Preliminary study on students’ chemical literacy level as the basis of developing NOSI learning model in acid base concepts

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Abstract. This study aims to obtain information about important things that should be developed in NOSI learning model which is aimed to increase students’ chemical literacy. The method used in this study is survey. The Scientific Literacy tests from PISA and VASI questionnaire used as the instruments of the study. The subject of this study is the students in one of classes in SMAN Sindang Indramayu. The result of this study reveals that students have low ability in chemical literacy in terms of: (1) explaining everyday scientific phenomenon; (2) Evaluate and design scientific enquiry; and (3) Interpret data scientifically. Based on the preliminary study, the NOSI learning model which is going to be developed should be emphasizing: concepts, process, creativity, attitudes and application, connections in a world view context and communications.

1. Introduction
The results of the 2015 PISA study show that Indonesian students’ literacy is ranked the 9th lowest of the 70 participating countries on the test, with the science literacy score in the Indonesian natural science study being 403 [1]. While the average score of all countries participants based on OECD (Organization for Economic Cooperation and Development) is 493 thus the score obtained by Indonesian student is still very low so that it can be concluded that Indonesian students have a low ability in the natural science study[1]. The low literacy of science achieved by students is inseparable from the lack of integration of scientific literacy in classroom learning. Scientific literacy needs to be integrated into the learning process of various subjects of science, especially in chemistry subjects.

Shwartz explains that the scientific literacy applied for chemistry is defined as chemical literacy[2].Chemical literacy includes the domain of knowledge, competence and attitude[2]. Chemical literacy is a part of scientific literacy. Chemical literacy includes four components[3]. The first component covers chemical content knowledge, which describes how a chemically literate students should understand: (a) general chemical ideas, including scientific investigations, how to generalize findings, and how to use knowledge to serve other disciplines in order to explain phenomena; (b) the characteristic (key ideas) of chemistry, such that they can explain processes, reaction, energy changes, the structure of living systems, and the contribution of scientific language to chemistry. The second component is chemistry in context, which state that chemically literate students should be able to use chemistry knowledge for explaining everyday situations, should understand daily life chemistry, be able to make effective decisions become involved in social arguments on chemistry related issues, and see the relatedness of innovations in chemistry and sociology. The third component is about higher order
thinking skills, which refer to asking questions, investigating relevant information when required, and evaluating the pros/cons of debates. The last component covers the affective aspects, that is a literate person should show an interesting chemistry issues, specifically in non-formal environments, such as the mass media [3]. Literate persons will be understand the relationship between science and chemistry, chemistry in context, and should be able to make any question, analyses information that related with the question about phenomena.

Generally the process of learning chemistry in the classroom emphasizes understanding of the concept and has not linked it with the application of concepts in daily life. To achieve the learning process that is expected to increase the chemical literacy of students, the role of teachers in learning is very important. The effectiveness of learning depends on the role of the teacher. One of the learning approaches to developing science literacy for teachers and students is to use the NOS (Nature of Science) and SI (Scientific Inquiry) point of view [4]. Lederman, Schwartz and Neumann state that NOSI has been established as a framework for learning which is distinct from knowledge of SI as well as from nature of science (NOS) [5]. Although NOSI, SI and NOS are interrelated they must not be conflated with each other [5]. NOSI aspects cover the characteristics of the scientifics inquiry through which scientific knowledge is constructed [6]. NOSI serves as a framework of learning objectives because its contents are an important part of scientific literacy [6]. Considering NOSI as a framework of learning and its contents are an important part of scientific literacy so this study addresses to level scientific literacy of students as the basis to develop NOSI learning model.

2. Method
This research was conducted by using survey method. The Scientific Literacy tests from PISA and VASI questionnaire used as the instruments of the study. The subjects used were 40 students from one of SMAN in Sindang Indramayu. Then the students are given 10 items scientific literacy tests related to acid-base concepts that is adopted from the scientific literacy test in 2006 as much as 4 question, and 3 questions from the scientific literacy test in 2012, and 3 questions of scientific literacy test in 2015. The ability of science literacy students is shown in the form of percentage score obtained from the calculation of the average total score of scientific literacy test. the answers categorized according to the table 1 [7].

| Interval     | Category   |
|--------------|------------|
| 86%–100%     | Very good  |
| 76%–85%      | Good       |
| 60%–75%      | Enough     |
| 55%–59%      | Low        |
| ≤54%         | Very low   |

VASI questionnaire was applied to the students in high school and seeking the answer for the research what were the views about nature of scientific inquiry of the students [4]. VASI consists of seven open ended questions and aimed to emerge students’ ideas about eight aspects of NOSI which were: Scientific investigations all begin with a question and do not necessarily test a hypothesis; There is no single set of steps followed in all investigation (no single scientific method); Inquiry procedures are guided by the same procedures may not get the same results; Inquiry procedures can influence results; Research conclusions must be consistent with the data collected; and Research conclusions must be consistent with the data collected.

3. Result and discussion
PISA defines scientific literacy as an individual’s scientific knowledge, and use of that knowledge, to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science related issues; understanding of the characteristic features of science as a form of human knowledge and enquiry and cultural environments; and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen [8]. The data regarding the students’ understanding of scientific literacy were presented in table 2.
Table 2. The results test of students’ scientific literacy.

| Knowledge | Competencies                                      | Question Number | Average (%) |
|-----------|---------------------------------------------------|-----------------|-------------|
| Content   | Explain phenomena scientifically                    | 1,8,10          | 58.75       |
|           | Evaluate and design scientific enquiry             | 7,9             | 41.37       |
| Procedural| Interpret data and evidence scientifically          | 2,3,4,5,6       | 41.25       |
|           | **Total Average (%)**                             |                 | **47.13%**  |

The cultural achievement of science has been to develop a set of explanatory theories that have transformed our understanding of the natural world [9] such as acid rain it is caused nitrogen oxides and sulfuric oxides which increase by pollution. Based on the scientific literacy interval of table 1, the students' scientific literacy on the competence aspect explains the scientific phenomenon belongs to the low category. This shows that the students have not been able to apply the concept to the phenomena that exist on daily life. On the aspect of procedural knowledge the students ability to evaluate and design scientific enquiry, interpret data, and evidence scientifically belongs to low category. This shows that the students have not been able to understanding of the goal of scientific enquiry which is to generate reliable knowledge to evaluate reports on scientific findings and investigations critically [4].

For assessing students’ understanding of NOSI that will be developed as a learning model, VASI questionnaire was used to know what were the views of nature of scientific inquiry [4] of the students. The data reveal the students understanding of NOSI aspects were presented in table 3.

Table 3. Students categorized views across eight NOSI aspects.

| NOSI Aspect                                                                 | Unclear | Naive | Transitional | Informed |
|----------------------------------------------------------------------------|---------|-------|--------------|----------|
| Scientific investigations all begin with a question and do not necessarily | 1       | 9     | 10           | 10       |
| test a hypothesis                                                          |         |       |              |          |
| There is no single set of steps followed in all investigation (no single   | 13      | 10    | 7            | 10       |
| scientific method)                                                         |         |       |              |          |
| Inquiry procedures are guided by the question asked                        | 2       | 8     | 15           | 15       |
| All scientist performing the same procedures may not get the same results  | 4       | 26    | 4            | 6        |
| Inquiry procedures can influence results                                    | 1       | 8     | 11           | 20       |
| Research conclusions must be consistent with the data collected            | 5       | 15    | 10           | 5        |
| Scientific data are not the same as scientific evidence                     | 5       | 15    | 10           | 10       |
| Explanations are developed from a combination of collected data and what    | 4       | 10    | 10           | 16       |
| is already known.                                                           |         |       |              |          |

Based on the results of the questionnaire, it is found that students have a positive view in NOSI aspects which were ‘Scientific investigations all begin with a question and do not necessarily test a hypothesis, Inquiry procedures can influence results, enquiry procedures are guided by the question asked and Scientific data are not the same as scientific evidence. The naïve views almost 65% had indicated objective science view stating that all scientist find the same results when they do the same thing. The aspect of research conclusions must be consistent with the data collected and Scientific data are not the same as scientific evidence and 37.5% of them thought that research conclusion doesn’t related with data but it is related with purpose of the research, and the students though that scientific data as same as scientific evidence. This is may causes students have low ability for use scientific data. Therefore learning in the classroom requires renewal that can increase student interest of NOSI aspects then students can achieve good scientific literacy skills.
Over the years there have been numerous models of curriculum and instruction designed to improve the quality of science teaching [7]. In the end, all of these models are related to construct of scientific literacy [7]. Ledderman and Atink state that they recommended that attention to NOS and SI be integrated into instruction focusing on traditional subject matter. Without such knowledge, students’ will be compromised in their ability to make informed decisions, and without such knowledge students will not be able to emulate the desire goal of scientific literacy [10]. This study is mainly concerned about important things that should be developed in learning model which is foster students’ chemical literacy. Striple and Sommer state that lab work is fundamental constituent of the science classroom and its offers great potential for teaching NOSI (Nature of Scientific Inquiry) [5]. The standards NOSI address all the important steps of inquiry (question, planning design, collection data interpreting data). Table 4. is aspects of the NOSI framework [5].

| Osborne 2003 | Shwartz 2008 | Lederman 2014 |
|-------------|-------------|---------------|
| Science and questioning: continual and cyclical process of asking questions and seeking answers, which then lead to new questions; new scientific theories and techniques | Scientific question guide investigation. | Scientific investigation all begin with a question and do not necessarily test a hypothesis. Inquiry procedures are guided by the question asked. |
| Diversity of scientific methods: science uses a range of methods and approaches; no one scientific method or approach | Multiple methods of scientific investigations. | There is no single or sequence of steps followed in all investigations. |
| Scientific method and critical testing: science uses the experimental method to test ideas; there are basic techniques such as controls; outcome of a single experiment is rarely sufficient to establish a knowledge claim. | Not addressed | Not addressed |
| Observation and measurement: observation and measurement are core activities of scientists; subject to some uncertainty but there may be ways of increasing our confidence in measurement (not one of the original six important aspects). | Not addressed | All scientists performing the same procedures may not get the same results. |
| Analysis and interpretation of data: science involves skillful analysis and interpretation of data; process of interpretation and theory-building that can require sophisticated skills; scientists can legitimately come to different interpretations of the same data, and therefore to disagree | Justification of knowledge claims. Recognition and handling of anomalous data. Distinction between data and evidence. | Inquiry procedures can influence results. Scientific data are not the same as scientific evidence. Research conclusions must be consistent with the data collected. |
| Hypothesis and prediction: scientists develop hypotheses and predictions about natural phenomena; essential process for the development of new knowledge claims. | Not addressed | Explanations are developed from a combination of collected data and what is already known. |
| Creativity: science involves creativity and imagination as much as many other human activities; some scientific ideas are enormous intellectual achievements; scientists are passionate and involved humans whose work relies on inspiration and imagination | Not addressed | Not addressed |
| Not addressed | Science as a community of practice | Not addressed |
| Not addressed | Multiple purposes of scientific investigations | Not addressed |

These links between NOSI and standards had been follow by German Chemistry Standards; NOSI aspects and Germany standards include science and questioning E1: recognize and develop questions
that can be answered using chemical knowledge and investigations, particularly using experiments. B4: develop up-to-date questions with connections to everyday phenomena which can be answered using chemical knowledge; E2: plan suitable investigations to test predictions and hypotheses; E3: carry out qualitative and simple quantitative experiments and other investigations and write lab reports on them; B4: develop up-to-date questions with connections to everyday phenomena which can be answered using chemical knowledge; E5: collect data from investigations, particularly experiments, or research them; E6: identify trends, structures and relationships in their own or research data, explain these and draw conclusions; E7: use appropriate models (e.g. models of the atom, the period table of elements) in order to solve chemical questions. From the NOSI aspect which had been applied by German Chemistry Standards we can see that creativity not addressed. Creativity is the important thing for the teaching and learning. The teacher’s creativity opens space for students to respond in creative ways. Creative ways from the students could influence their attitudes. Attitudes are important because students’ responses to scientific issues represent their interest in these issues, how supportive they are of the scientific approach, and their sense of responsibility for the situation. According to the Germany standard and Indonesia Curricula and the result of this study, we had information about learning model this should be in line with emphasis NOSI learning model. There are seven areas of emphasizes: concepts, process, creativity, attitudes and application, connections in a world view context and representation.

4. Conclusion
Based on these findings, the researcher concludes that learning in the classroom has not been able to increase the chemical literacy on the acid base concept, it is necessary to develop a learning model that can facilitate students to develop the ability to analyze a phenomenon, formulate problems, hypothesize, design and test critical hypothesis, data, observing and analyzing data, representing data to more understandable forms and creating new ideas or ideas about existing phenomena. NOSI learning model can be developed with seven emphasizing: concepts, process, creativity, attitudes and application, connections in a world view context and communications.

Acknowledgment
Thank to the postgraduate of the Indonesian University of Education who gave me the opportunity to study Magister in the chemistry education department.

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