Understanding the Nature of Science Through a Content Analysis of Dynamic Fluid: Voices of Pre-Service Physics Teachers

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Abstract. Understanding the Nature of Science (NOS) is useful for pre-service, novice, and senior teachers. The specific purposes of this research were analysing the reasoning of NOS among Pre-Service Physics Teachers’ (PSPTs) regarding the fact, concept, principle, hypothesize, law, and theory of dynamic fluid, and analysing these NOS variables based on gender, GPA, and score of Philosophy of Science course. This research utilised a mixed-method study, descriptive-interpretive approach with supporting by quantitative analysis of the NOS in relating to PSPTs voices on dynamic fluid. A content analysis was considered in helping the researcher to better comprehend the process of constructing meaning. The study involved of a written questionnaire and followed by a semi-structured interview. A number of thirty one (31) PSPTs in public university in Surabaya, Indonesia were invited to complete the questionnaire form and joined a semi-structured interview. The PSPTs’ voices were categorised into four levels: dissatisfied (naïve), intelligible, plausible, and fruitful that represents the levelling of reasoning. The findings indicated the distribution of PSPTs’ reasoning in dynamic fluid concept varied from the level of dissatisfied to fruitful. PSPTs female performed better in reasoning of NOS than male of dynamic fluid. Moreover, PSPTs whose GPA is better also performed better in reasoning of NOS. Finally, the score of course had also in line with the level of reasoning of NOS.

1. Introduction

“The phrase ‘history and philosophy of science’ (HPS) has been used to describe the interplay of disciplines that inform science education (SE)……However, a more encompassing phrase to describe the scientific enterprise for SE is the ‘nature of science’ (NOS)” [1].

Generally, NOS is an accepting of the characteristics of scientific knowledge that deals with its empirical nature, its creative and imaginative nature, characteristics of its theory, its social-cultural nature, and its tentative nature [1-4]. NOS is also connected to the epistemology and sociology of science, namely science as a way of knowing, or a value and belief that is inherent in science and its development [3]. As a way of knowing, NOS has some implications: (a) knowledge is not a mere picture of the world of reality, but is always a construction of reality through the activities of the subject; (b) subjects form cognitive schemes, categories, concepts, and structures that are necessary for knowledge; and (c) knowledge is formed in one’s conception structure [2].

The structure of conception shapes knowledge when that conception applies in dealing with one’s experiences. By doing so, NOS includes two aspects, namely body of knowledge which is often referred
to as product aspects and methods known as process aspects. So, the nature of science is a bridge for students to uncover and understand the reality of nature. To help students understand the NOS, a good physics teacher will always emphasise the NOS in every teaching. Nevertheless, the teaching about the NOS will be limited to time, but should still be carried out explicitly in the relevant teaching material. This is because students will not have a good understanding of the NOS if they do not have first-hand experiences through empirical scientific methods [4].

Emphasizing the nature of science in learning is an effort to empower students through education, i.e. physics education. There are three important components of science in physics education in schools [5]: products of science, process of science, and attitude of science. Science knowledge that is often called a science product is an accumulation between the results of empirical activity and the analysis of scientists. Science products are produced through scientific investigations involving scientific attitudes and scientific processes. Science products that are built on attitudes and scientific processes will then regenerate new scientific products through scientific processes and investigation of new phenomena in nature.

The product of science included facts, concepts, principles, and theories. Facts are products of empirical activities of science, while concepts, principles, and theories are products of analytical activities [5]. Knowledge, principles, laws and theories are the results of fabrications or man-made in understanding and explaining nature with various phenomena that occur in it. Thus, science as a scientific product includes concepts, laws and theories that are developed as fulfilment of human curiosity. In science learning, product aspects appear in the form of teaching materials that contain the subject matter.

Scientists use a variety of empirical and analytical procedures in their efforts to uncover universal reality. This procedure is better known as the science process. The process aspect refers to a method of gaining knowledge. This method is called the scientific method. The standard scientific method is currently the result of previous developments. The scientific method is a combination of rationalism which believes that knowledge can be obtained through thought and empiricism which believes that knowledge can be obtained through experience. Generally, it has six basic frameworks of procedures, namely being aware of problems and formulating problems, observing and collecting relevant data, compiling or classifying data, formulating hypotheses, deductions and hypotheses, and testing the correctness of hypotheses.

Science process skills are a form of science as a process. In science learning, it is very important to help students learn science process skills or inquiry skills to solve problems. Science process skills are a form of science as a process. The expected intellectual process skills in the nature of science-oriented learning are 1) building principles through induction, 2) explaining and predicting, 3) observing and recording data, 4) identifying and controlling variables, 5) making graphs to find relationships; 6) designing and carrying out scientific investigations, 7) using technology and mathematics during the investigation, 8) describing conclusions from the evidence [3, 4-6]. Scientists study phenomena and events through scientific processes, such as observation, experimentation, and other empirical and analytical activities.

In addition to these two aspects of science, Carin [5] stated that the third aspect of science is scientific attitude. The attitude aspect in question is a variety of beliefs, opinions, and values that must be maintained by a scientist especially when looking for or developing new knowledge, including responsibility, curiosity, discipline, diligence, honesty, and being open to the opinions of others. Physics education that is relevant to the nature of science requires an atmosphere that allows students to be directly involved in the learning process. So that by having a scientific attitude and after going through a series of learning processes, students can arrive at a conclusion that they form themselves.

Based on the authors’ experiences in research on the essence of philosophy of science [7] and the physics conception and physics knowledge [8-11,13], then this article manifests the emerging idea the nature of knowledge and the nature of science specifically in fluid dynamic concept. By doing so, this research explores the reasoning of NOS among PSPTs regarding the fact, concept, principle, hypothesize, law, and theory of dynamic fluid and to sightsee the PSPTs’ existing knowledge and
reasoning of dynamic fluid. In order to make a clear the research direction, the following two research questions (RQ) were proposed:

RQ 1: What reasoning of NOS among PSPTs do regarding the fact, concept, principle, hypothesize, law, and theory of dynamic fluid?
RQ2: What reasoning of NOS among PSPTs do regarding gender, GPA, and Score of Philosophy of Science course?

2. Method
This research used a mixed-method with content analysis was well-organized in serving the researchers to grasp the process of creating meaning [12]. Indeed, previous researchers used four types of content analysis based on some assignments were designed to provide insight into the kinds of understandings each participant of constructing meaning, i.e. reflection journals, a research paper (students’ issues and arguments), class assignments (informal interviews, reaction papers, and provocative questions), and a position paper [15]. For the reason of cost and time allocation, this study used a written questionnaire and followed by a semi-structured interview (see Figure 1). Totally, there were thirty one (31) participants contributed in the research. All of them were joined in the course Philosophy of Science with 2 credits. Therefore, they learned about the three foundation of Philosophy of Science: Epistemology, Ontology, and Axiology of knowledge [7]. They have also learned the content of dynamic fluid through the courses Fundamental Physics and Mechanics. The distribution of demographic variables of participants is depicted in Table 1.

Table 1. The demographic factors of participants.

| Variable               | Frequency | Percentage (%) |
|------------------------|-----------|----------------|
| Gender                 |           |                |
| Male                   | 4         | 12.90          |
| Female                 | 27        | 87.10          |
| GPA                    |           |                |
| GPA≤2.75               | -         | 0              |
| 2.75<GPA≤3.00          | 2         | 6.45           |
| 3.00<GPA≤3.25          | 7         | 22.58          |
| 3.25<GPA≤3.50          | 19        | 61.29          |
| 3.50<GPA≤3.75          | 3         | 9.68           |
| 3.75<GPA≤4.00          | -         | 0              |
| Score of Philosophy of Science course |           |                |
| A                      | 4         | 12.90          |
| A-                     | 21        | 67.74          |
| B+                     | 6         | 19.36          |
Figure 1. Sample of written questionnaire (a) and semi-structured interview form (b).

The voices of participants were coded by pseudonyms name. The data gained from the results of the written questionnaire and semi-structured interviews [12,15]. By deducting the data, the PSPTs’ reasoning of NOS in terms of fact, concept, principle, hypothesize, law, and the existing knowledge and reasoning of dynamic fluid reasoning was categorised into four levels: “dissatisfied (naïve), intelligible, plausible, and fruitful” [7].

3. Result and Discussion

RQ 1: What reasoning of NOS among PSPTs do regarding the fact, concept, principle, hypothesize, law, and theory of dynamic fluid?

Table 2 summarises the level of reasoning performed by PSPTs. There are the different reasoning of PSPTs regarding the fact, concept, principle, hypothesize, law, and theory of dynamic fluid. It was about 12.90% among them have the lowest level or in the dissatisfied (naïve) level.

| Level of reasoning | Frequency | Percentage (%) |
|--------------------|-----------|----------------|
| dissatisfied (naïve) | 4 | 12.90 |
| intelligible | 9 | 29.03 |
| plausible | 9 | 29.03 |
| fruitful | 9 | 29.03 |

The following quotes are the samples of PSPTs reasoning the dissatisfied level.

Fact: “flowing fluid experiences friction with objects around it” [Inayah]
“...dynamic fluid in the form of liquid, gas which has a constant speed with time” [Jelita]

Concept: “Concepts are a series of statements or ideas. Airplane wings are an example of the application of static fluids” [Dian]

Principle: “moving fluid is influenced by time and friction” [Inayah]
“fluid has a constant speed with time, it does not change volume, it doesn’t turbulent, and it doesn’t experience rotation” [Melly]
“dynamic fluid has limited coverage” [Dian]
Hypothesis: “if the fluid doesn’t have a constant velocity then the fluid isn’t a dynamic fluid” [Melly]

Law: “Bernoulli’s law is divided into 2 things: compressed and uncompressed flow” [Dian]

Theory: “Water is liquid that flows” [Jelita]

All quotes above are categorised into (naïve) level of reasoning because of some reasons:

a. Simple reasoning either wrong or incomplete reasoning, indeed it performs too general sentences. “Airplane wings are an example of the application of static fluids”, this is an example of general information.

b. There is unclear information, i.e.: “fluid has a constant speed with time”, so the question is what kind of fluid?

c. Just providing any quantities or variables of physics, however, there are inappropriate quantities, for example, from the expression of: “moving fluid is influenced by time and friction”.

In the intelligible level, it is about 29% of PSPTs indicating inappropriate statement. However, their performance was better than the previous level.

Fact: “airplanes can fly because of the aircrafts’ wings” [Intan]
“water is a type of fluid that easily flows” [Nabilah]
“fluid has speed when it flows” [Reny]

Concept: “Airplane wings used concept of dynamic fluid” [Nabilah]

Principle: “water is a liquid” [Nabilah]

Hypothesis: “if water flows then there is a pressure of liquid” [Nabilah]

Law: “Bernoulli’s law applies constantly” [Ella]

Theory: “Water is the fluid of the liquid that flows is influenced by gravity, density, pressure, and volume” [Nabilah]
“Fluid is considered to have a constant speed with time, no change in volume, and not thick” [Ella]

The expressions above are considered into intelligible level of reasoning due to these reasons:

a. Simple correct reasoning, but sometime it performs too general expression; for example: “Airplane wings used concept of dynamic fluid”; “fluid has speed when it flows”.

b. Providing quantities or variables of physics, however, there are inappropriate quantities, for example, from the expression: “Water is the fluid of the liquid that flows is influenced by gravity, density, pressure, and volume”.

In the next level, the PSPTs’ reasoning about dynamic fluid reached in the plausible level. They performed better in giving reasoning. The following illustration shows their reasoning.

Fact: “Airplanes have wings like those of a bird, which are curved and thicker at the front than at the rear” [Radit]

Concept: “A number of masses of water m at height h have potential energy, Ep = mgh” [Hari]

Principle: “The greatest fluid pressure is on the part with the smallest flow rate, and the smallest pressure is on the part with the greatest flow rate” [Radit]

Hypothesis: “By intuition, we might think that for a horizontal pipe, the fluid pressure is greatest at the point where the flow rate is greatest” [Ruly]

Law: “Bernoulli used the energy-effort theory to derive the energy conservation equation in dynamic fluids” [Hari]
Theory: “if the fluid that flows does not change in volume (or density) when pressed, the fluid flow is said to be incompressible” [Ruly]

If we compare to intelligible reasoning, the plausible level reasoning based on the logical thinking and considering the relationship among physical quantities. Taking for example, “By intuition, we might think that for a horizontal pipe, the fluid pressure is greatest at the point where the flow rate is greatest”, this hypothesis considers the relation between variables of pressure and the flow rate (speed) at the point of pipe. Other example is, “Bernoulli used the energy-effort theory to derive the energy conservation equation in dynamic fluids”. This law is expressed by participant due to he/she understand how the Bernoulli law was derived.

In the fruitful level, the PSPTs’ reasoning about dynamic fluid is getting better than the previous level. The reasoning provided by participants performs more complex and comprehensive. For example, Rina expresses her principle based on scientific principle which proposed by scientist, “If a fluid flows with steady flow, then the mass of fluid entering one end of the pipe must be the same as the mass of fluid coming out of the other end of the pipe during the same time interval”.

Fact: “When we use a water hose, and we put pressure on the end of the hose, the water reaches farther away” [Faradila]

Concept: “Discharge is a quantity that states the volume of fluid flowing through a certain cross section in a certain time unit” [Dian]

Principle: “If a fluid flows with steady flow, then the mass of fluid entering one end of the pipe must be the same as the mass of fluid coming out of the other end of the pipe during the same time interval” [Rina]

Hypothesis: “The greater the cross-sectional area of the pipe, the smaller the velocity of fluid flow” [Ayu]

Law: “Implications of Bernoulli’s law: In horizontal (horizontal) pipes, the greatest fluid pressure is in the part with the lowest flow velocity, and the least pressure is in the section with the highest flow rate” [Dian]

Theory: “If the velocity v at a point is constant with time, the fluid flow is said to be steady. If the fluid that flows does not change in volume (or density) when pressed, the fluid flow is said to be incompressible” [Ayu]

From the illustration above, the researchers agreed the essence of NOS especially in exploring the PSPTs’ understanding of fact, concept, principle, hypothesize, law, and theory of dynamic fluid. All the PSPTs’ reasoning above mapped the characteristics of the NOS in science education that were understandable by PSPTs. Indeed, previous researchers analysed recent science education curriculum documents and identified statements about the NOS that are common to most curricula [16-18]: “(a) Science is an attempt to explain natural phenomena; (b) people from all cultures contribute to science.’ (c) scientific knowledge, while durable, has a tentative character; (d) scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments and scepticism; (e) there is no one way to do science – therefore, there is no universal step-by-step scientific method; (f) new knowledge must be reported clearly and openly; and (g) laws and theories serve different roles in science – therefore, students should note that theories do not become laws even with additional evidence”.

**RQ2: What reasoning of NOS among PSPTs do regarding gender, GPA, and Score of Philosophy of Science course?**

After carefully coding the participants’ response regarding their opinion of their NOS in the concept of dynamic fluid, then we classified their answer based on the demographic background: gender, GPA, and score of philosophy of science course, (see Table 3).
Table 3. The level of reasoning performed by PSPTs in dynamic fluid concept.

| Demographic variables | Level of reasoning [frequency(%)] |
|-----------------------|-----------------------------------|
|                       | dissatisfied (naïve) | intelligible | plausible | fruitful |
| Gender                |                      |              |           |          |
| Male                  | 1(3.22)              | 2(6.45)      | 1(3.22)   | 0        |
| Female                | 3(9.68)              | 7(22.58)     | 8(25.81)  | 9(29.03) |
| GPA                   |                      |              |           |          |
| 2.75<GPA≤3.00         | 1(3.22)              | 1(3.22)      | 0         | 0        |
| 3.00<GPA≤3.25         | 2(6.45)              | 5(16.13)     | 0         | 0        |
| 3.25<GPA≤3.50         | 1(3.22)              | 3(9.68)      | 9(29.03)  | 6(19.35) |
| 3.50<GPA≤3.75         | 0                    | 0            | 0         | 3(9.68)  |
| Score of Philosophy of Science |              |              |           |          |
| B+                    | 4(12.90)             | 2(6.45)      | 0         | 0        |
| A-                    | 0                    | 7(22.58)     | 9(29.03)  | 5(16.13) |
| A                     | 0                    | 0            | 0         | 4(12.90) |

Based on Table 3, we underlined some points:

a. Based on gender, the level of reasoning of dynamic fluid perform female better than male PSPTs, with dominance in plausible and fruitful categories.

b. Regarding GPA, PSPTs whose better GPA performs better level of reasoning.

c. The score of Philosophy Science course have also in line with the level of reasoning. It means, if the score is higher that the level of reasoning is also greater.

4. Conclusion

The conclusion can be prompted from this study includes: (a) The distribution of PSPTs’ reasoning in dynamic fluid concept varied from the level of dissatisfied to fruitful; (b) There was no dominant level of reasoning among PSPTs regarding the concept of fluid dynamic; (c) PSPTs female performed better in reasoning of NOS than male of dynamic fluid; (d) PSPTs whose better in GPA performed better level of reasoning; and (e) The score of Philosophy Science course have also in line with the level of reasoning. This result gives the implication that PSPTs need to learn in-depth this concept and overcome the understanding that is still wrong in their mind.

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