The effect of science-technology-society approach-based worksheets on improving Indonesian students' scientific literacy

Anisa O. S PRATAMA[1], Abdurrahman ABDURRAHMAN[2] and Tri JALMO[3]

[1]Junior High School Science Teacher of Abung Selatan, Lampung, INDONESIA
[2, 3]Graduate School of Science Education, University of Lampung, INDONESIA

[1]Email: nisa_bio09@yahoo.com
[2]Email: abdurrahman.1968@fkip.unila.ac.id
[3]Email: tri.jalmo@fkip.unila.ac.id

Received 1 May, 2017
Revised 3 Apr., 2018

Contents

Abstract

The aim of this study was to examine the effectiveness of science-technology-society (STS) approach based worksheets on improving Indonesian students' scientific literacy of 'environmental pollution' topic. Through quasi-experimental research method (nonequivalent pre-post control group design), the sample of the study comprised of 64 junior high school students in Lampung Province, Indonesia. The sample was assigned to two groups, namely experimental and control classes. An independent samples t-test and ANCOVA were rectruited to reveal any difference between the experimental and control groups' learning effectiveness and effect sizes. The results showed that the STS approach-based worksheets increased the students' scientific literacy levels. Given the values of n-Gain for the experimental (0.66) and control classes (0.48), the experimental class performed a higher value than the control one. The experimental group's eta square value was found to be $p.\eta^2 = 0.767$.

Keywords: scientific literacy, STS, worksheets

Introduction

Rapid development of science and technology, which calls for the 21st century skills, challenges various fields of life. Therefore, a good learning process needs to equip students with scientific literacy, which enhances their capabilities of science and technology in comprehensively solving the real-life problems (Inzanah, et al., 2014). Scientific literacy is very important for reflecting many national conditions. If the number of qualified people is increased, the national quality also enhances. In other words, the better people have scientific literacy levels, the better science and technology determine the societal issues or quality of a society (Fensham, 2008).

The results of the 2015 PISA (Program for International Student Assessment) indicated that 40 out of 70 countries gained lower scores in science achievement than international average ones (493) (OECD, 2016). The 2011 TIMSS (Trends in International Mathematics and Science Study) revealed that the Indonesian students' scientific literacy levels was on the 40th of 42 countries. That is, Indonesia's average score was 406, which was lower than the international avarege score (500) (IEA, 2012). This means that Indonesia has failed in the International Assessments even though many national efforts have been carried out so far (Suprapto, 2016). Phrased differently, the results of the PISA and TIMMS have pointed that the Indonesian students' abilities of science learning have still been very low. This discrepancy seems to have stemmed from instructional materials and the depth of science topic (Rahayuni, 2016).

Although the TIMMS and PISA require high-order thinking skills and scientific literacy, the Indonesian science education or science learning process has still included conventional learning processes. That is, teachers have grinnovative learning strategies and integrating scientific literacy in science classes. As a matter of fact, Sumarti et al. (2015), who studied with 10 Indonesian teachers at a Junior High School in Lampung, reported that most of the teachers lacked of innovative teaching ways to develop scientific literacy levels in the school. They also addressed why many Indonesian students were very good at memorizing science content/ knowledge and possessed very limited skills in transferring their knowledge to novel issues (Sumarti, et al., 2015). Indeed, it is not suprising that teachers tend to apply conventional learning process or teacher-centered instruction (Lau, 2013) rather than inquiry-based learning and conceptual understanding (Cheung, 2000). Because achieving scientific literacy emphasizes science content knowledge (Chiappetta & Koballa, 2006), teachers need to look for effective learning approaches in teaching science.

Student worksheets

Teaching materials can be classified under four categories: printing materials (i.e., handouts, books, modules, student worksheets, brochures, leaflets, wallcharts, photos or pictures, and models), listening (audio) materials (e.g., cassettes, radio, phonograph recordings, and compact discs), audio visual teaching materials (i.e., video compact discs, and movies) and interactive multimedia teaching materials (e.g., computer Assisted Instruction (CAI), interactive multimedia compact disks, web-based materials) (Prastowo, 2015).

Prastowo (2015) explains that worksheet, as a learning activity, has at least four functions: (1) minimizing the role of an educator; (2) enabling students to understand the provided instructional material; (3) engaging students in rich practical duties; and (4) facilitating the instructional implementation. Nyamupangedengu and Lelliot (2012) reveals that the worksheet, which focuses on the topic, learning objectives, contains learning tasks/activities.

Science, Technology and Society (STS) Approach

The goal of STS approach is to give students with the opportunity to compare science, technology and society with each other and to appreciate how science and technology contribute to the latest knowledge/information construction (Yager, 1996). The National Science Teachers Association (2003) reveals that teachers and educators are responsible for their educational outcomes. The STS approach has emerged as a major movement in science education since the 1970s and remained as a worldwide science education reform (Pedretti & Nazir, 2011). The STS generally refers to discuss the relationships and cycles among science, technology, society and the environment (Yager & Akcay, 2008). In contrast to the traditional curriculum emphasizing mastery knowledge, the STS approach has a major role in developing social responsibility for decision making procedure on socio-scientific issues or science and technology-related issues (Lau, 2013).

The STS approach has recently been used for technology-centered and problem-based instructional designs. Yet, conventional learning process or traditional science employs teaching, demonstration and direct experimentation. In contrast, the STS approach includes such various interactive learning activities as role playing, discussion, simulation, game, decision making, debate and problem solving (Lau, 2013). In view of Yager (1996), the STS approach has five domains: concept, **process, application, creativity and attitude (see Figure 1).**

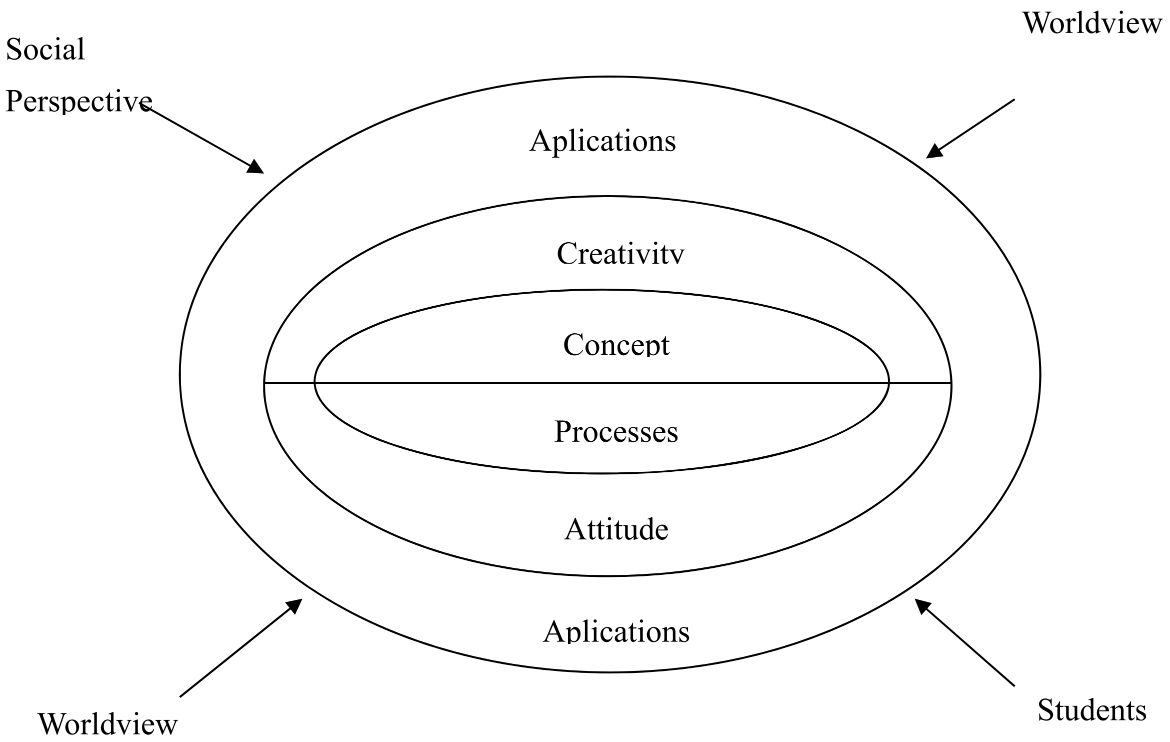

Figure 1. Five domains of the STS approach

Scientific Literacy

Scientific Literacy, which is the ultimate goal of science education (Lau, 2013), is defined by the PISA. Namely, each student should acquire four domains of scientific literacy: scientific knowledge (identifying and acquiring new knowledge, explaining scientific phenomena, and drawing evidence-based conclusions), understanding science as a form of human knowledge and investigation, awaring of how science and technology shape materials, intellectual, and cultural environments; and willingness to engage science-related issues and integrate science in daily-life issues.

Knowledge domain of scientific literacy reflects three indicators: the processes of knowledge, attitudes toward science and awareness of the science-technology-society cycle. This means that the PISA assessing scientific literacy focuses on three competencies of science: content, process, and context.

Science literacy defined by the PISA emphasizes the real-life issues (OECD, 2013). This current research raises environmental pollution, which plays an important role in increasing scientific literacy. Because environmental pollution has become a natural phenomenon that we faced, students with good scientific literacy skills may reduce any environmental pollution. Therefore, there is a need for measuring the effect of the STS approach-based worksheets on improving the Indonesian students' scientific literacy levels of ‘environmental pollution’ topic.

Methodology

Within a quasi-experimental research design, two grade 7 classes were purposefully selected from junior high schools in Lampung, Indonesia. The same topic (environmental pollution) was taught to both classes. The control group (n = 32 students) was exposed to the conventional instruction, whilst the experimental group (n = 32 students) was instructed with the worksheets. Then, the experimental and control groups’ scientific literacy levels were assessed and compared. Later, independent samples t-test was employed to determine the effects of the teaching interventions on their scientific literacy levels. The data were obtained through the ‘scientific literacy’ questionnaire. The indicators of scientific literacy were classified into 3 domains: content, process, and scientific context.

Table 1. The indicators of scientific literacy

Aspects of science content
✓ Presenting facts, concepts, principles, and laws.
✓ Presenting hypotheses

✓ Theories, and models
✓ Ask students to remember knowledge or information
Aspects of the science process
✓ The essence of science and science as a way of thinking
Spects of the scientific context
✓ The interaction of science, technology, and society.

(Chiapetta & Koballa, 2006).

To assess grade 7 students' conceptual understanding of the 'environmental pollution' topic, the researchers created 15 a questionnaire on the relationship(s), understanding, and application(s) of the 'environmental pollution' topic. These questions were suitable for Bloom's taxonomy (C3-C6) and the foregoing three domains of scientific literacy. The researchers pilot-tested the 'environment pollution' questionnaire with 32 students, who had previously taken the same topic. Two groups firstly took a pre-test before the teaching intervention. Then, they were treated and immediately given apost-test (see Table 2). Afterwards, their results were compared (Sugiyono, 2010).

Table 2. The Procedure of a Quasi-Experimental Research Design

Group	Pre test	Treatment	Post test
Experimen	O_1	X	O_2
Control	O_3	-	O_4

Note:

O_1 = Experimental group's pre- test scores,
O_3 = Control group's pre-test scores,
X = Treatment,
O_2= Experimental group's post-test scores,
O_4 = Control group's post-test scores (Sugiyono, 2010)

After the results of pre-test and post-test are gained, it is obvious that students' scientific literacy levels increase from pre-test to post-test. The normalized gain (n-Gain) is calculated using the following formula:

$$N - Gain = \frac{Spost - S\,pre}{Smaks - Spre}$$

Note : Spost = post-test value, Spre = pre-test value, Smaks = ideally maximum value (Hake, 2002)

The normalized gain values of three classifications are presented in Table 3.

Table 3. Three Classifications of the Normalized Gain Value

Average Gain Normalized	Classification	Level of Effectiveness
$\langle g \rangle \geq 0,70$	High	Effective
$0,30 \leq \langle g \rangle < 0,70$	Medium	Effective enough
$\langle g \rangle < 0,30$	Low	Less effective

(Hake, 2002)

Independent samples t-test was used determine the effectiveness of the worksheets-oriented instruction via IBM SPSS Statistics 21 program. Then, percentages of the controls and experimental groups were counted on domains of scientific literacy. Both of the groups took the same test after the teaching intervention. Then, analysis of covariance (ANCOVA) was run for adjusting their learning scores to compare the experimental and control groups with one another.

Result

Scientific literacy consists of content (science as knowledge), process (science as a process of investigation and a way of thinking) and context (the interaction(s) amongst science, technology, and society). The results of the normalized gain scores (n-Gain) for each domain of the grade 7 students' scientific literacy levels are displayed in Table 4.

Table 4. The results of n-Gain and independent samples t-test

Group	*Mean*			Criteria	Uji-t n-Gain *Sig.* *(2- tailed)*
	Pre test ($\bar{x} \pm sd$)	Post test ($\bar{x} \pm sd$)	*n-Gain* ($\bar{x} \pm sd$)		
Control (n=32)	$44,4 \pm 8,41$	$67,6 \pm 6,62$	$0,48 \pm 0,13$	Medium	Significantly different *(pPre tes=0,017, pPost tes=0,000, pn-Gain=0,000)*
Experiment (n=32)	$49,4, \pm 7,95$	$77,3 \pm 7,28$	$0,66 \pm 0,14$	Medium	

As seen in Table 4, n-Gain value of the experimental group was found to be 0.66, meaning a significant improvement of grade 7 students' scientific literacy levels from pretest to posttest, whilst that for the control group was calculated to be 0.48, meaning an improvement for low rank students in scientific literacy level. Therefore, improvements significantly occurred in the experimental group. Based The value of Sig. (2-tailed) <0.05 rejected to a significant difference between the experimental and control groups' n-Gain scientific literacy levels. An increase in each student's n-Gainis shown in Figure 2. N-Gain scores of grade 7 students' scientific literacy levels on domains of the content, process, and context of science illuminates that the experimental group had a higher n-Gain average, which fell into the moderate category.

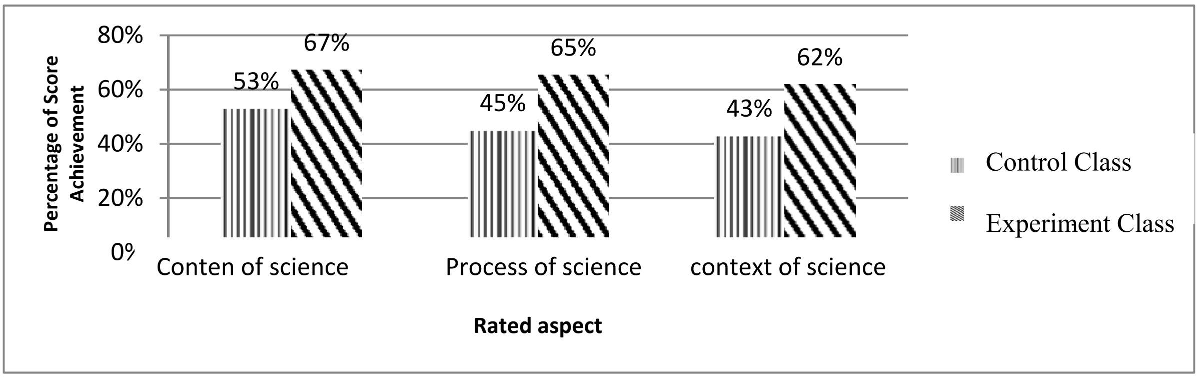

Figure 2. N-Gain scores of grade 7 students' scientific literacy levels

Finally, a power analysis to determine the minimum effect size of the quasi-experimental research design was conducted. For analysis of grade 7 students' skills in pre-test and post-test, a total of the sample of the study was assumed to be N= 64. That is, there were two groups and two assessment times (i.e., pre-test and post-test). Effect size of the least analyse fort he experimental group was found to be p.η^2 = 0.767.

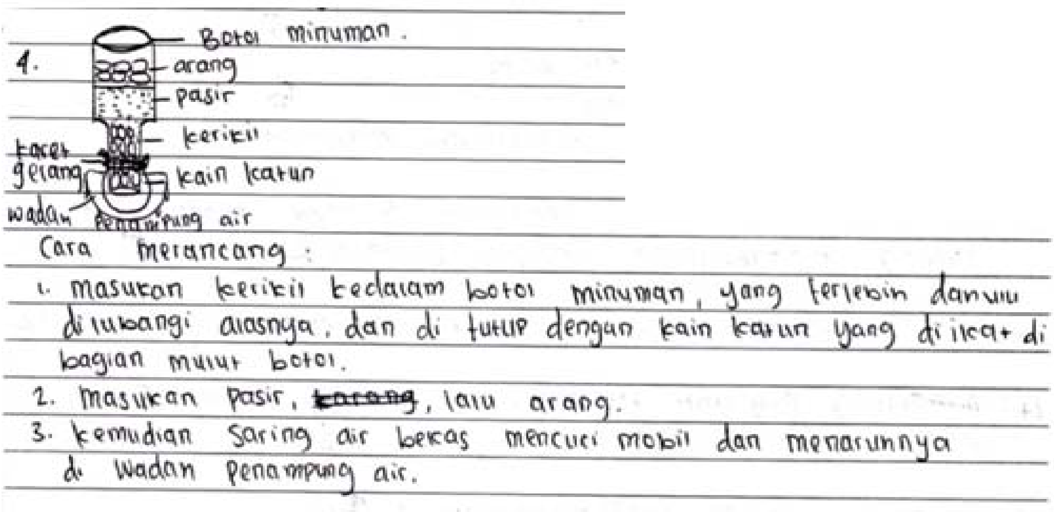

Figure 3.A sample response from the grade 7 students with a high n-Gain score

As can be seen from Figure 4, the grade 7 students with a medium n-Gain score did not provide the detailed pictural explanations, verbal arguments, and reasoning skills.

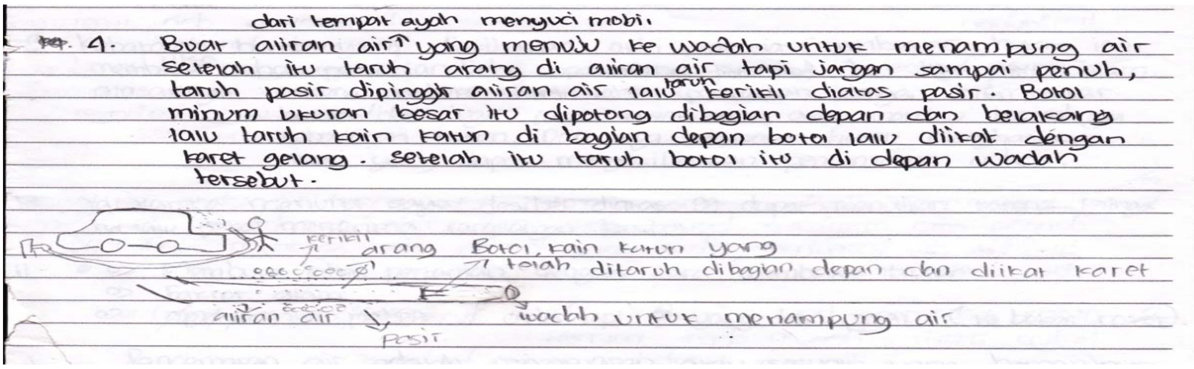

Figure 4. A sample response from the grade 7 students with a medium n-gain score

As seen from Figure 5, the grade 7 students with a low n-Gain score revealed transcription and verbal argumentation.

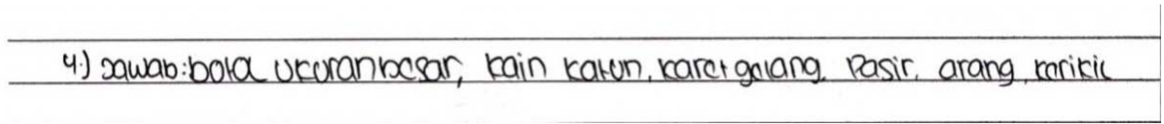

Figure 5. A sample response from the grade 7 students with a low n-Gain score

Three students with different n-Gain scores had various ways to answer the same questions. This means that the grade 7 students with a low n-Gain score had difficulty in comprehending and depicting the process of science. The results of the scientific investigation process indicated that the grade 7 student were able to conduct an investigation alike a scientist. Rustaman (2009) states that the process of science refers to the mental processes involving in answering a question or problem-solving (e.g., identifying and interpreting evidence) and explaining the conclusions of the scientific investigations. That is, the results pointed that the STS approach was even better in facilitating student learning of scientific knowledge than the traditional teaching. A STS approach of this study is feasible overtly exam-driven context of Hong Kong in light of its superiority in conceptual understanding over traditional teaching (Lau, 2013).

Conclusion

In brief, this study showed the collaborative connections between the STS approach and worksheets to improve the grade 7 students' scientific literacy skills of science learning outcomes. The current study found that the collaborative connections highly influenced the grade 7 students' learning of the content of science as compared with the other domains of scientific literacy. This means that the STS approach-oriented worksheets, which supported collaboratively to make sense of scientific literacy, were efficient in increasing scientific literacy levels.

Acknowledgements

The authors would like to thank Faculty of Teacher Training and Education University of Lampung for their kind assistance and support in preparing and funding this manuscript.

References

Abdulrob, M., & Daniel, E. (2015). Comparison between Student Learning Outcomes in Higher Elementary School Science with an STS Modules and Typical Textbooks. *Oida International Journal of Sustainable Development, 1*(4), 87-103.

Akcay, B. & Akcay H. (2015). The effectiveness of science-technology-society (STS) instruction on student understanding of the nature of science and attitudes toward science. *International Journal of Education in Mathematics, Science and Technology*, *3*(1), 37-45.

Cheung, D. (2000). Analyzing the Hong Kong junior Secondary Science Syllabus Using the Concepts of Curriculum Orientations. *Educational Research Journal*, *15*(1), 69-94.

Chiapetta & Koballa. (2006). *Science Instruction in the Middle and Secondary Schools: Developing Fundamental Knowledge and Skills for Teaching*, sixth edition. Pearson Education, Inc. New Jersey.

Chiappetta, E.L, Fillman, D.A, dan Sethna, G.H. (1991b). "A Quantitative Analysis of High School Chemistry Textbooks for Scientific Literacy Themes and Expository Learning Aids". *Journal of Research in Science Teaching, 28* (10), 939-951.

Fensham, Peter, J. (2008). *Science Education Policy-Making* Eleven *Emerging issue*: UNESCO.

Hake, R. R. (2002). Analyzing Change/Gain Scores. November 2015. http://www. physics. indiana. edu/~ sdi/AnalyzingChange-Gain.pdf.

Hillman, W. (2003). Learning How to Learn: Problem Based Learning. *Australian Journal of Teacher Education*, 28 (2), 1-10.

Hudson, Derek. (2002). Some Thoughts in Scientific Literacy: Motivaties, Meanings and Curriculum Impactions. *Asia-Pacific Forum on Science Learning and Teaching, 3*(1), foreword. 1-20.

IEA (International Association for the Evaluation of Educational Achievement). (2012). *TIMSS and PIRLS 2011 Achievement.* Boston. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Inzanah, Ibrahim, M., & Widodo, W. (2014). Pengembangan Perangkat Pembelajaran IPA Berbasis Kurikulum 2013 untuk Melatih Literasi Sains Siswa SMP. *Pendidikan Sains Pascasarjana UNESA, 4*(1), 459-467.

Karsli & Sahin. (2009). Developing worksheet based on science process skills: Factors affecting solubility. *Asia-Pacific Forum on Science Learning and Teaching, 10*(1), 15, 1-12.

Lau, K. C. (2013). Impact of STSE high school biology course on the scientific literacy of Hong Kong students. *Asia-Pacific Forum on Science Learning and Teaching, 14*(1), 6,1-24.

Lee, Che-Di. (2014). Worksheet Usage, Reading Achievement, Classes' Lack of Readiness, and Science Achievement: A Cross-Country Comparison. *International Journal of Education in Mathematics, Science and Technology, 2*(2), 96-106.

Liliasari & Muh. Tawil. (2014). *Keterampilan-Keterampilan Sains dan Implementasinya dalam Materi IPA.* Universitas Negeri Makassar. Makassar.

Millar R. & Osborne J.F. (1998). *Beyond 2000: Science education for the future*. King's College. London.

National Science Teacher Association and Association (NSTA) for Education of Teachers in Science. (2003). *Standard for Science Teacher Preparation:* Social Context. Washington.

Noer, M. A. (2016). The Improvement On Reading Literacy (Competence) Students of Chemistry Department-FKIP-Universitas Riau Through Students Worksheet of English for Chemistry-Based Active Learning. *Jurnal Pendidikan Kimia.* 8(2), 14-19.

Norris, S. & Phillips. (2003). How Literacy In Its Fundamental Sense is Central to Scientific Literacy. *Science Education, 8*(7), 224-240.

Nyamupangedengu, E. & Lelliot, A. (2012). An Exploration on Learners Use of Worksheets During a Science Museum Visit. *African Journal of Research in Mathematics, Science and Technology Education, 16*(12), 1-15.

OECD (Organisation for Economic Co-operation and Development). (2013). *Strong Performers and Successful Reformers in Education.* Paris. OECD Publishing. Retrieved from http://www.pearsonfoundation.org/oecd/index.html

OECD (Organisation for Economic Co-operation and Development). (2016). *PISA 2015 Results: What Students Know and Can Do Student Performance in Mathematics, Reading and Science Volume I.* Paris. OECD Publishing. Retrieved from http://www.oecd.org/pisa

Pedretti, E. & Nazir. J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. *Science Education, 95*, 601-626.

Peruche, M. Babette. (2007). *The Implications of Internal and External Motivation to Respond without Prejudice for Interracial Interactions*. Florida State University Libraries.

Prastowo, Andi. (2015). *Panduan Kreatif Membuat Bahan Ajar Inovatif*. Diva Press. Jogjakarta.

Rahayuni, Galuh. (2016). Hubungan Keterampilan Berpikir Kritis dan Literasi Sains pada Pembelajaran IPA Terpadu dengan Model PBL dan STM. *Jurnal Penelitian dan Pembelajaran IPA, 2*(2), 2, 131-146.

Rustaman, N., Y. (2009). Literasi Sains Anak Indonesia 2000 & 2003. *Artikel Ilmiah.* Universitas Pendidikan Bandung. Bandung.

Sugiyono. (2010). *Model Penelitian Pendidikan Pendekatan Kuantitatif Kualitatif dan R & D.* Alfabeta. Bandung

Sumarti, S., Rahayu, Y. S, & Madlazim. (2015). Pengembangan Perangkat Pembelajaran Berbasis Inkuiri Terbimbing untuk Melatih Literasi Sains Siswa. *Pendidikan Sains Unesa, 5*(1), 822-829.

Suprapto, Nudi. (2016). What should educational reform in Indonesia look like?-Learning from the PISA science score of East-Asian countries and Singapore. *Asia-Pacific Forum on Science Learning and Teaching, 17*(2), 8,1-19.

Toharudin, U., Hendrawati S., & Rustaman, A. (2011). *Membangun Literasi Peserta Didik.* Humaniora. Bandung.

Yager, R. E. & Akcay, H. (2008). Comparison of Student Learning Outcomes in Middle School Science Classes with an STS Approach and a Typical Textbook Dominated Approach. *Research in Middle Level Education,* 31(7), 1-16.

Yager, R. E. (1996). *Science/ Technology/ Society.* Providing and Appropriate Science for All. A-Paper- presented at the seminar on Science Education and the Graduate School of IKIP Bandung.

Yoruk, N., Morgil, I., & Secken, N. (2009). The Effect of STSE Education on Student's Career Planning. *US-China Education Review, 6*(8), 68-74.