How do the pre-service chemistry teachers view about the nature of science and technology?

I G E D Adiputra¹*, A Mudzakir² and T Widhiyanti²

¹Magister Pendidikan Kimia, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
²Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*ekadarma@student.upi.edu

Abstract. This study is intended to explore the view of pre-service chemistry teachers (PCT) about the nature of science and technology (NOST). This study is the second part of the Model of Educational Reconstruction (MER). 63 of PCT in one of Chemistry Education Department in Central Indonesia participated to fill in the questionnaire about the view of NOST that has been modified from Tairab and Aikenhead. The PCT’s view described and categorized as Realistic, Has Merit, and Naïve. The results of the questionnaire suggest that many PCT were in Has Merit and few of them were in naïve. It means that many PCT’s views were not completely appropriate with the general view of science or technology but there were certain parts that fit the concepts and theories of science or technology. The results of this study will serve as a consideration in designing the instructional material at the third part of MER.

1. Introduction

Having 15 years in participating the study of Program of International Student Assessment (PISA), Indonesia still shows low performance in scientific literacy (see table 1) [1-6]. Meanwhile, achieving a good performance in scientific literacy is one of Indonesia education goals [7]. This problem should be addressed as a serious problem and need a comprehensive solution. It was believed that one of the main reasons for that problem is the science teachers’ view about science and technology [8-10]. According to Tairab, science teachers’ views about nature of science and technology have an important role in guiding students to have a scientific literacy [8].

Table 1. Indonesia’s scientific literacy performance for 15 years.

|          | 2000 | 2003 | 2006 | 2009 | 2012 | 2015 |
|----------|------|------|------|------|------|------|
| Indonesia average | 393  | 395  | 393  | 383  | 382  | 403  |
| OECD average   | 500  | 500  | 500  | 501  | 501  | 493  |

The nature of science and technology emerged from the importance of understanding the nature of science (NOS) and the nature of technology (NOT) in the 21st century. NOS is an integral part of scientific literacy [6, 11], which described the characteristic of science. Meanwhile, NOT relates to what the objectives and characteristics of technology and how the relationship of technology not only with science but also with society [8]. In the 21st century where technological developments are growing very rapidly, mastering NOT is as important as mastering NOS.
Understanding the nature of science and technology (NOST) is believed to help science teachers, also pre-service chemistry teacher (PCT), in guiding students to understand the concept of science and to describe the relationship between science and technology [8]. Therefore, it is important for chemistry teachers to understand how science is done and how it relates to science and technology. At this point, the teacher preparation program should be able to provide a learning environment that enhances the PCT’s understanding of NOST.

The aim of this study is to analyze PCT’s view about NOST, particularly at; (a) the characteristics of science and technology, (b) the aim of science and scientific research, (c) the characteristics of scientific knowledge and scientific theories, (d) the relationship between science and technology, and (e) how to obtain scientific knowledge and scientific theory.

Previous research studies [12-15] have shown that if individuals are to develop the knowledge and skills necessary for effective participation in rapidly changing societies, they need an understanding of NOST, their similarities and differences, and their independence. It is hoped that this study will provide an additional dimension as to how PCT’s view NOST and will serve as a consideration in designing the instructional materials, learning activities, and teaching and learning sequence at pre-service levels.

2. Method
This study is the second part of Model of Educational Reconstruction (MER) [16], it is investigating the PCT’s view about NOST. MER is a theoretical framework for improving instructional practice and teacher professional development programs. It concern on science subject matter issues as well as students learning needs and capabilities have to be given equal attention in an attempt to improve the quality of teaching and learning. Furthermore, the results of this study will serve as a consideration in the third part of MER, it is designing and evaluating the instructional materials.

63 PCTs in one of Chemistry Education Department in Central Indonesia involved to fill in the questionnaire about science and technology that has been modified from Nature of Science and Technology Questionnaire (NSTQ) [8] and View On Science-Technology-Society (VOSTS) [17]. The instrument contains 11 items measuring various aspect of NOST and items 1 to 10 require the respondent to select from given responses the option(s) that fits their personal point of view(s), item 11 require the respondent to provide written views about the difference(s) between science and technology. In table 2 provide an item of the questionnaire.

There were 3 categories of the options in the questionnaire items, it was R ‘realistic’, HM ‘has merit’, and N ‘naïve’. A ‘realistic’ item is the one that expresses an appropriate view of the nature of science or technology. Similarly, a ‘has merit’ option is the one that, while not being completely appropriate, expresses a view that has a certain part that appropriates with the nature of science or technology. On the other hand, a ‘naïve’ view is seen as the one that expresses a view that is not relevant or appropriate to the nature of science or technology. The ‘none of the above options fits with my view’ option was classified as ‘uncategorized’ (*) [15].

| Item of questionnaire                                                                 | Category |
|--------------------------------------------------------------------------------------|----------|
| A. The application of science to enhance life.                                       | N        |
| B. Manufactured artifacts such as appliances, tools and scientific instruments.       | HM       |
| C. The hardware, techniques, processes, people associated with items such as tools,   | R        |
| appliances and scientific instruments.                                               |          |
| D. Inventing, designing, developing and testing things such as appliances, tools and  | HM       |
| scientific instruments.                                                              |          |
| E. Very similar to science.                                                           | N        |
| F. The process of manufacturing and the underlying know-how.                          | N        |
| G. I do not have enough knowledge to make choices.                                    | N        |
| H. I do not understand.                                                               | N        |
| I. None of the above options fits with my view.                                       | *        |

Table 2. An item of a questionnaire about science and technology.
3. Result and discussion
The PCTs’ views about NOST are presented in table 3 to 7, it provides the percentage of respondents’ view in each item. In table 3, the PCTs’ views were greater in has merit and naïve than in realistic. For instance, in has merit view, respondent viewed science as a body of knowledge that explains the world around us and few of them viewed science as an organization of people called scientist who have ideas and techniques for discovering new knowledge. Furthermore, respondent viewed technology as inventing, designing, developing and testing things such as appliances, tools and scientific instruments. In naïve view, most respondents conceived science as a study of fields, such as biology, chemistry and physics, meanwhile, they viewed technology as the application of science to enhance life. In realistic view, respondents believed that science as a systematic investigative process and the resulting knowledge, while they view technology as the hardware, techniques, processes, people associated with items such as tools, appliances and scientific instruments. These results were confirmed and similar with results in item 11, where PCTs described the different between science and technology. The fact that none of the respondents selects the option ‘I do not understand or I do not know enough about this subject to make a choice’ serve as a great evidence that these PCTs were quite certain about their view. From these results, it concludes that most PCTs’ views about the characteristic of science and technology still not in an appropriate view.

| Item of questionnaire | Percentage of respondent view |
|-----------------------|-------------------------------|
| Science is            | Realistic | Has Merit | Naïve | Uncategorized |
| Technology is         | 12.7      | 33.3      | 52.4  | 1.6           |

Interestingly, in table 4, most of respondents have realistic view in the item about ‘the aim of science’. For example, the respondents viewed the aim of science was to understand, explain and interpret the continued change in nature and its characteristics, a view categorized as realistic. Meanwhile, other respondents viewed the aim of science was to discover, collect and group facts about nature then few respondents choose the option ‘to find ways to make people live better’. These views were categorized as has merit. For naïve view, PCTs choose option ‘To make sure that what has been discovered about the world is really true’. On the other item, most of the respondents have has merit view, they believed that scientific research is to try out their explanations for why things happen. They also believed that scientific research is to collect data as much as possible and to draw out scientific laws from data. On the other hand, the respondents choose the option ‘to make new discoveries’ and ‘to make something which will help people’, options that categorized as realistic. It can be concluded that even PCTs view ‘the aim of science’ in a realistic view, they failed to view ‘why scientist do scientific research’ in a realistic view.

| Item of questionnaire | Percentage of respondent view |
|-----------------------|-------------------------------|
| The aim of science    | Realistic | Has Merit | Naïve | Uncategorized |
| Why scientist do scientific research | 42.9      | 36.5      | 15.9  | 4.8           |

In table 5 showed PCTs’ view on aspect of the characteristic of scientific knowledge and scientific theory. For instance, in realistic view, they viewed scientific knowledge as a well-organized collection of facts, while most PCTs believed scientific theory as a fact which has been proved by many experiments. On the has merit view, they conceived scientific knowledge as scientific perspectives, ideas and interpretation from the pasts, meanwhile they considered scientific theory as a most appropriate interpretation and explanation which has been approved by scientist. On naïve view, PCTs view...
scientific knowledge as knowledge which contains only statement that 100% true. Few PCTs do not know and do not enough knowledge to choose for item ‘understanding about scientific knowledge and scientific theory’. This indicated most respondent quite certain about their choice. Interestingly, 4.8% respondents choose the option ‘None of the above options fits with my view’ that showed some respondent have other point of views in this item and need to explore for the future work. Table 5 inferred that PCTs have better understanding about scientific theory than understanding about scientific knowledge.

**Table 5.** Percentage of respondents’ view on aspect of the characteristic of scientific knowledge and scientific theory.

| Item of questionnaire | Percentage of respondent view |
|-----------------------|------------------------------|
|                       | Realistic | Has Merit | Naïve | Uncategorized |
| Understanding about Scientific knowledge | 28.6 | 50.8 | 15.9 | 4.8 |
| Scientific theory is | 71.4 | 20.6 | 3.2 | 4.8 |

An interesting finding in table 6 was PCTs have greater realistic view than has merit or naïve view. Most PCTs believed that scientific discoveries occurred from a logical series of investigations because research begins by checking the results of an earlier experiment to see if it is true, a new experiment will be checked by the people who come afterwards. On the has merit view, PCTs conceived that scientific discoveries usually results from a logical series of investigations because science is not completely logical, there is an element of trial and error, as well as hit and miss in the process. Furthermore, in naïve view, few PCTs believed that most scientific discovery occurred from a result of accidental and did not have enough knowledge about this question. It indicated most respondents were quite certain of their choice. From this result, it can conclude that most respondents agreed that scientific discoveries were not a result of accidental or piecing together of previously unrelated bits of information but because of a logical series of investigations.

**Table 6.** Percentage of respondent view on aspect of how to obtain scientific knowledge and scientific theory.

| Item of questionnaire | Percentage of respondent view |
|-----------------------|------------------------------|
|                       | Realistic | Has Merit | Naïve | Uncategorized |
| Scientific discoveries occur because a series of investigations, each one building on an earlier one, and each one leading logically to the next one until the discovery is made | 74.6 | 12.7 | 12.7 | - |

Table 7 presented the PCTs’ views on aspect of the relationship between science and technology. Around 96% respondent agreed that science, technology, and society are mutually dependent, it was indicated from only 3.2% of the respondents choose the option “Because science, technology, and society are independent mutually, they do not affect each other”. Furthermore, more than half of respondents (around 77.8% respondent) believed that science and technology affect society and society can also affect science and technology, a view that was categorized as realistic. For other items in table 7, PCTs’ views science and technology have closely related each other because science is the basis of all technological advances; though it is hard to see how technology could aid science, a view that categorized as has merit. PCTs’ view also in a realistic view which science and technology are closely related to each other because scientific research leads to practical applications in technology, and technology development increases the ability to do scientific research. On the other item, the PCTs that have realistic view believed that technology advances by relying equally on both scientific discoveries and technology’s own body of knowledge. In the has merit view, PCTs conceived that every technological developments builds on a scientific discovery because scientific discovery
always find a use, whether for technological developments or for other scientific issues. They also conceived that every technological development build on a scientific discovery because science provides the background information and the new ideas for technology. In the naïve view for both items, few PCTs did not know about this question and they see science and technology as a similar thing. These results indicated that PCTs have already known about science and technology issues especially in their relationship, although not all respondents have a realistic view.

Table 7. Percentage of respondent view on aspect of the relationship between science and technology.

| Item of questionnaire                                                                 | Percentage of respondent view |
|--------------------------------------------------------------------------------------|-------------------------------|
| Circle all statements that you agree with:                                           |                               |
| Technological innovations and/or development of science bring about environmental problems such as pollution and acid rain. (HM) | 39.7                          |
| Science and technology often make our lives healthier, easier, and more comfortable. (R) | 27                            |
| The prosperity of the nation depends on science and technology. (R)                   | 63.5                          |
| Science and technology rarely do harm to our lives (N)                                | 3.2                           |
| We cannot solve all the problems which we are facing only by the power of science and technology. (HM) | 36.5                          |
| Because science, technology, and society are independent mutually, they do not affect each other. (N) | 3.2                           |
| Science and technology affect society on the one hand, society affects science and technology on the other hand. (R) | 77.8                          |
| Science and technology are closely related to each other                              | 42.9                          |
| Technologists have their own body of knowledge to build on. Few developments in technology have come directly from discoveries made in science. | 34.9                          |

These results showed that PCTs expressed more has merit and realistic view than naïve view about NOST. This indicated that during their educational program in chemistry education department have exposure to issues about science and technology but not completely transferred in a proper way. Consequently, an adoption of science and technology approach and consideration to them has merit and naïve view as a way in designing the instructional materials, learning activities and teaching and learning sequence could result in a greater emphasis in the relation between science and technology even society. It would give better learning environment for PCTs in understanding about science and technology.

4. Conclusion
Based on the results above, it concludes that PCTs generally view the nature of science and technology in has merit view where not all the view completely inappropriate with the nature of science and technology but there were some certain parts that fit the general concept of nature of science and technology, particularly in the aspect of the characteristic of science and technology, and the aim of science and scientific research. The PCTs also were quite certain about their view in the aspect of (a) the characteristic of science and technology (b) the aim of science and scientific research and (c) the
relationship of science and technology. It also suggests for future study to find out the view of respondents when they choose the option ‘None of the above options fits with my view’ by using an interview or other methods. This study also suggests in designing the instructional materials, learning activities and teaching and learning sequence need more explanation or even give example about what is science and technology and relate it to the society. So that PCT could have bigger exposure to science and technology issues to have a better understanding about science and technology.

Acknowledgments
Authors wishing to acknowledge for a full scholarship from Indonesia Endowment Fund for Education (LPDP).

References
[1] OECD 2003 Literacy Skill for the World of Tomorrow – Further Results from PISA 2000 (Paris: OECD Publishing) p 109
[2] OECD 2004 Learning for Tomorrow’s World – First Results from PISA 2003 (Paris: OECD Publishing) p 293
[3] OECD 2007 PISA 2006 Science Competencies for Tomorrow’s World – Volume 1-Analysis (Paris: OECD Publishing) p 49
[4] OECD 2010 PISA 2009 Results: Executive Summary (Paris: OECD Publishing) p 35
[5] OECD 2014 PISA 2012 in Focus. What 15-year-olds Know and What They Can Do with What They Know (Paris: OECD Publishing) p 5
[6] OECD 2016 PISA 2015 Results in Focus (Paris: OECD Publishing) p 5
[7] Permendikbud 2016 Standar Kompetensi Lulusan Pendidikan Dasar dan Menengah (Jakarta: Depdiknas) p 4
[8] Tairab H H 2001 Res. in Sci. and Tech. Education 19 235-250
[9] Lederman NG, Lederman JS, and Antink A 2013 Int. J. of Education in Math, Sci and Tech 1 138-147
[10] Vesterinan V 2012 Nature of Science for Chemistry Education: Design of Chemistry Teacher Education Course (Finland: Department of Chemistry, Faculty of Science, University of Helsinki) p 1
[11] OECD 2016 PISA 2015 Results (Volume I): Excellence and Equity in Education (Paris: OECD Publishing) p 131
[12] ABD-El-Khalik F and Lederman N 2000 Inter. J. of Sci. Educ. 22 665-701
[13] Aikenhead G, Fleming R, and Ryan G 1987 Science Education 71 145-161
[14] Fleming R 1987 Science Education 71 163-186
[15] Rubba P and Harkness W 1993 Science Education 77 407-431
[16] Duit R, Gropengießer H, Kattmann K, Komorek M, and Parchmann I 2012 Sci. Educ. Res. and Pract. in Europe: Retrospective and Prospective vol 5 ed D Jorde and J Dillon (Rotterdam: Sense Publisher) pp 13–37
[17] Aikenhead G and Ryan G 1992 Science Education 76 477-491