Evidence of The Importance of Philosophy of Science Course On Undergraduate Level

Suyono

1 Chemistry Department of Faculty of Mathematics and Science, Universitas Negeri Surabaya, Surabaya, Indonesia
suyono@unesa.ac.id

Abstract. This study aimed to describe academic impact of Philosophy of Science course in change of students’ conceptions on the Nature of science (NOS) before and after attending the course. This study followed one group pretest-posttest design. Treatment in this study was Philosophy of Science course for one semester. Misconception diagnostic tests of the NOS had been developed by Suyono et al. (2015) equipped with Certainty of Response Index (CRI). It consists of 15 concept questions about the NOS. The number of students who were tested on Chemistry Education Program (CEP) and Chemistry Program (CP) respectively 42 and 45 students. This study shows that after the learning of Philosophy of Science course happened: (1) the decrease of the number of misconception students on the NOS from 47.47 to 19.20% in CEP and from 47.47 to 18.18% in CP and (2) the decrease in the number of concepts that understood as misconception by the large number of students from 11 to 2 concepts on the CEP and from 10 to 2 concepts on CP. Therefore, the existence of Philosophy of Science course has a positive academic impact on students from both programs on undergraduate level.

1. Introduction

Doing tracing into the books of philosophy of science will get an understanding that there are three components in science, namely scientific products, scientific methods, and scientific attitude. Natural science is a scientific products produced and developed by scientist using scientific methods and based on scientific attitude ;. People’s understanding of scientific products, scientific methods, and scientific attitude is part of an understanding of the nature of science. Scientific methods or scientific approach is an epistemology of natural science [2]. How should students learn about science? Students must study science like how a scientist develops science, using scientific methods and scientific attitude [3].

To be able to comprehend the content and context of natural science in meaningful, students must have correct conception of the nature of science [4]. To be able to comprehend (wider and deeper), students also must have correct conception of ontology, epistemology, and axiology of the natural sciences. Before putting Philosophy of Science course into curriculum structure on undergraduate level (before 2014), in Faculty of Mathematics and Science (FMS) Universitas Negeri Surabaya (Unesa), there is no more explicit courses contain learning outcome so that the graduates of the FMS do not have the correct conception of the nature of science and for what science is developed. One of the philosophical messages
in the development of natural science that search and contemplation made by scientists in the field of science must lead to a wisdom. Through Philosophy of Science course, this message is internalized into the schema (cognitive structure) of each student individual [2]. It is generally accepted that students should not have misconceptions about the nature of science so that students’ understanding on content and context of natural science becomes meaningful and comprehensive. If Philosophy of Science course does not put into the curriculum structure on undergraduate level then there are some worries that (1) students whose misconceptions about the nature of science are not comprehensive in assessing the content and context of the natural sciences and (2) graduates of FMS will have misconceptions about the nature of science that will have detrimental effects to the world of work or to the scientific community.

Misconception is a conception that is inconsistent with the scientific understanding or understanding agreed by experts in the corresponding field [5, 6]. The misconception of the nature of science is the incompatibility of one's conception of concepts related to the true philosophical nature of science. Concerns that there are misconceptions about the nature of science in the scheme (cognitive structures) of the undergraduate students and graduates in FMS are reasonable because there are research results on this matter. Suyono et al. found a student who has misconception of the nature of science [7]. Those research findings further strengthen the author's expectations towards the contribution of the Philosophy of Science course as one solution to solve the problem of misconception about the nature of science, both among students and graduates in FMS. To see the reality of that expectation, the authors do research on the academic impact of Philosophy of Science course on students’ conception changes of the nature of science before and after following the course. The research is still limited to two Programs in FMS Unesa, namely Chemistry Education Program and Chemistry Program. During the completion of this study, students from both of these programs are equally involved in learning with chemistry as the main content and obtaining a lecture on Philosophy of Science by the same lecturer team. As has been pointed out in the paragraph of this article, one's conception of the nature of science is one's understanding of the scientific product, scientific methods and scientific attitude [4]. Scientific products in chemistry are classified into facts, concepts, principles, laws, and theories. The diagram of the scientific method as the science development paradigm is shown in Figure 1.

![Figure 1. Scientific Method in Chart [8].](image-url)
Based on Figure 1, comprehension of the nature of science viewed from methodology includes the understanding of: (1) the problem as a starting point in scientific studies through scientific inquiry as an implementation of the scientific method, (2) the hypothesis does not merely change the sentence of the question as the problem formulation into a statement sentence as a hypothesis formulation, but it must be based on a frame of thought induced from scientific domain, (3) deductive and inductive thinking, and (4) research conclusions that do not necessarily accept the hypotheses.

Curiosity, honest, disciplined, and open minded are some examples of what is called a scientific attitude [3]. Scientific attitude is integral part of learning in programs on FMS. Philosophy of Science course should give a comprehension to students so as not to become a contributor to the birth of a dishonest nation. On the opportunity of supervision in several chemistry classes of school, the authors saw directly how the chemistry teacher did not realize that she had contributed dishonesty to her students by forcing the acceptance of a conclusion while the experimental data the students obtained did not support the conclusion. This is one indication that the teacher cannot interpret the scientific paradigm in Figure 2. The test items used to measure students' understanding of the nature of science are based on names (labels), definitions, features (essential and non-essential), and examples and non-examples related to scientific product, scientific methods, and scientific attitude [9]. Fifteen items of questions in the form of conceptual statements that must be rated true or false by the research target students with the Certainty of Response Index, CRI [10] are as follows: (1) All one’s thinking result developed through scientific methods can be declared as scientific product, (2) developing method of concept, principle, law, and theory consisted of problem posing stages, observation, hypothesis formulation, doing experiment, and making conclusion without developing conceptual frame of research can be referred as scientific method, (3) attitude that should be had by scientist or someone who do a research is a scientific attitude, (4) science is a one’s thinking result developed through scientific method and based on scientific attitude and is pure without considering the usefulness of the person's ideas, (5) scientific method is a stage in working and thinking used by someone to solve all the problems, (6) scientific attitude is intrinsic characteristic which should be had by scientist in solving the problems. It consist of curiosity, objective, honesty, open minded, etc. A good and wise scientist will try to find support for the idea and hypothesis, (7) characteristic of law in natural science is an ability to give explanation of the relationship between one variable with another variable, so that the law is abstract, (8) characteristic of thinking paradigm which may to be classified as a scientific method is the implementation of two ways of thinking. They are deductive reasoning and inductive reasoning, so the scientific idea must be born from the way of reasoning, (9) characteristic of scientific attitude is the attitude that a democratically valued scientific idea is based on the popularity of the idea, (10) with using natural science, we can argue the existed idea without new facts or evidence, (11) when the scientists analyze the problems, they should use both inductive and deductive thinking, (12) opinion that says research that does not reach the final conclusion will not provide benefits and does not need to be published is one example of a scientific attitude, (13) If new facts/ evidence are found to support the hypothesis, then existing theories must be updated or be canceled its validity, (14) experiment is an important part of scientific process. It means that scientific process always use the experiment and (15) facts/ observation result data from scientist should be believed in truth without asking the evidences which explain how the scientist works [2]. Statement in number (1), (2), and (3) are statements about label, then statement in number (4), (5), and (6) are statements about definition. Statement in number (7), (8), and (9) are statements about characteristics while statement in number (10), (11), and (12) are statements about examples, then statement in number (13), (14), and (15) are statements about non-examples, respectively for scientific products, scientific methods, and scientific attitude.

This study aims to describe academic impact of Philosophy of Science course towards students’ conception change on Nature of Science (NOS) before and after attending the course [4] with two
indicators. First, there is an increase in the number of students who have a true conception and/or a 
decrease in the number of misconception students on the NOS and second, there is a decrease in the 
number of concepts that are understood as misconceptions by the large number of students. Findings in 
this study are used to strengthen argument of the importance of Philosophy of Science course in the 
structure of undergraduate curriculum at the Faculty of Mathematics and Sciences. If both of indicators 
are proven empirically, then it can be concluded that Philosophy of Science course has an important role in 
the existence of curriculum structure on programs in undergraduate level.

2. Research Methods
This study followed pre-experimental group with pre-test posttest design type and began with 
identification stage of students’ conception or misconception status on the nature of science before 
following the Philosophy of Science course. Conception diagnostic test equipped with Certainty of 
Response Index (CRI). The number of students who were tested on Chemistry Education Program (CEP) 
and Chemistry Program (CP) respectively 42 and 45 students. The determination of the student's 
conception status is guided by Hasan et al. [10]. Treatment in this study is Philosophy of Science course 
that be taught by senior lecturer (lecturer team consisted of professor and head of doctorate) and be guided 
with validated Semester Course Plan (SCP) [11]. The lectures are student centered oriented. Learning 
material is given by the lecturer and students are given the task in thinking activity (doing search and 
contemplation), including logical practice of using syllogism and building concepts based on 
observational data. After the treatment of the target students, the study was reexamined with the same 
misconception diagnostic test.

Data collection instrument used in the study is a diagnostic test of conception about the nature of 
science [2]. Misconception diagnostic test of the nature of science has been developed by Suyono et al. 
[7] and consists of 15 concept questions about nature of science. This test instrument has been validated 
by two experts in chemistry education. All test items are declared valid both in content (relevance) and 
construction (consistency). Reliability of the misconception diagnostic test of the NOS based on the KR- 
20 formula is 0.80.

Based on the data of the diagnostic test results, the student's conception of the nature of science can be 
determined (1) the proportion of students know concepts, not knowing concepts, and misconceptions on 
each concepts and (2) concepts understood in large numbers of students. An individual's certainty index in 
answering concept questions according to Hasan et al. [10] is shown in Table 1.

| Scale | Certainty Level       | Information                                      |
|-------|------------------------|--------------------------------------------------|
| 0     | Totally Guessed Answer | If answering the problem 100% by guessing         |
| 1     | Almost Guess           | If answering the question with a guess percentage between 75% - 99% |
| 2     | Not Sure               | If answering the question with a guess percentage between 50%-74% |
| 3     | Sure                   | If answering the question with a guess percentage between 25%-49% |
| 4     | Almost Certain         | If answering the question with a guess percentage between 1%-24% |
| 5     | Certain                | If answering the question there is no guess at all (0%) |

Table 1. Index of One's Certainty in Answering Concept Questions4.

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4[10]
Determination of a person classified into the status of conception Knowing Concept (KC), Do not Know the Concept (DKC), or Misconception (MC) follows tabulation system created Hasan et al. [10] as presented in Table 2.

**Table 2. Criteria for Determining the Status of Person Classified into KC, DKC, or MC**

| Low CRI Index (smaller or equal to 2.5) | High CRI Index (> 2.5) |
|----------------------------------------|------------------------|
| The answer is correct, but the low CRI index means do not know the concept (DKC). | The answer is correct and high CRI means knowing the concept (KC). |
| The answer is wrong and low CRI means do not know concept (DKC). | The answer is wrong but high CRI means misconception (MC). |

To define the concept of misconception by a large number of students, a misconception is identified in groups. The formula for calculating the average CRI of the respondent who answered incorrectly (CRII) and the respondent fraction that answered correctly (Cf) is presented below.

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CRII = \frac{\text{total number of CRI from wrong answer}}{\text{the number of students who answered incorrectly}} \\
Correct \ fraction = \frac{\text{number of students who answered correctly}}{\text{total number of students}}
\]

For a concept, if CRII values are high (> 2.5) and low Cf values (<0.5), then it can be concluded that the concept led to a large number of students experiencing misconceptions.

3. Research Findings

The result of the mapping of students' conception of Chemistry Education Program of FMS Unesa on NOS before and after learning of Philosophy of Science course is represented: (1) proportion of average number of students knowing concept, not knowing concept and misconception of 15 concepts that has been tested (Figure 2) and (2) a decrease in the number of concepts understood by misconceptions by large numbers of students (Figure 3).
Based on the data in Figure 2 it can be concluded that there is a decrease in the number of misconception students on the NOS, from 47.47 to 19.20%.

It appears that prior to the *Philosophy of Science* study of the 15 items of misconception diagnostic tests of the NOS, there are 11 concepts understood as misconceptions by the large number of students on Chemistry Education Program. Majority (73.33%) of subject matter about the NOS understood as misconception by the large number of students. What is the concept map about the NOS to students after completing the course of Philosophy of Science? After learning, from 15 diagnostic tests of the NOS only two concepts (13.33%) caused a large number of students to experience misconception, the concept of number 9 and 13. It can be concluded that there is a decline in the number of concepts that are understood as misconceptions by the large number of students. In other words, large numbers of students have left their misconceptions status to know the concept of the NOS.
What about the students of Chemistry Program? Results of students’ conception map of Chemistry Program at FMS Unesa about the NOS before and after learning of *Philosophy of Science* course are presented in Figure 4 and Figure 5.

**Figure 4.** Average Proportion Number of Students Knowing Concept, Do not Know Concept, and Misconception about the NOS from Chemistry Program Before and After Learning *Philosophy of Science* Course.

Based on the data in Figure 4, it can be concluded that there is a decrease in the number of misconception students on the NOS, from 52.52 to 18.18%.

**Figure 5.** Students’ Concept Map in Chemistry Program on the NOS Before and After Learning *Philosophy of Science* Course.

The same thing happened to the target research students from Chemistry Program. Before the study of *Philosophy of Science* course, of the 15 points of concept comprehension of the NOS, there are 10 conception test items (66.67%) cause misconception in large number of students on Chemistry Program. After attending the course, from 15 points of concept comprehension of the NOS, it found only two
concepts (13.33%) which caused a large number of students experiencing misconceptions, the concept of number 6 and 13.

4. Discussion
Empirical evidence has been found that (1) there is an increase in the number of students having true conceptions and/or decreasing the number of misconception students on the NOS and (2) a decrease in the number of concepts understood as misconceptions by the large number of students. Almost the same fact applies both to the students of Chemistry Education Program and Chemistry Program. These two evidences reinforce the argument that Philosophy of Science course has a positive academic impact so that its existence in the curriculum structure on undergraduate level in the Faculty of Mathematics and Science is a necessity.

Two concept statements about how the NOS is found are still understood as misconception by the large number of students after Philosophy of Science course, in both programs. That is concept statement in number 6, 9, and 13. Concept statements number 6 and number 9 are both related to the components of their respective scientific attitudes on the attributes of definitions and examples of scientific attitudes. Concept statement in number 13 relates to non-sample attributes of a scientific product. It means that Philosophy of Science course conducted during one semester was not able to make students understand about the whole concept of the NOS. The study of Philosophy of Science courses conducted during one semester has not been able to eliminate the phenomenon of misconception about the NOS to the students. But in general, Philosophy of science course has shown a good academic effect, that is, it has succeeded in raising the number of students having a true conception and/or decreasing the number of students’ misconception on the NOS and reducing the number of concepts understood as misconceptions by the large number of students.

The existence of Philosophy of Science course within the curriculum structure on programs at FMS Unesa does not subsequently eliminate the role of other courses in teaching the concept of the NOS. The substance of the essence of science is still made an integral charge in the courses beyond the Philosophy of Science. Through Philosophy of Science course which is the compulsory subject in FMS Unesa, students are habituated to think philosophically, by: (1) living and practicing scientific methods as one of the paradigms in problem solving, (2) constructing the concept, principle, and law with scientific methods paradigm equipped with scientific attitudes, (3) do searching and contemplation in answering three science questions (ontology, epistemology, and axiology), (4) ratify philosopher's advice such as Socrates (learn not only to answer questions but to question answers) and Rene Descartes's advice (doubt everything then solve the doubt), (5) takes learning to love wisdom.

5. Conclusion and Recommendation
Philosophy of Science course proved able to (1) decrease the number of misconception students on the nature of science and (2) decrease the number of concepts understood misconception by the large number of students. This conclusion applies to the students on Chemistry Education Program and Chemistry Program FMS of Unesa. The existence of Philosophy of Science course has a positive academic impact so that its existence in the curriculum structure on undergraduate Level in FMS is a necessity.

The quality of study in Philosophy of Science course is always done because there are still a number of students who still have misconception about the NOS after learning and found the concept that still caused misconception on the large number of students. For students who still have misconceptions about the NOS, it is possible to be taught through remedial teaching.

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