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THE USE OF SCIENCE LITERACY TAXONOMY TO MEASURE CHEMISTRY LITERACY OF THE SCIENCE TEACHER CANDIDATES

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Abstract

Mastery of scientific literacy is one of the objectives in science learning. This study aims to measure literacy levels of chemical science student teachers in the subject of Basic Chemistry. Ability scientific literacy of students that will be measured are to: 1) recognize chemical concepts (nominal literacy); 2) Describe the chemical concepts (functional literacy); 3) use their understanding of chemical concepts (conceptual literacy); and 4) use their understanding of chemistry to analyze information from short paragraph (literacy multi-dimensional). Sampling was done by purposive random sampling technique. The sample (N= 61) was composed of first and second year in the Department of Science Education. Data collection techniques were questionnaires and open-ended paragraphs. The validity of the instrument used was expert judgment. The literacy skills of students by 56.64% nominal or category, please, and functional literacy of 26.40% or category was very low. Meanwhile, conceptual literacy was 61.50%; multidimensional literacy was 50.20%. The low level of ability on functional literacy and multidimensional was because students are not accustomed to using assessment that revealed a high level thinking skills. These findings are expected to help in the design process of the new curriculum (KKNI) which put an emphasis in developing chemical literacy.

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INTRODUCTION

Some innovations in science bring an important change for human's welfare. The knowledge of science literacy becomes an absolute thing, because it is needed by everyone, not only for the needs of researcher, expert, or scientist. According to PISA (Programme for International Student Assesment), science literacy was an ability to use the knowledge in science, identify question, and draw a conclusion based on the evidences, in order to understand and make a decision related to nature and its changes. Handayani (2015) argued that the implication of science literacy would affect one's ability in identifying science issues which became the base of personal, local, and national decision making that also showed science and technology position he/she accepted. The definition of science literacy above shows that it is not only numeral, functional, and conceptual, but also multi-dimensional. It is not only knowledge on science, but larger than that.

Assessment was an important component in teaching and learning. It was also important when the result of science literacy became the main goal of a learning process (Shwartz et al., 2006). The term 'assessment' has different definitions according to some sources. Kumano (2001) defined assessment as "The process of collecting data which shows the development of learning." There is also a definition of assessment as the assessment of process, improvement, and students' learning result (Stiggins, 1994). Puji et al. (2012) said authentic assessment based on science literacy was a real assessment, meaningful for the students, able to improve the high level thinking skill, and having a science literacy dimension (concept, process, and context). Scientific literacy in today's scientific and technological society should consist of the understanding of the norms and methods of science, key scientific terms and concepts, and the impact of science and technology on society (Miller, 1983)

Trefil and Hazen (2010) argued that science consisted of some branches such as biology, physics, chemistry, environment, geology, health and safety, astronomy, and technology. It can be seen that chemistry is part of science. This is similar to research conducted by Holbrook & Miia (2009) which states that students who have high test results, not accompanied by a high social ability. Learning chemistry was a strong motivation in developing technology to create a better life. Gilbert & Treagust (2009) noted that there were many chemistry literacy aspects that had direct applications in our daily life, which enabled someone to understand a report and discuss chemicals, and solved some issues like greenhouse effect, ozone, acidity, etc (Show-Yu, 2009)

The graduate students of Science Education program are not expected to be a teacher only, but also to be a consultant for science and technology products so that they need to have a good knowledge on science literacy. There have not been many researches conducted to find how the students' mastery of science literacy is. Most of the researches related to science literacy were conducted for high school students.

Rahayu (2014) explained her writing about literacy categorization, that according to PISA, an individual could not be categorized as a "scientifically literate" or "scientifically illiterate" person, but as a "less developed" into "more developed" person. The 2006 curriculum (KTSP) is conceptually similar to the 2013 curriculum (K-13), which is competency-based, and has generally directed students to develop science literacy, through inquiry and scientific approaches (Anjarsari, 2014). A student with less developed science literacy is able to solve a problem in a simple and intimate situation, while a student with more developed science literacy is able to solve a problem in a complex and less intimate situation. Shwartz et al., (2006) suggested the use of a more appropriate theoretical comprehensive scale to assess scientific literacy during the learning process of science. The scale is presented hierarchically in Table 1.

Based on the background, the researcher considers that a research on chemistry literacy assessment is needed to be conducted for the students of science education program by using science literacy taxonomy. The purpose of this research is to measure the students' chemistry literacy in terms of: 1) nominal literacy; 2) functional literacy; 3) conceptual literacy; and 4) multi-dimensional literacy by using science literacy taxonomy. The result of this research is expected to help the lecturer explaining and mapping the material based on the science literacy mastery of the students which is pointed to the compilation of Basic Chemistry handout.

METHOD

The subjects of this research were 61 students of Science Education program in the first and third semester. This research take place in Pancasakti University Tegal.

Table 1. Hierarchy Scale of Scientific Literacy

Scientific illiteracy	Students are not able to connect and respond to the answers of some questions related to science. They do not have dictionary, concept, context, or cognitive capacity to identify the questions scientifically.
Nominal scientific literacy	Students recognize some concepts related to science, but are not able to understand them clearly which leads to misconception.
Functional scientific literacy	Students are able to describe the concepts correctly, but they have limited understanding.
Conceptual scientific literacy	Students develop some schemes about the understanding of sciences' disciplines main conceptual and connect the schemes to a more general understanding. Inquiry and technology design are included in this level.
Multidimensional scientific literacy	This perspective combines science understanding which is enlarged with other disciplines like philosophy, history, and social dimension in science and technology. Students are able to combine their understanding with the issues from other disciplines.

The data were collected through documentation, observation, and test. The data were analyzed using descriptive analysis. Based on Shwartz et al. (2006), instruments used in the assessment of chemistry literacy following three form:

1) Questionnaire form of chemistry concept definition and identification

This form was used to assess chemistry literacy in nominal and functional levels. The questionnaire list consisted of general concept, sub-micro, specific and general substance, including chemical reaction. This form was a Likert (1-3) type scale.

2) Questionnaire form 2: the explanation of chemistry daily phenomena

This form was used to assess the students' ability in explaining daily phenomena based on chemistry. It consisted Likert scale with three interval. There are true, false, and not given. It measured conceptual literacy.

3) Questionnaire form 3: critical reading on an unknown short paragraph

It was aimed to assess the ability to analyze a paragraph which contained of chemistry information. It was considered to measure multi-dimensional literacy.

The test for questionnaire validity was done using construct validity or content validity considering the experts judgment. Multi-dimensional literacy was tested using opened-closed paragraph which was assessed by rubric. The categorization of the literacy result is shown below.

Table 2. The Categorization of Chemistry Literacy Assessment

No	Score (%)	Category
1	$86.00 \leq n \leq 100$	Excellent (E)
2	$71.00 \leq n \leq 85.00$	Good (G)
3	$56.00 \leq n \leq 70.00$	Intermediate (I)
4	$41 \leq n \leq 55$	Low (L)
5	$0 \leq n \leq 40$	Very Low (VL)

The research stages are presented in Figure 1.

RESULT AND DISCUSSION

In the beginning of the research, the questions review was made. The questions were chosen according to general and specific category. The categorization of the concept on nominal, functional, conceptual, and multi-dimensional aspects show in figure 1.

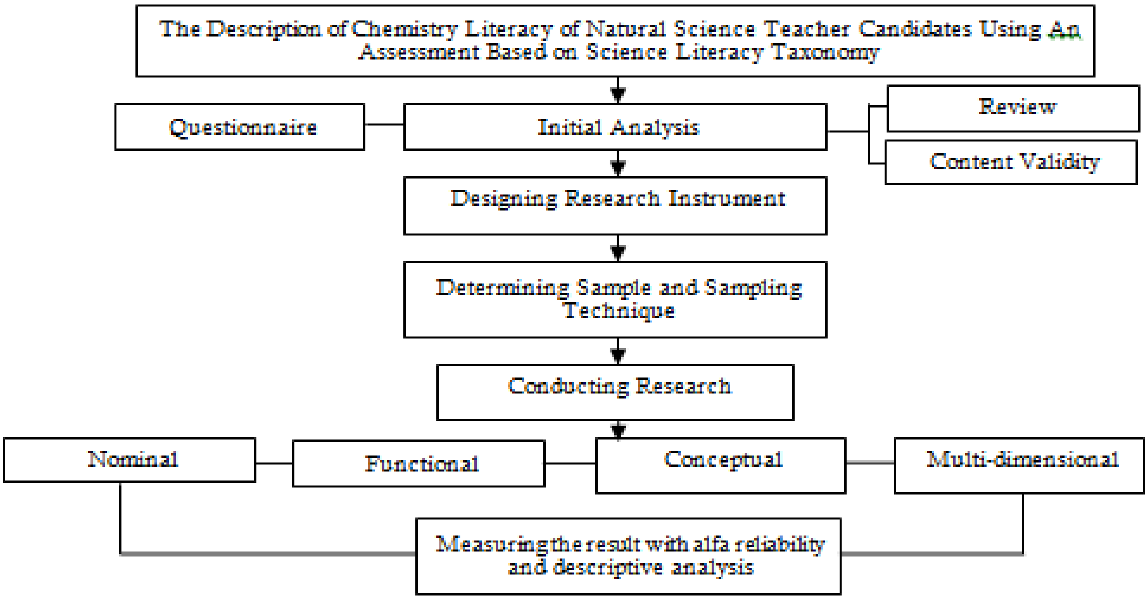

Figure 1. Research Stages

The validity of the instrument was measured based on the experts' judgments. The total average was 3.4 in the range of 3.25 ≤ n ≤ 4.00, which meant that this instrument was valid and appropriate for students.This research use questionnaires data. The first questionnaire describes nominal and functional aspects, while the second questionnaire describes conceptual and multi-dimensional aspects.

In the first stage, 61 students were asked to give a checklist (√) on right, false, or not sure columns to assess nominal aspect, while the students were asked to write an explanation from their choices to assess the functional aspect. The percentage of every question is presented in Table 4 and 5.

Table 4. The Result of the Students' Nominal Literacy Assessment

Question no-	Percentage (%)	Average (%)
1	59.02	56.64
2	36.07	
3	88.52	
4	75.41	
5	37.70	
And so on until question no-20	25.25	

In the functional literacy assessment 61 students were asked to explain their answers on the nominal literacy assessment.

Table 5. The Result of the Students' Functional Literacy Assessment

Question no-	Percentage (%)	Average (%)
1	63.33	26.4
2	60	
3	26.67	
4	35	
5	38.33	
6	38.33	
7	33.33	
8	28.33	
9	15	
And so on until question no-20	11.67	

The next questionnaire was used to assess conceptual or procedural literacy and multi-dimensional literacy. In the conceptual literacy, students were asked to give a checklist (√) on the three available statements whether the statement was right, false, or not given. There were 30 questions and 60 respondents.

In the multi-dimensional literacy assessment, there was a short paragraph about chemistry information. The topic was Green Chemistry. The paragraph was developed to assess the manifestation of high level thinking skill (analysis, synthesis, information interpretation) in chemistry context. This assessment, which was consisted of seven questions, was given to 20 random students only because of the time constraints. The score was using scale 4, 3, 2, and 1.

The overall result was analyzed using descriptive analysis as shown in Table 6 and the result is supported by Figure 2

Table 6. The Result of Students' Chemistry Literacy Analysis

No	Literacy aspect	Result (%)	N respondent	N Question
1	Nominal	56.64	61	20
2	Functional	26.40	61	20
3	Conceptual	61.50	60	30
4	Multi-dimensional	50.20	20	7

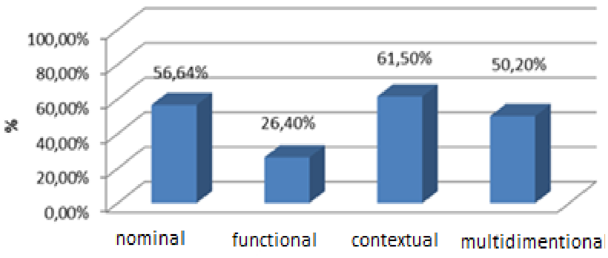

Figure 2. The Result of Students' Chemistry Literacy Analysis

The categorization of the literacy aspects could be divided into five categories, according to Table 3.3, namely Very Low, Low, Intermediate, Good, and Excellent. Based on the score, the categorization of each aspect can be seen in Table 7.

Table 7. The Category of Students' Literacy Analysis

Literacy	Score (%)	Category
Nominal	56.64	Intermediate
Functional	26.40	Very Low
Contextual	61.50	Intermediate
Multi-dimensional	50.20	Low

The assessment of each literacy aspect used different instruments. It was because many chemistry concepts could not be assessed using one instrument only. Aside from complexity, each aspect showed different meaning. Soobard & Ranikmae (2011) suggested to use a framework to determine science literacy level based on situation, age, experience, and ability, consisted of four science literacy levels such as nominal, functional, procedural, and multi-dimensional literacy. Most studies about chemical molecule identification were based on the studies about science literacy, so that chemistry literacy was measured based on science literacy (Suat, 2014)

Based on the category, the students' nominal literacy is intermediate (56.64%), while the category of functional literacy is very low (26.40%). The questions in the nominal and functional instruments were connected. The assessment of nominal literacy was done by giving a checklist, and the assessment of functional literacy was done by explaining the answers in the nominal literacy assessment. Most students were able to answer the questions in nominal literacy assessment because the assessment developed in high school emphasized on formula memorization. The assessment must have been focused on higher order thinking, as stated by Sahlan & Rusilowati (2012). The students' low science literacy in functional aspect (26.40%) shows that the students have a minimum knowledge. They found it difficult to explain the reason and correct the misconception in the questionnaire. Almost all students had limited knowledge about concepts. The answers given were in the macroscopic scope, without explaining microscopic scope. For example in question (5) "Molecule is part of element". There were many students who said that the statement was correct. Whereas it is clear that molecule is not part of element, but element is part of molecule. The macroscopic explanation is: "Molecule which consists of two or more equal elements is called element molecule, while molecule which consists of two or more different elements is called compound molecule." The microscopic explanation can be given by mentioning some examples like "element molecule N_2, O_3; compound molecule H_2O, NH_3", etc. Another example in question (7) "Temperature is a thermal energy which is obtained or given to the environment". There were still many students who said correct and not sure. There is a misconception about temperature and heat. Heat is an energy obtained and given to the environment.

In contextual literacy, the students were asked to connect their understanding in chemistry with daily phenomena. Some daily life cases are presented in the questionnaire, for example “diffusion and gas rate”, “temperature”, “acid and lime stone reaction”, “reduction-oxidation reaction”, and “oil and water”. The result of conceptual literacy analysis is intermediate (61.50%). The result of conceptual literacy is better than functional literacy, because the students are more interested to respond to some cases. In acid and limestone ($CaCO_3$) reaction, many students were distracted by the question about the transformation of solid limestone when it was reacted to acid. Many students said correct, whereas it was the transformation from gas into liquid. In the beginning of the reaction, foams or CO_2 are formed, and then it turns into liquid. There are misconception related to reduction and oxidation as shown in question (1) and (4). Most of them chose false for a statement that said the mass growth of a nail was caused by its reaction with water. They also chose correct for a statement that said covalent bond was created when metal was reacted to oxygen. Most of the students had limited information about hydrofobic polarization in the material of oil and water mixture.

Multi-dimensional literacy was the last aspect to be tested. It was given to 20 respondents because of the time and cost constraints. The topic was Green Chemistry. The students were given seven questions related to a given paragraph. The assessment result of this literacy is 50.20 % or low. It is disappointing because college students are expected to have a higher level of thinking. The students found it difficult to connect inter-disciplinary science and used it to solve a problem in decision making.

The assessment design should consider the higher level of thinking, as stated by Sahlan & Ruslan (2012). The result of literacy analysis shows that the chemistry literacy of the science teacher candidates is below expectation or low. It indicates that there are contexts, contents, processes, and scientific manners in chemistry basic concept that have not been achieved. Chemistry itself is a part of science. The low chemistry literacy gives a bad effect for their teaching ability when they become teachers or consultants in science. The knowledge of chemistry literacy is not limited by age, as said by Show-Yu (2009) that chemistry literacy is related to people of all ages, so that it is needed to be improved into a higher level. Chemistry literacy is related to people of all ages and education levels whether science or non-science. (Sujana, 2014)

To get a higher level of literacy, the change in chemistry content, pedagogic, and curriculum was needed. Putting the result of conceptual and multi-dimensional literacy as the learning goals also helped improving chemistry literacy into a higher level (Shwartz et al., 2006).

Eric & Dinah (2005) noted that although not every problem could be solved by science, such as moral, belief, and value, at least science gives some proofs to help people decide and consider the good and bad of an individual or group.

“Science for all” education needs to be prepared, approved, and adapted into the society, because science education will help them improving their understanding and thinking habit which are needed to be able to think critically, perceptive and caring, independent, and positive for Indonesian nation building.

CONCLUSION

Based on the explanation above, it is known that science literacy of the science teacher candidates is still below expectation. Nominal literacy level is 56.64 % or intermediate; functional literacy is 26.40 % or very low; conceptual literacy is 61.50 % or intermediate; and multi-dimensional literacy is 50.20% or low. The low level of chemistry literacy is caused by some things, such as they are not used to the assessment that measures high level thinking skill. The assessment is usually in the form of using formula and material memorization, so that it is difficult for them to explain the reasons and facts. It can be seen from the result of functional and multi-dimensional literacy analysis. Sujana (2014) stated that one of the efforts to improve chemistry literacy is by improving learning process which does not focus on content only, but also context, process, and manner. Another effort can be done through assessment, in which it does not use questionnaire only, but also multiple choices. It is important to focus on the students’ high level thinking skill.

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