Finding Learning Strategy in Improving Science Literacy
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Abstract

The result of science literacy in Indonesian students has been satisfactorily yet. The government has introduced some new learning strategies. The research is aimed to finding some learning strategies can improved literacy science. The research was conducted in Indonesian school involving 213 participants who are divided into study groups using several learning strategies. Research involved all student on 10 th grade in that school. Improvement of science literacy was analyzed by N-gain and comparing some strategies of learning was analyzed by Anova followed Turkey. The results shows the improvement of science literacy in the learning by using scientific approach was not as good as inquiry approach, Argument Driven Inquiry (ADI), and Science Technology Education Matematics (STEM). The results of science literacy finding the improvement in science literacy of students who learn by using scientific approach comparing using scientific approach is similar to the one using Science Technology Socciety (STS) strategy.

Keywords: Inquiry, Science Literacy, ADI, STS, STEM.
INTRODUCTION

Science literacy plays an important role in people's daily life. Some educational experts believe that the 21st century society needs people who have knowledge of technological and scientific issues in order for the democratic process to run well (Turiman et al., 2011). There are four rationales on the necessity and importance of science literacy in the society, i.e. economy, personal, democratic, and culture rationales.

Economic rationale is determined by the development of a country as well as the skills of the society in science and technology. Personal rationale lies on the ability of an individual in facing issues and challenges that encourage him to make a decision in the daily life. The democratic rationale rests on the claim that a democracy only functions when its citizens are informed participants in civic decision making. The cultural rationale for science literacy is the idea that the sciences offer some of the “best that is worth knowing” (Snow & Dibner, 2016).

There has been considerable debate over the definition of science literacy since the term was first used in 1958 (DeBoer, 2000; Nbina & Obomanu, 2010). Firstly, in Laugksch’s research (2000) on science literacy articles in 1962-1993, literacy was defined as a learning, a competence and social function. Next, according to the study of 100 articles, literacy science relates to six aspects, i.e. the interrelationships of science and society, the ethics, the nature of science, conceptual knowledge, science and technology, and the interrelationships of science and humanities.

Finally, the OECD (2016) defines science literacy as the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. Science literacy is very beneficial, i.e. in the practical scientific literacy, the application of scientific principles to improve living standards; in civic scientific literacy, how to understand and engage with contemporary science-related issues; and in the cultural scientific literacy, how the appreciation of science as a major human achievement (Shen, 1975). The sustainability of future democracy as well as economy is determined by the literacy of the society. Literacy enables society to fully participate in the democracy and economy according to the demands of the 21st century (Greenleaf, et al, 2011).

The result of science literacy in Indonesia has not been satisfactorily yet since 2000 until 2015. The biggest average score of Indonesian science literacy is 403. It placed below the
international average score (OECD, 2016).

If science literacy of Indonesian students has not been improved yet, it will endanger the future of Indonesian democracy. Therefore, Indonesia needs to boost the students’ science. In 2003, Indonesia has proposed a new curriculum. The new curriculum changes learning steps from exploration, elaboration, and confirmation; to scientific approach which consists of five learning steps i.e. observing, questioning, experimenting, associating, and communicating (Indonesia Ministry of National Education, 2016). The new learning approach is expected to be able to improve Indonesian students’ science literacy in the future.

The United States of America has developed a learning approach that improves science literacy and becomes an indicator in the success of science education. Science Technology Society (STS) approach has been acknowledged as the best way in promoting science literacy since 1970s – 1990s (DeBoer, 1991). Yager (1996) described STS as an approach which departs from an issue. The students plan and perform the activities based on issues happen in society. STS has been developing in order to gain science literacy and adapt to the demand of teaching and learning in 21st century.

Science Technology Engineering and Mathematics (STEM) is not new. In 1989 Science for All Americans that promoted literacy science have set the stage with discussions such as “Engineering Combines Scientific Inquiry and Practical Views” and “The Essence of Engineering is Design Under Constraint”. In 1996, the National Science Education Standards included standards on science and technology for all grade levels. One of the standards directly addressed the “abilities of technological design” as a complement to the abilities and understandings of scientific inquiry standards. In 2011, the NRC released a new framework for science education that included science and engineering practices (Bybee, 2013: 3).

On the other hand, the standard of science teaching and learning continues to be developed to improve science teaching and learning. In 1996 the National Research Council issued the National Science Education Standard, the standard emphasizes that science education needs to give students three kinds of scientific skill and understandings. These three kinds of scientific skill and understandings can be achieved when teachers teach using inquiry approach (NRC, 2000). Scientific inquiry continues to be developed to improve science
proficiency. Sampson, et al. (2014) developed the Argument Driven Inquiry (ADI) because the results of most laboratory activities do little to promote the development of science proficiency.

The science literacy of Indonesian students is still low; therefore, the Ministry of Education created a new curriculum. The new curriculum changes the learning approach, from constructivism to scientific approach. The curriculum is expected to increase science literacy of Indonesian students in the future. Is the scientific approach effective in improving science literacy of Indonesian students when compared to other learning approaches that introduced by the United States of America?.

The study focuses on the acquisition of science literacy through the implementation of several learning approaches. Scientific approach, which has been the goal of Indonesian curriculum since 2013 is used as the learning approach. STS approach was further developed into STEM and inquiry approach recommended by NRC (1996) was later developed into Argument Driven Inquiry (ADI) by NSTA.

**METHOD**

The research used a quasi-experiment. A quasi-experimental design can be seen in the Table 1.

<table>
<thead>
<tr>
<th></th>
<th>O1</th>
<th>X1</th>
<th>O2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O1</td>
<td>X1</td>
<td>O2</td>
</tr>
<tr>
<td>2</td>
<td>O1</td>
<td>X2</td>
<td>O2</td>
</tr>
<tr>
<td>3</td>
<td>O1</td>
<td>X3</td>
<td>O2</td>
</tr>
<tr>
<td>4</td>
<td>O1</td>
<td>X4</td>
<td>O2</td>
</tr>
<tr>
<td>5</td>
<td>O1</td>
<td>X5</td>
<td>O2</td>
</tr>
<tr>
<td>6</td>
<td>O1</td>
<td>X6</td>
<td>O2</td>
</tr>
</tbody>
</table>

Note:
X1 = scientific approach  
X2 = Inquiry approach  
X3 = Science Technology Society (STS) Approach  
X4 = Argument Driven Inquiry (ADI) Approach  
X5 = Science Technology Engineering Mathematics (STEM) Approach  
O1 = Pre test  
O2 = Post test

The research engages public senior high schools in Depok, West Java, Indonesia. PISA survey in Indonesia involved students with age 15 in 10th grade or Senior High School and 9th grade or Junior High School (Indonesia Ministry of National Education, 2016). So the sample is students in grade 10 of Science program. The participants are 213 students with the age 15-16 years old. Table 2 shows sample distribution and numbers of participant as the research sample.
Table 2. Treatments and Number of Sample

<table>
<thead>
<tr>
<th>Strategy of Learning</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific approach</td>
<td>45</td>
</tr>
<tr>
<td>Inquiry approach</td>
<td>43</td>
</tr>
<tr>
<td>Science</td>
<td>43</td>
</tr>
<tr>
<td>Technology Society (STS)</td>
<td>43</td>
</tr>
<tr>
<td>Argument Driven Inquiry (ADI)</td>
<td>45</td>
</tr>
<tr>
<td>Science Technology Engineering Mathematics (STEM)</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>213</td>
</tr>
</tbody>
</table>

The data collected from learning outcomes on pre and posttest. The test items are created according to Science Literacy of PISA. Test items are based on PISA criteria. PISA science literacy measures students’ ability to identify scientific issues, explain phenomenon scientifically, and use scientific evidence.

The test items were tested on 69 students. The results show that 9 test items are valid with Cronbach’s alpha 0.69 and arranged based on the difficulty levels: 55.6% belongs to easy.

The data is analyzed in Normalized Learning Gain (Meltzer, 2001) and according to Hake (1999) the category of the learning improvement belongs to high, medium and low. Normalized learning gain analysis and its category is used to find the improvement in science literacy both before and after the learning process. The formula of Normalized Learning Gain is:

\[
\text{Gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum possible score} - \text{pretest score}} (1)
\]

- High-g courses as those with \(<g\) > 0.7
- Medium-g courses as those with 0.7 > \(<g\) > 0.3
- Low-g courses as those with \(<g\) < 0.3.

The improvement science literacy data is analyzed on one way ANOVA. When it is known that the data has normal distribution, it is tested using Shapiro-Wilk normality test (statistic=0.928, df=213, Sig.= 0.00). Then, the post-hoc test is using Tukey test. Data analysis in ANOVA and Tukey’s Post-Hoc Test is used to find the distinction between one experimental group and the other group. Data analysis is conducted by SPSS program.

RESULTS AND DISCUSSION

After the learning process, students’ science literacy shows satisfactorily results. The mean of post test score has exceeded 80 (maximum score is 100). The score is still low on the explanatory aspect of scientific phenomena (see figure 1). Most students are failed to make inferences from the available data.

Here is the example, students are asked to infer the data of the pH
correlation and Auricularia growth based on the Table 3:

Tabel 3. Task Example

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH of each treatment</th>
<th>The numbers of fungi</th>
<th>Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>5.5 – 6</td>
<td>10</td>
<td>20%</td>
</tr>
<tr>
<td>Sago dregs</td>
<td>4.5 – 6.5</td>
<td>19</td>
<td>38%</td>
</tr>
<tr>
<td>Rotting wood</td>
<td>4.5 – 6.7</td>
<td>13</td>
<td>26%</td>
</tr>
</tbody>
</table>

The sample of students’ answer:

“Using sago dregs makes the fungi’s growth increases and the numbers of fungi at the most amount. Meanwhile using straw makes the fungi’s growth decreases and has the least amount.” [DI]

“The numbers and the growth of fungi increase a lot in sago dregs because it has the least pH compared to the other media.” [SAS]

Most students responded as in the example above. Students only describe the data and succeed in finding a suitable media for the Auricularia growth, but fail in explaining the inferences that the optimum pH for fungi growth is between 4.5 – 6.5. The students failed to predict the possibility of the most optimum pH for Auricularia growth is 6.1 – 6.5.

Figure 1 showed pre and post test result of science literacy. Students’ science literacy increased significantly both in total (tpair 0.27, Sig. 0.00), and in each indicator. Each indicator of science literacy i.e. identifying scientific issues (tpair 0.18, Sig. 0.00), explaining phenomenon scientifically (tpair 0.21, Sig. 0.00), and using scientific evidence (tpair 0.24 Sig 0.00).

Although student’s science literacy increased. However, the increase of the science literacy is still in medium not high category (N-Gain average 0.48 stdev. 0.27).

Figure 1. Pre and Post Test Results of Science Literacy

Note:
A = Pretest of total science literacy
B = Posttest of total science literacy
C = Pre test of identifying scientific issues
D = Post test of identifying scientific issues
E = Pre test of explaining phenomenon scientifically
F = Post test of explaining phenomenon scientifically
G = Pre test of using scientific evidence
H = Post test of using scientific evidence
The distribution of students’ N-Gain according to the learning strategy used can be seen in Table 3. Table 3 shows 57% students are in medium N-Gain.

Table 3. The distribution of students’ N-Gain

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Low n (person)</th>
<th>Medium n (person)</th>
<th>High n (person)</th>
<th>Total n (person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific</td>
<td>20</td>
<td>22</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Inquiry</td>
<td>2</td>
<td>29</td>
<td>12</td>
<td>43</td>
</tr>
<tr>
<td>STS</td>
<td>20</td>
<td>22</td>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td>ADI</td>
<td>3</td>
<td>28</td>
<td>14</td>
<td>45</td>
</tr>
<tr>
<td>STEM</td>
<td>0</td>
<td>21</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>122</td>
<td>46</td>
<td>213</td>
</tr>
</tbody>
</table>

Figure 2 clarifies the mean of N-Gain sorted from the learning strategy that gets the highest mean to the lowest one. They are STEM, ADI, Inquiry, STS, and scientific learning strategies. The results of ANOVA test showed the disparity of N-Gain mean among each treatment was significantly different (F. 23.07, Sig. 0.00).

The increase of science literacy in ADI, STEM, and Inquiry learning strategies shows better results compared to scientific and STS learning strategies.
Tukey test shows STEM, ADI, and inquiry are strategies that can improve science literacy better. STEM, ADI, and inquiry are insignificantly different. It means that the three strategies are effective in increasing science literacy. Scientific and STS learning strategies are not significantly different because these two strategies show lower literacy improvements than the other strategies.

Table 4. Tukey Test Among Learning Strategies

<table>
<thead>
<tr>
<th>Scientific Inqury</th>
<th>STS</th>
<th>ADI</th>
<th>STEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Sig. 0.00*</td>
<td>Sig. 0.92</td>
<td>Sig. 0.00*</td>
</tr>
<tr>
<td>Inquiry</td>
<td>Sig. 0.00*</td>
<td>Sig. 0.97</td>
<td>Sig. 0.13</td>
</tr>
<tr>
<td>STS</td>
<td>Sig. 0.00*</td>
<td></td>
<td>Sig. 0.00*</td>
</tr>
<tr>
<td>ADI</td>
<td></td>
<td></td>
<td>Sig. 0.39</td>
</tr>
</tbody>
</table>

Noted: *significant at 0.05 level

Although student’s science literacy increased. However, the increase of the science literacy is still in medium not high category. This results showed that learning strategies have not yet given spectacular effect for improving student’s science literacy. Seddon (2017:45) recomended strategies intergrated literacy into a science classroom i.e: 1) look at all aspects of life for phenomena Effective phenomena motivate students to figure something out with a sense of urgency. 2) look for the controversial issues in science that have multiple perspectives or claims. 3) develop a driving questions that students try to answer. The five learning strategies have accommodated point 1 dan 3, but point 2 hasn’t yet implemented on the five strategies. Issue socioscientific discussion is a strategy of learnig that used controversial issue. ADI developed some issues but not controversial issues or issue socioscientific, ADI only used scientific issues example “Do you agree that temperature affects growth acceleration in fungi?”. Some research show that issue socioscientific could promote science literacy (Osborne, 2005; Dawson & Venville, 2009; Marreo & Mensah, 2010; Nuangchalerm, 2010).

Among the five learning strategies studied, three of them are highly result in improving science literacy. They are inquiry, argument driven inquiry (ADI), and Science Technology Engineering Mathematics (STEM). Meanwhile scientific approach and Science Technology Society (STS) aren’t high enough in improving students’ science literacy. Table 5 presents the Analysis between the OECD (2014) science literacy and learning qualities.

Table 5. Learning Activities and the
Table 5 shows that many aspects of science literacy at the time of learning are not factors that determine the high increase of literacy test result. Inquiry strategy explores fewer aspects of science literacy than STS strategy; however, the improvement of the science literacy test results in inquiry strategy is higher than STS strategy. It also shows that there are some similar types of questions provided in the aspect of identifying issues between scientific approach and inquiry strategy. Nevertheless, the results in inquiry strategy are better than scientific approach. The differences are quite obvious on the aspects of explaining the phenomenon scientifically. The activities in inquiry, ADI, and STEM approaches involve variable control and hypothesis. Meanwhile in scientific approach and STS, the activities are about how to find good information based on the references or field observations. The quality of activities during investigation justifies the the students’ low aspects in explaining scientific phenomenon. Investigation activity requires the students to conduct variable control and verify the hypothesis in increasing their science literacy competence especially in the aspect of explaining scientific phenomenon. Inquiry strategy has impact in laboratory investigation that can improve the component of science
literacy, i.e., the skill of science process. According to Brickman et al. (2009) in inquiry learning, students were challenged to solve a particular problem through open-ended observation followed by opportunities for making and testing their predictions through a self-planned experiment.

ADI learning strategy can improve science literacy. ADI strategy uses argumentation and discussion methods. According to Jagger & Yore (2012) there were 17 articles that state the argumentation and discussion methods closely related to science literacy. Viera & Viera (2016) explained that science literacy will be obtained successfully if every student has seven competences.

The competences are (a) Ask or find answers to questions arising from their own curiosity regarding everyday experience, (b) Describe, explain, and predict natural phenomena, (c) Interpret newspaper about science in the media and engage in public social discussion about the validity of conclusions presented and methods used, (d) Indentify scientific issues underlying local and national decisions, (e) Take and express positions based on scientific and technology knowledge, (f) Assess scientific information based on the credibility of the source and the validity of methods used to generate it, and (g) Evaluate argument based on scientific evidence. In ADI strategy, students are trained with the seven competences.

Besides ADI, STEM approach is also quite effective in improving science literacy. Khaeroningtyas, Permanasari, & Hamidah (2016) stated that STEM trains procedural skill and conceptual understanding.

CONCLUSION

Scientific approach, a new learning strategy created by Indonesian Ministry of Education, is capable of improving the students’ science literacy. However, the improvement of science literacy will be best if during experimental stage, students are provided with investigation activity which involves hypothesis verification and variable control such as in inquiry, ADI, and STEM learning.

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