Finding Learning Strategy in Improving Science Literacy

(Received 24 February 2019; Revised 26 May 2019; Accepted 26 May 2019)

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DOI: 10.30870/jppi.v5i1.4902

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 impovement 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 Scociety (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 1. A quasi-experimental Research Design

1	O_1	X_1	O_2
2	O_1	X2	O_2
3	O_1	X_3	O_2
4	O_1	X_4	O_2
5	O_1	X_5	O_2
6	O1	X_6	O_2

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

O_1 = Pre test

O_2 = Post test

The research engages public senior high schools in Depok, West Java, Indonesia. PISA survey in Indonesia involved students with age 15 in 10^{th} grade or Senior High School and 9^{th} 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

Strategy of Learning	Number of samples
Scientific approach	45
Inquiry approach	43
Science Technology Society (STS)	43
Argument Driven Inquiry (ADI)	45
Science Technology Engineering Mathematics (STEM)	37
Total	213

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:

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

- 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

Treatment	*pH of each treatment*	*The numbers of fungi*	*Growth (%)*
Straw	5.5 – 6	10	20%
Sago dregs	4.5 – 6.5	19	38%
Rotting wood	4.5 – 6.7	13	26%

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).

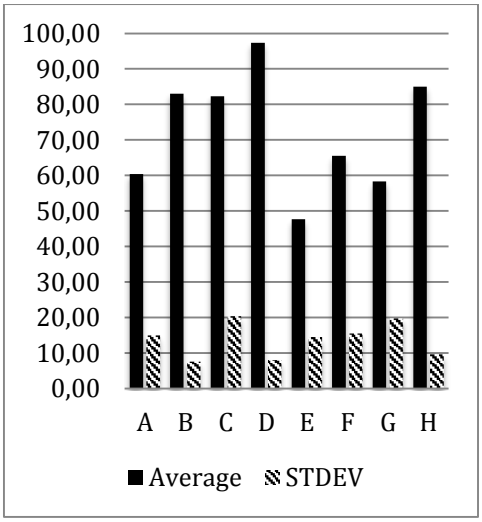

Figure 1. Pre and Post Test Results of Science Literacy

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.

The increase of science literacy in ADI, STEM, and Inquiry leraning strategies shows better results compared to scientific and STS learning strategies.

Table 3. The distibution of students' N-Gain

Treatments	N-Gain			Total
	Low n (person)	Medium n (person)	High n (person)	 n (person)
Scientific	20	22	3	45
Inquiry	2	29	12	43
STS	20	22	1	43
ADI	3	28	14	45
STEM	0	21	16	37
Total	43	122	46	213

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).

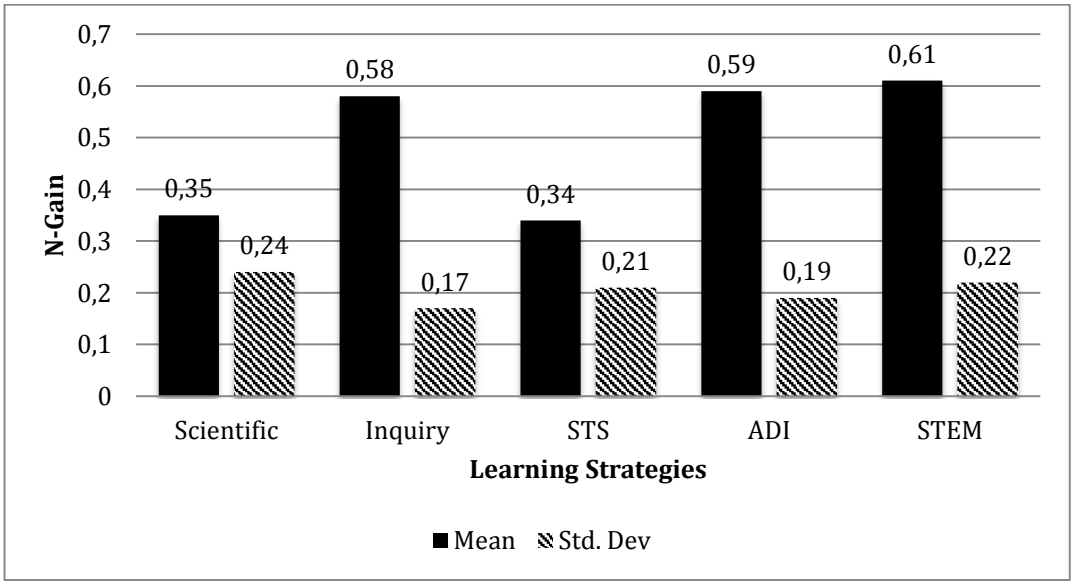

Figure 2. N-Gain Mean According to Learning Strategies

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

	Scientific	Inquiry	STS	ADI	STEM
Scientific		Sig. 0.00*	Sig. 0.92	Sig. 0.00*	Sig. 0.00*
Inquiry			Sig. 0.00*	Sig. 0.97	Sig. 0.13
STS				Sig. 0.00*	Sig. 0.00*
ADI					Sig. 0.39

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 spectular 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; Nuangchalernm, 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

Aspect of Science Literacy

The Aspect of Science Literacy	Scientific Approach	Inquiry	ADI	STS	STEM
Identify Scientific Issues	According to the video, is the reproduction of fungi limited to the display on the video?	Do all fungus reproduce sexually?	Do you agree that temperature affects growth acceleration in fungi?	What is the biggest organism in the world?	Why does bread tend to get moldy after several days?
Explain Phenomenon Scientifically	Find information about fungi reproduction.	Perform an experiment to verify the hypothesis.	Investigate the influence of temperature to fungi growth.	Identify the fungus around the school.	Conduct a research on how fungus reproduce in the bread.
Use Scientific Evidence	-	-	-	*Tempeh* production	Oyster Mushroom Cultivation

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 obtain successfully if every student has seven competences.

The competences are (a) Ask or find answers to questions arising from their own curriosity regarding everyday experience, (b) Descibe, 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) Indetify scientific issues underlying local and national decisions, (e) Take and express positions based on scienctific and technology knowledge, (f) asses scientifik information based on the credibillty of source and the validity methods used to generate it, and (g) evaluate argument based on sciencetific 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.

ACKNOWLEDGMENTS

The researchers would like to thank to the Research Center for the support offered to this reseach through DIPA Syarif Hidayatullah State Islamic University Jakarta in 2017.

REFERENCES

Brickman, P, Gormally, C, Amstrong, N & Hallar, B 2009, 'Effects of Inquiry-based Learning on Students's Science Literacy Skills and Confidence', *International Journal for The Scholarship of Teaching and Learning*, vol. 3, no. 2, pp. 1-22.

Bybee, RW 2013, *The Case for STEM education Challenges and Opportunities*, NSTA Press, Virginia.

Dawson, V. & Venville, G.J 2009, 'High School Student's Informal Reasoning and Argumentation about Biotechnology: An Indicator of Science Literacy?', *International Journal of Science Education*, vol. 31, no. 11, pp.1412-45.

DeBoer, GE 1991, *A history of Ideas in Science Education*, Teacher College Press, New York.

DeBoer, GE 2000, 'Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform', *Journal of Research in Science Teaching*, vol. 37, no. 6, pp. 582-601.

Greenleaf, CL, Litman, C, Hanson, TL, Rosen, R, Boscardin, CK, Herman, J, Schneider, SA, Madden, S & Jones, B 2011, 'Intergating Literacy and Science in Biology: Teaching and Learning Impacts of Reading Apprenticeship Professsional Development', *American Educational Research Journal*, vol. 48, no. 3, pp. 647-717.

Hake, RR 1999, Analyzing Change/Gain Scores, Viewed 15 October 2018, <http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf>

Jagger, SL & Yore, LD 2012, 'Mind the Gap: Looking for Evidence-Based Practice of Science Literacy for All in Science Teaching Journals', *Journal of Science Teacher Education*, vol. 23, pp. 559-77.

Indonesia Ministry of National Education 2016, Peringkat dan Capaian PISA Indonesia Mengalami Peningkatan, viewed 20 May 2019, < https://www.kemdikbud.go.id/main/blog/2016/12/peringkat-dan-capaian-pisa-indonesia-mengalami-peningkatan>

Khaeroningtyas, N, Permanasari, A & Hamidah, I. 2016, 'STEM Learning in Material of Temperature and Its Change to Improve Scientific Literacy of Junior High School Students', *Jurnal Pendidikan IPA Indonesia*, vo. 5, no. 1, pp. 94-100.

Laugksch, RC 2000, 'Scientific Literacy: A Conceptual overview', *John Wiley & Sons, Inc. Sci. Ed*, vol. 84, pp. 71–94.

Marrero, M.E. & Mensah, F.M.M 2010, Socioscientific Decision Making the Ocean: The Case Study of 7th Grade Life Science Students. *Electronic Journal of Science Education*, vol. 14, no. 1, pp. 1-26

Meltzer, DE 2002 'The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores', *American Journal of Physics*, vol. 70, no. 12, pp. 1259.

National Research Council 1996, *National Science Education Standards*, The National Academies Press, Washington DC.

National Research Council 2000, *Inquiry and the National Science Education Standars: a guide for teaching and learning*, National Academi Press, Washington DC.

Nbina, JB & Obamanu, BJ 2010, 'The Meaning of Scientific Literacy: A model of relevance in science education', *Academic Leadership The Online Journal*, vol. 8, no. 4, pp. 1-7.

National Research Council 2000, *Inquiry and the national science education standards: A guide for teaching and learning*, National Academies Press, Washington DC.

Nuangchalerm, P 2010, Engaging Students to Perceive Nature of Science Though Socioscientific Issue-Based Instruction, *European Journal of Social Science*, vol. 13, no. 1, pp. 34-37.

Sampson, V, Enderle, P, Gleim, L, Grooms, J, Hester, M, Southerland, S & Wilson, K 2014, *Argument Driven Inquiry in Biology*, NSTA Press, Arlington Virginia.

Seddon, M 2017, 'Strategies for integrating literacy into a science classroom', viewed 20 May 2019, < https://scholarworks.uni.edu/grp/115>

Shen, BSP 1975, 'Science Literacy: Public understanding of science is becoming vitally needed in developing and industrialize countries alike' *American Scientist*, vol. 3, no. 3, pp. 265-68.

Snow, CE & Dibner, KA 2016, *Science Literacy: Concepts, Contexts, and Consequences*, The National Academies Press. Washington DC.

Turiman, P, Omar, J, Daud, AM, & Osman, K 2012, 'Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills', *Procedia-Social and Behavioral Sciences*, vol. 59, pp. 110-116.

OECD 2001, *Knowledge and Skills for Life: First Result From The OECD Programme for International Student Assessmentt (PISA) 2000*, OECD Publishing. Paris.

OECD 2004, *Learning for Tomorrow's World: First Result from PISA 2003*, OECD Publishing. Paris.

OECD 2007, *PISA 2006: Science Competencies for Tomorrow's World Volume 1*, OECD Publishing. Paris.

OECD 2010, *PISA 2009 Results: What Students Know Can Do Volume I*, OECD Publishing. Paris.

OECD 2014, *PISA 2012 Result in Focus: What 15-year-olds know and what they can do with what they know*, OECD Publishing. Paris.

OECD 2016, *PISA 2015 Result in Focus*, OECD Publishing. Paris.

OECD 2016, *PISA 2015 Assesment and Analytical Framework: Science, Reading, Mathematic, and Financial Literacy,* OECD Publishing. Paris.

Osborne, J 2005, The Role of argument in Science Education. K. Boesma, M. Goedhart, O. De Jong, & H. Eijkelhof [Eds]. *Research and Quality of Science Education.* Dordrecht, Nederlands: Spinger.

Viera, RM & Viera, CT 2016, 'Fostering Sciencetific Literacy and Critical Thinking in Elementary Science Education', *International Journal od Science and Math Education*, vol. 14, pp. 659-680.

Yager, RE 1996, *Science technology society as reform in science education*, Suny Press