonesia. Their experience teaching was between 5-30 years. Twenty teachers graduated from science teachers’ bachelors, 2 teachers have master degree in science education, 2 teachers in environmental science, and one teacher from social science. TPD was conducted at Biology Education Department, Indonesia University of Education, in every Saturday for 4 weeks from 08.00 am-17.00 pm exclude homework 2.5 hours each week.
5. Results and Discussion
The results before and after TPD are summarized at table 1. Before TPD, science teachers’ knowledge about scientific inquiry was not satisfaction. They did not understand what is scientific investigation, kinds of investigation or not, is a method viewed as a scientific or not, the relationship among question, procedure, and conclusion, the differences between scientific data and scientific evidence.
After TPD, nearly all the percentage of scientific inquiry aspects increased for informed category, except for scientific evidence, method is viewed as a scientific procedure, and data collected to support conclusion did not improve. The increment was around 5% to 60%, and no one aspect of scientific inquiry decreased. The biggest increasing was the relationship between same question and same procedure with conclusion was 60% followed experiment as a method and scientific data were 40%. Other aspects increasing were 5% to 30.0%. The increasing result for informed category after TPD did not mean the decreasing of naive category. The results showed that decreasing nearly in all aspects of scientific inquiry except scientific evidence and information were needed to support their finding. Both aspects in naive category increased 5% and 10% after TPD. It is showed in Figure 1. Even though naive category decreased, it did not mean change to be informed category, part of naive category change to partially informed category.
Some aspects decreased for partially informed were experiment as a method, conclusion for the same question and the same procedure, scientific data and evidence. Two aspects of scientific inquiry increased for partially informed category were scientific investigation (5%) and scientific investigation can followed more than one method (30%), a method was viewed as scientific (75%), scientific question (15%), conclusion for the same question but different procedure (25%), and conclusion consistent with data (15%). Decreasing of naive category followed by increasing of partially informed indicated that respondents have not understood yet about scientific inquiry.
5.1. Scientific investigation
Scientific investigation consists of four questions, no one of respondents give answer in informed category for question 1a, 1c, and 1d. Only 25% respondents answered for 1b question in informed category (Table 1). These results indicate that science teachers have not yet understand about scientific investigation. Respondents answered that an investigation was scientific if followed “scientific method” with orderly steps. All science teachers stated that investigation (in discourse) was not scientific because it did not follow scientific methods and did not do experiment. This statement is a main misconception. A scientific investigation begin with question and answer question through data analysis and then give explanation based on evidence that collected through observation (Bell, Maeng, Peters, 2013). In relation to scientific investigation, only 25% respondents answered correctly to kinds of method. Lederman (2004, 2009)defines experiment if there is a manipulative variable and planned to find out cause and effect relationship. Experiment includes manipulation or observe natural world to test hypothesis (Lawson, 1995).
The first question related to scientific investigation consists of four sub questions, the first three questions can be answered by 70% respondents appropriately. However, they could not give accurate reason. Ninety percent of science teachers did not give answer to the question that was viewed as scientific investigation, so nearly all (90%) respondents belong to naive category. These results showed that science teacher not understand that an investigation is scientific. It means there was a tendency that respondents did not understand characteristics of investigations. To develop scientific understanding of learners, they should have experience and guidance to do explicit reflective model context to topic (Abd-El-Khalick & Lederman, 2000). If teachers have understanding and can teach science inquiry-based, they can help students learning inquiry-based science as curriculum suggested. Teachers should help students to learn inquiry through problem-based investigation to learn concepts specific. To train teachers in inquiry, they need actively engaged in laboratory activity to answer a question (McBride et al., 2004).
Table 1. Science teachers’ understanding on scientific inquiry before and after TPD

| No | Aspect of Scientific Inquiry                                                                 | Informed | Partially Informed | Naive |
|----|--------------------------------------------------------------------------------------------|----------|--------------------|-------|
|    |                                                                                             | Pre | Post | Pre | Post | Pre | Post |
| 1. | Is that investigation scientific? (Yes: 90.0%, No: 10.0%)                                    | 0.0 | 10.0 | 75.0 | 80.0 | 25.0 | 10.0 |
|    | Is that investigation an experiment? (Yes: 30.0%; No: 70.0%)                                   | 25.0 | 65.0 | 40.0 | 20.0 | 35.0 | 15.0 |
|    | Is scientific investigation can follow more than one method? (Yes: 85.0%; No: 15.0%)           | 0.0  | 15.0 | 35.0 | 65.0 | 65.0 | 20.0 |
|    | Whether that method can be viewed scientific? (No response: 90.0%; Yes: 10%)                  | 0.0  | 20.0 | 5.0  | 80.0 | 95.0 | 0.0  |
| 2. | Is scientific investigation always begins with scientific question? (Yes: 70.0%; Not: 20.0%; Yes/No: 10.0%) | 10.0 | 25.0 | 25.0 | 40.0 | 65.0 | 35.0 |
| 3. | If question and procedure are the same, are scientists reaching the same conclusion? (Same conclusion: 10.0%; different: 90.0%) | 15.0 | 75.0 | 45.0 | 25.0 | 40.0 | 0.0  |
|    | If questions are the same but procedures different, whether scientists reach the same conclusions? (Same conclusion: 55.0%; Different: 30.0%; Same/Different: 15.0%) | 0.0  | 5.0  | 15.0 | 40.0 | 85.0 | 55.0 |
| 4. | Are scientific data same with scientific evidence? (Same: 5.0%; Different: 95.0%)               | 40.0 | 80.0 | 20.0 | 0.0  | 40.0 | 20.0 |
|    | Scientific data                                                                               | 35.0 | 40.0 | 20.0 | 20.0 | 45.0 | 40.0 |
| 5. | Questions guide procedure.                                                                    | 35.0 | 40.0 | 20.0 | 20.0 | 45.0 | 40.0 |
|    | A better than B (75.0%).                                                                     | 90.0 | 95.0 | 0.0  | 0.0  | 10.0 | 5.0  |
|    | B better than A (10.0%).                                                                     | 40.0 | 45.0 | 10.0 | 15.0 | 50.0 | 40.0 |
|    | Not A or B (15.0%).                                                                          | 40.0 | 45.0 | 10.0 | 15.0 | 50.0 | 40.0 |
| 6. | Conclusions must consistent with data collected. (Conclusion A: 95.0%; B: 0.0%; C: 5.0%).        | 50.0 | 80.0 | 40.0 | 15.0 | 10.0 | 5.0  |
|    | reason refers data                                                                           | 0.0  | 5.0  | 55.0 | 40.0 | 45.0 | 55.0 |
All aspects of scientific investigation in informed category increased around 10-40%. The biggest increasing was experiment as a method. It is showed by their answered in posttest that investigation in discourse was not an experiment. However, this understanding did not occur to all respondents, only 65% respondents answered in informed category. Respondents still lack of understanding for scientific of investigation and scientific definition. Respondent understanding about method was limited to only one method, experiment so when facing to other method respondent can not answer. This view as is caused by scientific method understanding, where experiment is one step of scientific method.

5.2. Scientific investigation begins with question
Seventy percent respondents answered that scientific investigation begin with question and 20.0% did not need scientific question and 10.0% answered may begin or not begin with scientific question. From 70% respondents who answered that scientific knowledge begin with scientific question, only 10% included to informed category. Before TPD, only 10% teachers belong to informed category and most of them did not understand the role of question in an investigation.
Respondents’ answer on whether scientific investigation begins with question was not satisfied. There was 30% decreasing in naive category from 65% to 35%, however it was not change to informed but it was changed to partially informed category. These results showed that respondents have not understood yet about the role of question in an investigation. Question roles were to identify reasons to do an investigation, to search information and to synthesize of finding and evaluate conclusion (Lewis, 2014). Many of respondents answered that hypothesis must be answered in an investigation, not a question. This view was possibly come from scientific method misconception. After TPD, 40% respondents answered that investigation begin with scientific question to guide, direct, and focus investigation to reach conclusion. An investigation depends on question proposed (NRC, 2000). Students should have experience to design and to do different investigation include laboratory experiment and field observation (NRC, 2012). By doing these activities, teachers and students will understands that investigation have more than a method and direct experiences.

5.3. The same procedures may not results same conclusion
To the question whether scientists will get a same conclusion if they have same questions and same procedure? Ninety percent respondents answered will not get the same conclusion and only 15% of them belong to informed category. However, if the procedures are different, 55.0% respondents answered that scientists will get the same conclusion, 30% answered will get different conclusion and the rest (15%) may get the same or different conclusion and from those answered no one belong to informed category.
The next question is the relation between procedure and conclusion consists of two questions (Table 1). The first question increased 60% from 15% before TPD to be 75% in informed category. However, for the second question where the procedures different, respondents have not yet determined the conclusion. It was showed by their answer that only 5% increased. Naive category decreased 30% from 85% to 55%, however it was not increasing informed category but it was changing to partially informed category.

After TPD their reason more correct that conclusion possibly different although their question and procedures were same because of the differences of their education, experiences, ability, social and culture, scientists’ point of view, and scientists’ interest. Before TPD many of respondents have known that conclusion not only depend on data, many factors affect conclusion. Data can be interpreted in many ways so scientists have different interpretation from the same data (Osborne, et al., 2003). Scientists have same data and follow same procedure can reach different conclusion Lederman, et al., 2014). The most reasons that respondent from informed category, stated were the differences of experience, education, and culture. Scientist can be affected by culture, believe, interest, background, previous theory (Ozgelen, Yilmaz-Tuzun & Hanuscin, 2013).

5.4. Procedure affects results
When respondents were asked how the conclusion if question was the same but procedures different, their answered are same conclusion were 55%; different conclusion were 30% and same/different: 15%. These results showed that respondents have not understand yet that procedure will affect conclusion. Procedure was chosen affect results differently. Variable optimization, methods, variable measurement and method of data analysis affect results (Lederman, et al., 2014). After TPD, the increasing for this aspect only 5%, most of answers belong to partially informed. This result indicated that respondents did not understand what factors will affect an investigation conclusion. To improve respondents’ understanding on this problem, teachers and student need more exercise in different methods of investigation include laboratory experiment and field observation.

5.5. Procedure inquiry guided by question
To evaluate respondents’ understanding about relation between procedure and research question, respondents asked to choose one of two design A or B that agree with research question and they asked to explain their reasons.

Seventy five percent of science teachers exactly chose design A that presenting in table 1 question no 5, however their reason only 35% belong to informed category. The rest 20% include to partially informed category and 45.0% for naive category. The increasing after TPD was only 5%, from 35% to 40% for informed category. These results indicated that science teacher did not understand how to construct an experimental design and procedures. They could not make a design that appropriate with research question. Even though scientists present different procedure to answer the same question, procedures must answer research question (Lederman, et al., 2014).

5.6. Scientific data and scientific evidence
Ninety five respondents answered that scientific data and scientific evidence are differ, however their answered only 40% and 15.0% belong to informed category for data and evidence respectively. Forty percents for data and 70.0% for evidence belong to naive category. After TPD, improvement happened on scientific data from 40% to 80% for informed category. To scientific evidence there was no improvement. These results showed that respondents have not yet understand about scientific evidence. Respondents have not yet understood the differences between scientific data and scientific evidence. It is important to remember that data are theory-laden, it is not separate from previous theory or information (Crowther, Lederman & Lederman, 2005). Therefore the differences of scientific data and evidence should be discussed explicitly and need reflection after practical work finish.
5.7. **Conclusion must consistent with data collected**

Ninety five percent respondents exactly draw conclusion and 90.0% of this belong to informed category. However, if their conclusion should indicate or referred data only 40% belong to informed category and 50% to naive category. These results indicated that science teachers have not yet understand how to read data or relate data and their conclusion. This finding same as previous result that only half high school students able to identify, describe and explain based on data (Sadler, Chambers & Zeidler, 2004). After TPD, the increasing only 5% from 40% to 45% for informed category. They think that all data must support their conclusion. If there is an anomaly data or a data did not agree with their thinking even though most data are appropriate, they thing data were not support their conclusion. They had a notion that all data must support their conclusion, no data deviate.

5.8. **Explanation developed of combination data collected and previous information**

For the last question about relationship between investigation results and information were needed to support their finding, all respondent exactly chose conclusion and the best structure of possible Dinosaurs fossil. However, if their choice and conclusion relate to their reason only 50.0% of respondents belong to informed category. If their choice relate to what information was needed to support their conclusion, no one gave properly answered. Fifty five of respondents belong to partially informed and 45% belong to naive category. After TPD, increasing only 5% in informed category.

6. **Conclusions**

Before TPD, respondents’ views on scientific inquiry can be summarized as follows, 1) ninety percent respondents did not give answer to the question whether a method is viewed as scientific, 2) ninety percent respondents give answer that even do the same question and the same procedures, scientist will not have the same question, 3) ninety five respondents agree that conclusion should be consistent with data collected.

After TPD, nearly all the percentage of scientific inquiry aspects increased for informed category, except for scientific evidence, method is viewed as scientific, and data collected to support conclusion did not improve. The increment was around 5% to 60%, and no one aspect of scientific inquiry decreased. The biggest increasing was the relationship between same question and same procedure with conclusion was 60% followed experiment as a method of inquiry and scientific data were 40%. Other aspects increasing were 5% to 30%. The increasing for informed category after TPD did not mean the decreasing of naive category.

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